MANAGEMENT BY MEASUREMENT

A Performance Management Approach for Assessing ITS (Intelligent Transport Systems) Projects in South Africa

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MARCH , 2016

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Dissertation presented for the Degree of Doctor of Philosophy in the Faculty of (Civil) Engineering at Stellenbosch University

The advent of more sophisticated IT systems and the greater ease with which data collection systems can be created make for a paradigm shift in focusing on counting what counts. Systems across all fields (whether transport- or social services) fall victim to Albert Einstein's mantra:

"NOT EVERYTHING THAT COUNTS CAN BE COUNTED AND NOT EVERYTHING THAT CAN BE COUNTED COUNTS"

- Albert Einstein

DECLARATIONS

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ABSTRACT

Over the past decade, the South African transport environment has actively started to adapt a technology-driven setting. Intelligent Transport Systems (ITS) applications such as Advanced Traffic Management Systems (ATMS) and Advanced Public Transport Systems (APTS) have since been promoted and developed.

However, little thought is given to ITS performance management in the conceptualisation- and planning phases of the ITS applications. As a result, the monitoring is mostly done by a modular- and possibly inconsistent performance measurement approach. Moreover, in the absence of a set of widely accepted performance measures and transferable methodologies, it is very difficult for the local transport industry to objectively assess the effects of their specific applications with regard to the implementation of policies and technologies. The aforementioned concerns raise scepticism around the sustainability of the newly deployed advanced transport systems.

In order to ensure the sustainability of the ITS applicators, it is proposed that a systematic approach to performance management, through performance measurement, be promoted. Even though the concept of managing performance measurement is in its infancy, it is believed that, with the attainment of the proposition made herein, a performance management regime, possibly nation-wide, may follow.

The aim of this research project is thus to develop an all-encompassing measurement framework that lays the groundwork for managing the performance, and contributes towards the sustainability, of the ITS deployments. This was accomplished by executing six methodical steps. These were to: 1) identify all of the performance-related aspects that are applicable to the transport measurement environment, 2) present these aspects in a performance measurement framework, 3) establish the performance measurement structure by developing standards and/or targets and allocating importance weights towards evaluating these aspects, 4) create the measurement model by utilising Multi-Criteria Decision Making (MCDM) principles in determining the (overall) performance of the ITS applications, 5) transform the measurement framework into a Graphic User Interface (GUI) dashboard that can act as the performance management tool and 6) instigate performance management by implementing an incentivisation structure.

The advocated approach differs from the current measurement systems in place in that it embraces a structure for evaluating the performance of, specifically, technology investments in the South African transport environment. Moreover, it utilises a holistic and generic measurement framework as the baseline for performance appraisal. The method put forth herein, in the form of the envisioned performance management tool, serves as the reference point for ITS performance management. That is, it can assist implementing agencies in obtaining the necessary knowledge to easily make day-to-day informed decisions regarding the (overall) performance of their respective systems and can aid decision makers in the continuous assessment of their investment in transport technology.

The developed management tool has also met the prerequisites, as identified herein, for ensuring the wider use and application of a performance driven approach. These included, among others, that the tool be: **scalable and suitable** to address the specific requirements as posed by a developing country and by the evolution of ITS technologies; **holistic** in the sense that it considers and includes the opinions of all possible interested parties; **comprehensive** such that it can be applied to both the private- and the public transport environment; **concise** such that it does not fall victim to Albert Einstein's mantra ("*not everything that counts can be counted and not everything that can be counted counts*"); **agile** such that it can accommodate any changes in the employer's (or the client's) needs and/or the specific project's desired outcomes; and **easy to understand and use** such that it can facilitate the quick and effortless assessment of transport projects' performance in the field of technology investments.

In conclusion, this author submits that the developed tool has proven to have sufficient capability, provide invaluable insights and add significant value to the transport environment, as well as being multi-functional, consistent and all-inclusive.

OPSOMMING

Die afgelope dekade het die Suid-Afrikaanse vervoeromgewing by ’n tegnologiegedrewe ingesteldheid begin aanpas. Intelligente vervoerstelsels, soos gevorderde verkeersbeheerstelsels en gevorderde publieke vervoerstelsels, is sedertdien aktief bevorder en ontwikkel.

Daar word egter min aandag aan die bestuur van hierdie intelligente vervoerstelsels in hul voorstelling- en beplanningsfases gegee. Die monitering word dus hoofsaaklik deur ’n modulêre en moontlik inkonsekwente prestasiemetingsbenadering gedoen. Verder, met die afwesigheid van ’n stel prestasiemetings en oordraagbare metodologieë, wat algemeen aanvaar word, is dit baie moeilik vir die plaaslike vervoerindustrie om hul spesifieke toepassings, rakende die implementering van beleide en tegnologieë, te evalueer. Voorafgemelde aangeleenthede lei tot skeptisisme rondom die volhoubaarheid van die nuwe gevorderde vervoerstelsels.

Om die volhoubaarheid van die intelligente vervoerstelsels te verseker, word daar ’n sistematiese benadering tot prestasiebestuur, deur prestasiemeting, aanbeveel. Alhoewel die idee om prestasiemeting te bestuur in sy kinderskoene is, word daar geglo dat daar met die uitkoms van hierdie navorsingsprojek ’n prestasiebestuur-regime mag volg.

Die doel van hierdie navorsingsprojek is dus om ’n alomvattende metingsraamwerk wat die basis vir die bestuur van prestasie, asook die volhoubaarheid, van die ontwikkelde intelligente vervoerstelsels daar te stel. Dit is bereik deur ses metodiese stappe uit te voer. Hierdie sluit in: 1) die identifisering van al die bestuursverwante aspekte wat van toepassing is op die vervoer-metingsomgewing, 2) die daarstelling van hierdie aspekte in ’n bestuursmeting-raamwerk, 3) die bepaling van die bestuursmeting-struktuur vir die ontwikkeling van standaarde en/of mikpunte, asook die toekenning van betekenisvolle gewigte, om hierdie aspekte te evalueer, 4) die skep van ’n metingsmodel deur gebruik te maak van multi-kriteria besluitnemingsbeginsels om vas te stel wat die (algehele) prestasie van die intelligente vervoerstelsel-toepassings is, 5) die omskepping van die metingsraamwerk in ’n visuele paneel wat in een oogopslag die prestasie van die stelsels vir bestuursdoeleides uitbeeld en 6) die aansporing van prestasiebestuur deur ’n vergoedingstruktuur te bevorder.

Die voorgestelde benadering verskil van die huidige metingstelsels aangesien dit ’n struktuur vir die evaluering van die prestasie, van spesiek beleggings in tegnologie in die Suid-Afrikaanse vervoeromgewing, insluit. Verder wend dit ’n holistiese en generiese metingsraamwerk as die basis vir prestasiebepaling aan. Die voorgestelde metode vir die beplande instrument dien as verwysingspunt vir die prestasiebestuur van intelligente vervoerstelsels. Hierdie instrument

ondersteun die implementeringsinstansies in die verkryging van die nodige kennis om maklik dag-tot-dag, ingeligte besluite, rakende die (algehele) prestasie van hul onderskeie stelsels, te neem. Verder kan die instrument ook die besluitnemers help met die deurlopende evaluering van hul beleggings in vervoertegnologie.

Die ontwikkelde bestuursinstrument het ook aan die voorvereistes, soos in hierdie navorsingprojek geïdentifiseer, voldoen. Hierdie vereistes is daargestel om die wyer gebruik en toepassing van ’n prestasiegedrewe benadering te verseker. Die primêre vereistes verseker dat die instrument aan die volgende voldoen: **aanpasbaar en gepas** om aan die spesifieke vereistes, soos verlang deur ’n ontwikkelende land en die evolusie van intelligente vervoerstelsel-verwante tegnologieë, te voldoen; **holisties** tot so ’n mate dat dit die opinies van alle geïdentifiseerde belanghebbende partye in ag neem en insluit; **alomvattend** sodat dit op beide die privaat en publieke vervoeromgewing toegepas kan word; **bondig** tot so ’n mate dat dit nie in Albert Einstein se mantrastrik beland nie (“nie alles wat tel, kan getel word nie en nie alles wat telbaar is, tel nie”); **veranderlik** sodat dit enige verandering in die kliënt se behoeftes en/of die gewensde projekuikomste kan akkommodeer; en **maklik om te verstaan en te gebruik** sodat dit vinnige en moeitelose evaluering van die prestasie van vervoerprojekte in die tegnologie-beleggingsgebied kan fasiliteer.

Ten slotte beweer die skrywer dat die ontwikkelde instrument getoon het dat dit genoegsame vermoë, onskatbare insigte en beduidende waarde tot die vervoeromgewing toevoeg. Verder is dit ook multi-funksioneel, konsekwent en alomvattend.

ACKNOWLEDGEMENTS

I would like to express my heartfelt thanks to my supervisor, Doctor Johann Andersen, whose encouragement, guidance and support from the initial to the final level, enabled me to develop a profound understanding of this thesis subject.

Furthermore, I would like to thank the Civil Engineering Department for giving me the opportunity to write a doctoral thesis. I am also eternally grateful for the financial support I have received from both the Institute for Transport Technology (ITT) and the Southern African Transport Conference (SATC).

It is an honour for me to also thank Chantal Greenwood, Professor Theodore Stewart, Lize Roux and Professor Martin Kidd. They have provided me with very insightful and important information. I am sincerely grateful for their help and efforts.

In addition, I owe my deepest gratitude to Justin Coetzee, Randall Cable and the International Benefits, Evaluation and Costs (IBEC) working group. They have made available their support in a number of ways and without their assistance this research project would not have been possible.

I am also appreciative of Professor Ron Janssen’s willingness to provide me with a free version of his software.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of this research project. I am especially fully indebted to my parents Anton and Mariëtte Struwig and my partner Morné Visagie. They gave me hope in times I felt despondent.

TABLE OF CONTENTS

EXPLANATION OF HEADING HIERARCHY

HEADING 1

HEADING 2

HEADING 3

HEADING 4

HEADING 5

HEADING 6

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

DEFINITIONS

Intelligent Transport Systems (ITS)

"The ITS application is the use of different types of advanced technologies (e.g. electronics, computer, communications and sensor technologies), in an integrated manner, to increase the efficiency and productivity of transport systems by improving user mobility and safety." - Neudorff *et al.* (2006)

ACRONYMS/ABBREVIATIONS

AA: Automobile Association

AFC: Automated Fare Collection

AHP: Analytic Hierarchy Process

AMS: Arterial Management System

ANP: Analytic Network Process

ANPR: Automatic Number Plate Recognition

APC: Automatic Passenger Counter

APIS: Automated Parking Information Systems

APTS: Advanced Public Transport Systems

APQC: American Productivity and Quality Centre

ASCE: American Society of Civil Engineers

ATIS: Advanced Traveller Information System

ATMS: Advanced Traffic Management Systems

AVI: Automatic Vehicle Identification

AVL: Automated Vehicle Location

BI: Business Intelligence

BPM: Business Performance Management

BRT: Bus Rapid Transit

BSC: Balanced Scorecard

CBD: Central Business District

CBR: Case-Based Reasoning

CC: Chamber of Commerce

CCTV: Closed Circuit Television

CEO: Chief Executive Officer

CESA: Consulting Engineers of South Africa

CIA: Confidentiality, Integrity and Availability

CoCT: City of Cape Town

COLTO: Committee of Land Transport Officials

CONDUITS: Coordination of Network Descriptors for Urban Intelligent Transport Systems

CoO: City of Ottawa

COPRAS: COmplex PRoportional Assessment

CPTR: Current Public Transport Record

CSI: Customer Satisfaction Index

CSS: Customer Satisfaction Survey

CT FMS: Cape Town Freeway Management System

CUTA: Committee of Urban Transport Authorities

DEA: Data Envelopment Analysis

DG MOVE: Directorate General for Mobility and Transport

DMU: Decision-Making Unit

DoC NIST: Department of Commerce National Institute of Standards and Technology

DoE: Department of Energy

DoT: Department of Transport

EC: European Commission

ECSA: Engineering Council of South Africa

EFC: Electronic Fare Collection

EFQM: European Foundation for Quality Management

ELECTRE: Elimination et Choix Traduisant la Réalité

EMS: Electronic Message Sign

EMV: Europay, MasterCard and Visa

EPP: Electronic Parking Payment

EPS: Electronic Payment System

ESI: Employee Satisfaction Index

ESS: Environmental Sensor Station

ETC: Electronic Toll Collection

EU: European Union

EV: Electric Vehicle

EVI: Electronic Vehicle Identification

FCD: Floating Car Data

FHWA: Federal Highway Administration

FIFA: Fédération Internationale de Football Association

FMS: Freeway Management System

FTA: Federal Transit Administration

GABS: Golden Arrow Bus Services

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GIS: Geographical Information System

GP: Goal Programming

GPS: Global Positioning System

GRP: Gross Regional Product

GUI: Graphic User Interface

HAR: Highway Advisory Radio

HBR: Harvard Business Review

HCM: Highway Capacity Manual

HOV: High Occupancy Vehicle

HUT SAL: Helsinki University of Technology Systems Analysis Laboratory

IBEC: International Benefits, Evaluation and Costs (for ITS)

IBIS: Imager on Board the Integral Satellite

IFM: Interoperable Fare Management

IMS: Incident Management System

IRT: Integrated Rapid Transit

IRPTN: Integrated Rapid Public Transport Network

ISTIEE: Institute for the Study of Transport within the European Economic Integration

IT: Information Technology

ITT: Institute for Transport Technology

ITIF: Information Technology and Innovation Foundation

ITP: Integrated Transport Plan

ITS: Intelligent Transport Systems

ITSSA: Intelligent Transport Systems South Africa

KBS: Knowledge-Based Systems

KPI: Key Performance Indicator

LOS: Level of Service

MACBETH: Measuring Attractiveness by a Categorical Based Evaluation Technique

MAPE Minimum Absolute Percentage Errors

MAUT: Multi-Attribute Utility Theory

MAVT: Multi-Attribute Value Theory

MBNQA: Malcolm Baldrige National Quality Award

MCDM: Multi-Criteria Decision Making

MMS: Multimedia Messaging Service

MTBF: Mean Time Between Failures

MTTR: Mean Time To Repair

NHTS: National Household Travel Survey

NIDS: National Income Dynamics Study

NLTA: National Land Transport Act

NMT: Non-Motorised Transport

NORDAC: Nordic Electricity Distribution and Asset Management Conference

OD: Origin-Destination

ORSTW: Operations Research Society of Taiwan

PBM SIG: Performance-Based Management Special Interest Group

PES: Passenger Environment Survey

PGWC: Provincial Government of the Western Cape

PIDS: Passenger Information Display System

PPM: Parts Per Million

PRASA: Passenger Rail Agency of South Africa

PSRC: Puget Sound Regional Council

PROMETHEE: Preference Ranking Organisation Method for Enrichment Evaluations

RADAR: Results, Approach, Deployment and Assessment and Review

R&D: Research and Development

REC: Research Ethics Committee

RITA: Research and Innovative Technology Administration

ROI: Return on Investment

ROW: Right-of-Way

RRT: Rustenburg Rapid Transport

SA: South Africa

SABS: South African Bureau of Standards

SAICE: South African Institution of Civil Engineering

SANRAL: South African National Roads Agency Limited

SANS: South African National Standards

SAP: Systems, Applications and Products

SAPS: South African Police Service

SATC: Southern African Transport Conference

SAW: Simple Additive Weighting

SBSC: Sustainability Balanced Scorecard

SI: Système International

SLA: Service Level Agreement

SMART: Simple Multi-Attribute Rating Technique

SMS: Short Message Service

STARS: Sustainable Transport Analysis and Rating System

SWOT: Strengths, Weaknesses, Opportunities and Threats

TEN-T: Trans-European Transport Networks

TC: Technical Committees

TCRP: Transit Cooperative Research Program

TCT: Transport for Cape Town

TIC: Transport Information Centre

TMC: Transport Management Centre

TMH: Technical Methods for Highways

TOPSIS: Technique for Order Preferences by Similarity to Ideal Solutions

TPI: Transport Performance Index

TQM: Total Quality Management

TRB: Transportation Research Board

TRS: Transport Reporting System

UCT: University of Cape Town

USA: United States of America

UTC: Urban Traffic Control

UTG: Urban Transport Guidelines

VBA: Visual Basic for Applications

VDS: Vehicle Detection Systems

VMS: Variable Message Sign

VMT: Vehicle-Miles Travelled

VTPI: Victoria Transport Policy Institute

WCE: World Congress on Engineering

WRT: with regard/ respect to

WSDoT: Washington State Department of Transport

1. INTRODUCTION

1.1 BACKGROUND TO THE RESEARCH PROBLEM

1.1.1 THE NATIONAL TRANSPORT POLICY

In 2006, the honour of hosting the FIFA (Fédération Internationale de Football Association) World Cup 2010 was bestowed upon South Africa (SA). This prestigious event provided the Government with the necessary stimulus to spur a major evolution in the country's transport network.

In 2007, the Government introduced the National Land Transport Act (NLTA) as a national policy that dictates an integrated land transport network required for nationwide seamless travel. The NLTA stipulates the minimum requirements for the country's Integrated Transport Plans (ITPs).

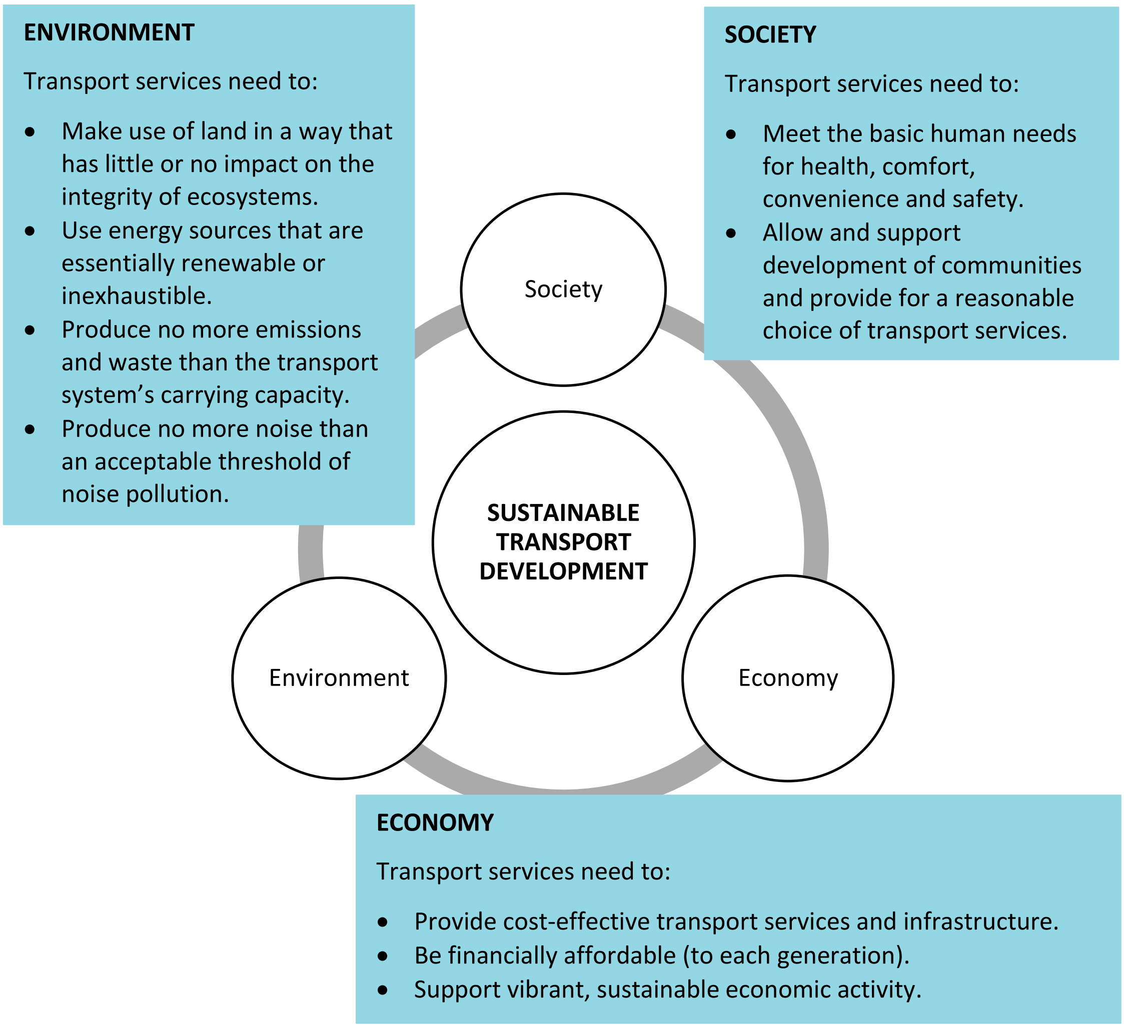
The ITPs target the achievement of a balanced transport network that promotes and gives priority to, specifically, public transport and other alternative modes of transport. One of its most important projects is the promotion of Integrated Rapid Transit (IRT). Integrated Rapid Public Transport Networks (IRPTNs) have been deployed and are being implemented in the 12 main metropolitan areas of SA (SA DoT 2007). IRPTNs combine the best features of rail with the flexibility and cost advantages of road-based public transport.

With the establishment of the NLTA, SA has actively started to promote system interoperability and seamless traveling. In essence, it is hoped that the envisioned integrated land transport network would aid the nation in delivering a high quality transport network that provides for basic mobility and that is accessible to all users.

1.1.2 SUSTAINABLE TRANSPORT DEVELOPMENT

During the last decade, sustainable development has emerged as a concept with global priority. If SA were to follow this, the nation could ensure the long-term viability of the transport network.

Sustainable transport is based on the concept of integrating social-, economic- and environmental sustainability. Figure 1 (Vanderschuren 2006) depicts the requirements of the transport services, with respect to each of these sustainability measures, associated with the achievement of sustainable transport development.



ENVIRONMENT

Transport services need to:

- Make use of land in a way that has little or no impact on the integrity of ecosystems.
- Use energy sources that are essentially renewable or inexhaustible.
- Produce no more emissions and waste than the transport system's carrying capacity.
- Produce no more noise than an acceptable threshold of noise pollution.

SOCIETY

Transport services need to:

- Meet the basic human needs for health, comfort, convenience and safety.
- Allow and support development of communities and provide for a reasonable choice of transport services.

ECONOMY

Transport services need to:

- Provide cost-effective transport services and infrastructure.
- Be financially affordable (to each generation).
- Support vibrant, sustainable economic activity.

Figure 1: Sustainable Transport Development

SA is pursuing sustainable transport development by adhering to the country's ITPs. The IRPTNs that have been deployed seem to reflect environmental sensitivities, support a growing economy and to be sustainable for future generations. However, the nation is faced with the following predicament: THE MERE PROVISION AND/OR ENHANCEMENT OF THE EXISTING LAND TRANSPORT NETWORK IS NOT SUFFICIENT TO INDUCE A SUSTAINABLE LAND TRANSPORT SYSTEM. The problem is that with excessive development and expansion of transport infrastructure come new challenges. For example: since the newly deployed IRPTNs utilise bold and exciting (new) technologies, the nation has been compelled to embark on a journey into the (unknown) territory of a technology-driven setting.

1.1.3 A TECHNOLOGY-DRIVEN SETTING

Over the past decade, the South African transport environment has actively started to adapt a technology-driven setting. Intelligent Transport Systems (ITS) applications such as Advanced Traffic

Management Systems (ATMS) and Advanced Public Transport Systems (APTS) have since then been promoted and developed.

In the private transport environment, various ITS applications are already in place on most of SA's major freeways and imminent expansion and enhancement among the major metropolitan areas are expected. A prominent ITS application in the field of ATMS is the Freeway Management System (FMS). Examples of ITS functions used in FMS are: communication systems, surveillance systems and traffic control systems. Currently, the major freeways are monitored with real-time accuracy (i.e. 24/7) and the drivers are informed about roadway performance and the extent and duration of incidents. Moreover, within the near future, when traffic detectors have been implemented, real-time travel time data will also be available for certain freeway segments.

In the public transport environment, a prominent ITS application in the field of APTS is the IRT system. Examples of ITS functions used in IRT are: information display systems, navigation- and warning systems, electronic payment systems and priority systems. Currently, the position and status of all the assets in the IRT system's fleet and the movement of all the commuters within the IRPTNs are monitored with real-time accuracy (during the span of the service). The commuters are provided with information on the arrival- and departure status (and overall timeliness) of the rapid transit vehicles. Moreover, with the smart card system that is in place, users can pay their fares effortlessly since the need to carry exact cash for payments is removed. Within the near future, when banks and transport entities are more involved, commuters will also be able to transfer effortlessly between different modes of transport, regardless of their mode choice, by only using one payment mechanism.

1.2 RESEARCH PROBLEM

1.2.1 FORMULATION

ITS deployments have been progressing rapidly. These deployments are spurred on by substantial investments from the government as well as supplementary contributions from provincial-, local- and municipal resources. This evolution of ITS technologies not only stimulates the need for assessing these investments and contributions, but also highlights new areas for consideration.

If the sustainability of the newly developed systems is to be ensured, sufficient attention needs to be given to the managing of their cardinal inherent technology-related aspects. These aspects are currently, to varying degrees, being measured and monitored. However, little thought is given to ITS performance management in the conceptualisation- and planning phase of ITS projects. As a result, the monitoring is mostly done by a modular- and possibly inconsistent performance measurement approach.

SA currently has no (holistic) performance management approach for measuring the technology-related aspects of ITS projects. Given this general lack of an established approach for a performance management regime as well as the absence of management tools, which can allow for the regular- and consistent measurement of such systems' performance, no real conclusions can be drawn to make an informed decision about the existing systems' overall health.

The current isolated performance measurement approach creates scepticism around the sustainability of the newly deployed ITS applications. Without consistent, pre-determined and pre-specified standards to measure their performance, the degradation of the systems (over time) is highly probable. For example: with the current state of affairs, transit agencies might not even be aware of the true performance of the ITS projects and their relating technologies could be gradually declining. This likelihood of degradation is also further exacerbated by our unmistakable ever-changing world of technology.

If the aforementioned would to occur, the ITS applications that have already been deployed might become obsolete. Therefore, millions of taxpayers' money could be lost and users' expectations could possibly not be met. This undoubtedly gives stimulus and provides further incentive for changing the current state of affairs.

1.3 RESEARCH PROPOSITION

1.3.1 OVERVIEW

In order to ensure the sustainable deployment of the ITS applications, their technology-related aspects need to be managed in a pre-defined, continuous and holistic manner. In essence, the local transport industry needs to be able to regularly and objectively assess the effects of their specific applications with regard to the implementation of policies and technologies.

The aforementioned can only be accomplished if a paradigm shift towards performance management occurs. This entails the adoption of a performance management regime. With the establishment of a performance management regime, SA will be able to maximise the socio-economic benefits reaped from their investments in ITS applications. As a result, the nation will have the ability to uphold an efficient- and effective transport system that intrinsically caters for sustainable mobility.

As the management guru Peter Drucker famously said: "*you cannot manage what you do not measure*." Based on the aforementioned mantra, it is clear that the foundation for a performance management regime is a measurement framework. That is, a framework that can serve as the reference point for ITS performance management by presenting guidelines to widely accepted performance measures and by capturing transferable methodologies.

However, in order to promote the wider use and application of a performance driven approach, the measurement framework needs to be portrayed as a management tool. That is, a tool that can aid in ensuring the continuous deployment and maintenance of ITS applications. More specifically, a tool that can: 1) assist the implementing agencies in obtaining the necessary knowledge to easily make day-to-day informed decisions regarding the (overall) performance of their respective systems and 2) aid decision makers in the continuous assessment of their investment in transport technology.

1.3.2 FORMULATION

In order to ensure the sustainability of the ITS applicators, it is proposed that a systematic approach to performance management, through performance measurement, be promoted. Even though the concept of managing performance measurement is in its infancy, it is believed that, with the attainment of the proposition made herein, a performance management regime, possibly nation-wide, may follow.

The aim of this research project is thus to develop an all-encompassing measurement framework that lays the groundwork for managing the performance, and contributes towards the sustainability, of the ITS deployments. In order to ensure the wider use and application of a performance driven approach, numerous prerequisites for ensuring the success of the envisioned management tool have been identified. These prerequisites were established by considering the desired functions of an ideal management tool and the limitations of the existing measurement approaches. A discussion of the prerequisites recognised for inclusion follows.

Firstly, the management tool needs to be **scalable and suitable** to address the specific requirements as posed by a developing country and by the evolution of ITS technologies. Secondly, the management tool needs to be **holistic** in the sense that it considers and includes the opinions of all possible interested parties. Thirdly, the management tool needs to be **comprehensive** such that it can be applied to both the private- and the public transport environment. Fourthly, the management tool needs to be **concise** such that it does not fall victim to Albert Einstein's mantra: "*not everything that counts can be counted and not everything that can be counted counts*". Fifthly, the management tool needs to be **agile** such that it can accommodate any changes in the employer's (or the client's) needs and/or the specific project's desired outcomes. Sixthly, the management tool needs to be **easy to understand and use** such that it can facilitate the quick and effortless assessment of transport projects' performance in the field of technology investments. Lastly, the management tool needs to adhere to a **cyclical life-cycle approach** such that it can allow for the continuous assessment and improvement of the ITS applications.

The objectives of this research project are to: 1) identify all of the performance-related aspects that are applicable to the transport measurement environment, 2) present these aspects in performance measurement framework, 3) establish the performance measurement structure by developing standards and/or targets and allocating importance weights towards evaluating these aspects, 4) create the measurement model by utilising Multi-Criteria Decision Making (MCDM) principles in determining the (overall) performance of the ITS applications, 5) transform the measurement framework into a Graphic User Interface (GUI) dashboard that can act as the performance management tool and 6) instigate performance management by implementing an incentivisation structure.

1.3.3 CLARIFICATION AND CONTRIBUTION

In order to clarify and identify the contribution of the research conducted herein, certain research-related questions have been posed. Some of these questions are answered here, while the others are only answered with the completion of this research project.

Note: when reference to the "transport environment" is made in this research project, it is meant to be understood as the transport environment in general and, in particular, the technology implementations evident in the transport environment. The transport environment is thus not considered exclusively and the ITS applications are considered in coherence with the transport environment since they cannot be dealt with in isolation.

Refer to Figure 2.

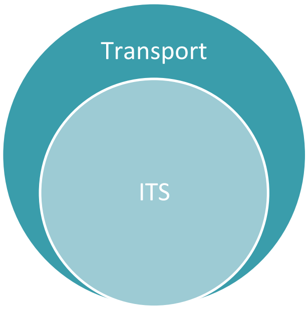


Figure 2: ITS and Transport Relationship

RESEARCH FOUNDATION

What is the rationale for doing the research?

Local ITS deployments are at a critical juncture and adoption of a performance measurement approach can be the first step towards sustainable systems. The South African transport industry is at the perfect stage to adopt such a performance measurement approach. The systems that have already been provided can act as the trail for such an approach, while the systems that are still in the planning- and implementation phases can reap the full benefits of the recommended performance driven approach; from start to end.

RESEARCH MOTIVATION

What is the motivation for doing the research?

Currently, in the South African transport environment, performance measurement is not well defined. No common ITS architecture and thus no common technical standard, for the technologies underlying ITS applications, exist. Moreover, the resulting required multi-facet deployment associated with implementing such technology-oriented systems renders the ease of their management. As a result, the management of these systems is, in general, not adequately exercised.

This current state of affairs deters the realisation of performance evaluation and hence impedes the advancement of the transport industry. If sustainable transport development is to be pursued, the nation needs to start acknowledging the unmistakeable need for adopting a systematic approach to performance management through performance measurement. In essence, the local transport industry needs to embrace a structure for evaluating performance in, specifically, the field of technology investments. It is the belief of this author that the realisation of the proposition made herein will aid the nation in realising a (national) performance management regime. Ultimately, the local ITS applications will be able to evolve into systems that form part of bigger, more complex applications and that are on par with other systems in the world.

RESEARCH APPLICATION

What is the application field of the developed tool?

Since there are many areas of interest that overlap when measuring performance in the private- and the public transport environment, it was decided that the tool needs to be comprehensive such that it can be applied to both of these environments. However, since these transport environments have their own specific operating conditions and -standards, not all of the aspects identified in the measurement framework will be applicable to both of these environments. Therefore, the tool needs to be agile such that only the applicable aspects are taken into consideration for performance appraisal.

After thoughtful consideration, it was also decided that the tool needs to be holistic in the sense that it considers and includes the opinions of all possible interested parties. An interested party refers to any person who can possibly be affected by, or who has an interest in, the transport environment. Three interested parties have been identified. They are the: 1) transport user, 2) operator or contractor and 3) employer or client. During standard- and target development, which forms the basis for performance evaluation, these parties' most important perceptions need to be matched and integrated with the specific aspects of the transport service.

Who will be the users of the developed tool?

The tool can be used by transport implementing agencies and -decision makers. The tool can assist implementing agencies in obtaining the necessary knowledge to easily make day-to-day informed decisions regarding the (overall) performance of their respective systems. Moreover, it can aid decision makers in the continuous assessment of their investment in transport technology.

What are the needs and specific requirements of the users?

For front-end use of the management tool, no specific requirements are needed. However, basic computer literacy and a general understanding of transport performance measurement would be favourable. Moreover, if the user wishes to understand the back-end design of the tool, he/she needs to at least have a basic understanding of the principles underlining MCDM.

RESEARCH VALUE

What makes the research unique and significant?

Currently, no holistic performance management approach is used in the South African environment. Moreover, the performance measures and -indicators, as identified in the literature, lack comprehensiveness and the necessary depth required in addressing the specific needs of the local transport environment. The proposed performance driven approach thus takes the uniqueness of the South African transport environment into account by using localised performance measures and -indicators that are, specifically, applicable to a developing country environment. This was accomplished by augmenting the existing performance measures and -indicators in such a way that they capture the specific aspects of the local transit environment. Moreover, in some cases, the introduction of new performance measures and -indicators were also warranted. With regard to the performance standards and/or -targets, new thresholds that are relevant to the South African transport environment were developed for all of the performance indicators considered. These thresholds consider the (few) identified standards, as found in the literature, and any other standards as determined by the identified interested parties' perceptions, self-identification and a comparison to typical industry standards or to peer-systems.

What are the key scientific issues that the research contributes to?

What sets the research apart from other existing tools and evaluation methods?

What value is associated with the approach used?

RESEARCH DRAWBACKS

What are the drawbacks of the approach used?

The approach pursued to managing performance measurement is undoubtedly broad in its application field. That is, the fact that the tool was developed to be suitable for evaluating the performance of projects in either the private- or the public transport environment. Nevertheless, its broadness is as much a deterrent as it is an incentive. It is the belief of this author that no such holistic tool (or approach), in totality, exists. This undeniably emphasises the significance of the research conducted herein.

MCDM is a broad field with many application methods; each posing its own advantages and disadvantages. Moreover, due to the various assumptions underlining each of the different MCDM methods, the results obtained with each may vary considerably. Therefore, when choosing among the various methods, extreme caution needs to be exercised.

How were the drawbacks solved?

RESEARCH VALIDATION

How was the research validated?

1.4 LAYOUT OF THE RESEARCH PROJECT

CHAPTER 2: LITERATURE REVIEW

This chapter provides an overview of the portraying aspects needed for assessing the performance of transport projects and -plans. Firstly, an introduction to performance measurement, in the context of the transport environment, is given. Secondly, a discussion on private transport- and FMS performance measurement is given. This is followed by a discussion on public transport- and IRT performance measurement. Then an overview of network performance measurement is given. Lastly, a discussion on how to use performance measurement information to drive improvement is given. That is, an overview of the steps associated with establishing a performance-based management program is given.

CHAPTER 3: STATUS QUO

This chapter provides an overview of the current evident technology applications and performance evaluation movements in the City of Cape Town's (CoCT's) transport environment. Firstly, a discussion on the City's transit- and traffic operations, the extensive recent implementation of technology systems and their relating ITS-aspects as well as the long-term viability of the advanced transport systems is given. Secondly, a discussion on some of the emerging performance measurement developments and their applications is given. This chapter then concludes with the main considerations drawn from the status quo analysis and their associated contribution towards the proposition made herein.

CHAPTER 4: RESEARCH DESIGN

This chapter provides an overview of all the aspects (excluding those pertaining to performance measurement) that contribute towards the realisation of the proposition made herein. Firstly, a discussion on the most prominent reference models for performance frameworks is given. Following from this discussion, the performance frameworks identified for inclusion are motivated and then considered in more detail. Then, the vast field of MCDM is considered; including a discussion on the popular models and applications. Following from this discussion, the MCDM model identified for inclusion is motivated and then considered in more detail. This entails an in-depth discussion on Multi-Attribute Value Theory (MAVT) as well as an overview of three decision support systems.

CHAPTER 5: RESEARCH METHODOLOGY

This chapter provides an overview of the methodology pursued in achieving the aim of this research project. Seven methodical steps were identified. These are: 1) develop a performance measurement framework, 2) elucidate performance measures, 3) establish the performance measurement structure, 4) acquire the measurement data, 5) create the measurement model, 6) develop the performance dashboard and 7) instigate performance management. Each of these steps is discussed in detail; with specific reference given to the practices, procedures and principles used during their execution.

CHAPTER 6: RESEARCH APPLICATION

This chapter presents the application of the seven methodical steps outlined in the research methodology. In this chapter, the outcomes corresponding to the execution of each of these steps are elucidated.

CHAPTER 7: SUMMARY OF RESULTS

This chapter provides a summary of the results obtained from the execution of this research project.

CHAPTER 8: CONCLUSIONS

This chapter re-examines the results obtained by answering the unanswered questions posed in the preliminary part of this research project and by discussing the implications of the advocated approach. This chapter then concludes with a discussion on the recommended way forward and some final remarks.

CHAPTER 9: RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter presents the main recommendations, as made by this author, for future research and development.

CHAPTER 10: REFERENCES

This chapter provides a comprehensive list of all of the references consulted in this research project.

2. LITERATURE REVIEW

2.1 INTRODUCTION TO PERFORMANCE MEASUREMENT

2.1.1 OVERVIEW

A comprehensive definition of performance measurement is offered by the United States Federal Highway Administration (FHWA) (TRB 2003d):

> *"Performance measurement is a process of assessing progress towards achieving pre-determined goals, including information on the efficiency with which resources are transformed into goods and services (i.e. outputs), the quality of those outputs (i.e. how well they are delivered to clients and the extent to which clients are satisfied) and outcomes (i.e. the results of a program activity compared to its intended purpose) as well as the effectiveness of government operations in terms of their specific contributions to program objectives."*

Performance measurement clearly has a significant impact on the development, implementation and management of existing and future transport plans and -projects (Kaparias and Bell 2011). It enables transport authorities to: 1) obtain the data necessary to compare the performance of different projects in future scenarios and 2) evaluate the performance of the same project at different points in time.

2.1.2 APPLICATION

Performance measurement is very useful for a variety of comparison- and/or evaluation purposes. According to Eboli and Mazzulla (2012), it can assist in: evaluating the transport project's overall performance; evaluating management's expectations of the transport project in relation to the community objectives; evaluating management's performance and diagnosing problems such as disproportionate cost in relation to service; allocating resources among competing transport properties; providing a management control system for monitoring and improving transport services; and facilitating the accountability sought by government funded agencies and demanded by legislators, regional- and transport authority boards as well as the general public.

2.1.3 REQUIREMENTS

Kaparias and Bell (2011) have identified the four most important desired functionalities of performance measurement to be the following:

1. performance measurement needs to assess benefits,
2. performance measurement needs to assist traffic managers in their decision-making procedures,
3. performance measurement needs to assist contract monitoring as well as promote cities' interests, and
4. performance measurement needs to be easy to apply and simple to convey to the public.

In order to meet the aforementioned desired functionalities, measures that can facilitate either the quantitative- or qualitative characterisation of the performance of the transport plans and -projects need to be in place.

2.1.4 STRUCTURE

Since the transport plans and -projects have goals and objectives that motivate the definition of performance measurement, transport planning and project design need to be performance-based. That is, the performance measures need to objectively relate to the identified goals and objectives. These measures also need to be classified according to dimensions or market segments. According to Kaparias and Bell (2011), this means that the measures need to relate to broad goal areas (i.e. performance areas). Moreover, each performance measure needs to have certain performance indicator(s) that are used to signify its performance.

2.1.5 TYPICAL MEASURES

A review of the literature on transport performance reveals that not all agencies use the same terms for performance measures. Furthermore, views of performance-based allocation and how indicators are calculated vary immensely. Therefore, in the literature, there are various classifications of transport performance measures; some are more schematic and others more articulate. An overview of some of the popular measures, per transport environment, follows.

PRIVATE TRANSPORT

In WSDoT (2014), six overall performance categories are identified. These are: 1) safety, 2) preservation, 3) mobility (i.e. congestion relief), 4) environment, 5) economic vitality and 6) stewardship (i.e. the ability to continuously improve the quality, effectiveness and efficiency of the transport project). STARS (2012) categorised their performance measures into eight categories. These are: 1) access and mobility, 2) safety and health, 3) equity, 4) economic benefit, 5) cost effectiveness, 6) climate and energy, 7) ecological function and 8) community context. Ramani *et al*. (2011) identified 12 performance measures. These included measures of congestion, safety, alternative modes and air quality. US CC (2011) developed a Transport Performance Index (TPI) to measure infrastructure performance of all modes of transport; including passenger- and freight transport. Overarching categories identified include: supply (i.e. density, access, capacity and intermodal connectivity), quality of service (i.e. congestion, safety and travel time reliability) and utilisation (i.e. reserve capacity).

PUBLIC TRANSPORT

TRB (2003a) categorised their performance measures into eight categories. These are: 1) availability, 2) service delivery, 3) safety and security, 4) maintenance and construction, 5) economy, 6) community, 7) capacity and 8) travel time. Zak (2010) chose waiting time, riding time, timeliness, situational safety, transferring frequency, comfort of travel, financial efficiency and investment probability. Nathanail (2008) considered multiple measures including, among others, itinerary accuracy, system safety, cleanliness, passenger comfort, servicing and passenger information. Yeh *et al*. (2000) utilised safety, comfort, convenience, operation and social duty as the primary measurements of performance. TRB (1995a) investigated five performance measures, namely: 1) route design, 2) schedule design, 3) economy and productivity, 4) passenger comfort and safety standard and 5) service delivery. In Chen and Chen (2009) service reliability was also taken as a viable measure.

2.1.6 PERFORMANCE PERSPECTIVE

According to Meignan *et al.* (2007), the performance of transport projects can be viewed from three perspectives. These are the: 1) traveller, 2) operator or contractor and 3) employer or client. These perspectives need to be taken into consideration during performance measure development.

The traveller's viewpoint reflects the his/her perception of the service. This is related to the perceived efficiency of the transport service. The interest of the operator or the contractor (i.e. the company operating the network) lies in (global) profits and operational costs. The interest of the employer or the client (i.e. transport authority) lies in balancing the profits of the operator or the contractor and the transit service (Meignan *et al.* 2007).

2.1.7 EVALUATION

Performance indicators can be established in various manners. A discussion of common approaches used in indicator development follows.

Performance indicators can, for example, be expressed in a format that provides “built-in” interpretation. A popular example of such a format is the concept of Level of Service (LOS), developed by the Highway Capacity Manual (HCM), that is used to evaluate the quality levels of the road traffic flow. Another viable approach is to use ratios. That is, the division of one individual measure by another. These ratios can, for example, facilitate comparisons between routes, areas or agencies. Alternatively, index measures can be adopted. Index measures combine the results from several other performance measures into one equation that produces a single output measure. In addition, TRB (2003a) identified six more viable methods. A discussion follows.

The first method is the comparison to an (annual) average. If a measure’s average value falls within the lowest or the highest groups (e.g. 10th percentile or 25th percentile), the measure is marked for further action. The second method is a variation of the first method. This methods entails the comparison to a baseline value. Here the value of each measure is compared to an average value of the measure in the first year that the performance measurement system was implemented. Measures that fall below a certain percentage of the baseline value are then also marked for further action. The third method is trend analysis. This entails that each measure’s performance be tracked from the previous year to the current year. The result is usually expressed as an improvement percentage. Measures that indicate worsening of performance could then also be marked for further action. The fourth method is referred to as the self-identification of the standard values. Here management sets standards or targets based on a combination of current agency performance, professional judgment and agency goals. Both the fifth- and sixth method are based on a comparison to typical industry standards or -targets or to peer systems. With regard to the fifth method, the agency surveys other representative agencies or finds examples of standards or targets in literature and applies an average or typical standard or target to its own operations. With regard to the sixth method, the agency identifies other agencies with similar conditions (e.g. city sizes and cost of living index values) and determines how well those agencies are performing in the measurement categories. Standards or targets are then based on the average values of the peer agencies for given measures or, alternatively, on some percentile values.

2.2 SYSTEMATISING THE PERFORMANCE MEASUREMENT PROCESS

In order to understand and cover all of the facets pertaining to the performance measurement process, it is helpful to take on a systematised view. The recommended disassembled logic to be taken can be seen in Figure 3.

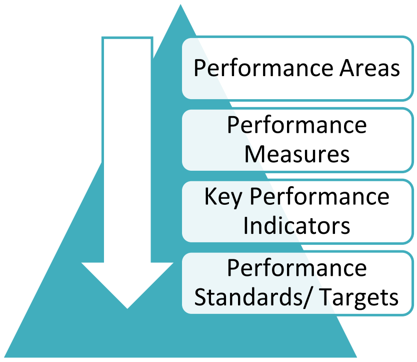


Figure 3: A Systematic (top-down) Approach towards Performance Measurement

A detailed discussion of each level of the measurement process - from top to bottom - as per transport environment follows.

2.3 PRIVATE TRANSPORT PERFORMANCE MEASUREMENT

2.3.1 PERFORMANCE AREAS

In Kaparias and Bell (2011), it is proposed that urban traffic management be evaluated by four performance areas. These are: 1) traffic efficiency, 2) traffic safety, 3) social inclusion and land use as well as 4) pollution reduction. An overview of the developed performance measurement framework can be seen in Figure 4 (Kaparias and Bell 2011).

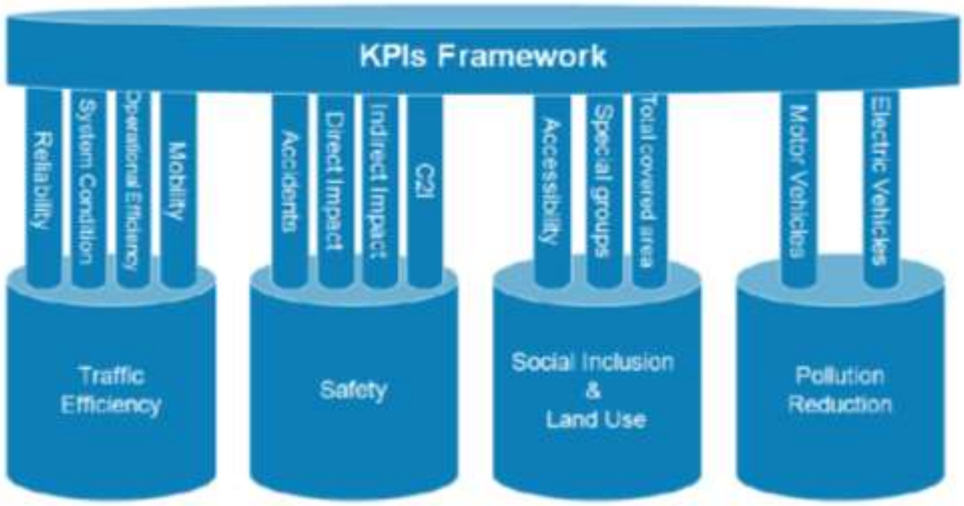


Figure 4: Overview of Performance Measurement Framework

TRAFFIC EFFICIENCY

The majority of urban traffic management policies and solutions, including those involving ITS, have the improvement of traffic efficiency as one of their main objectives. The term traffic efficiency may cover a variety of aspects. For the purposes of the study conducted in Kaparias and Bell (2011), traffic efficiency was constituted by four sub-categories. These are: 1) mobility, 2) reliability, 3) operational efficiency and 4) system condition and -performance. A discussion of these sub-categories, as given in Kaparias and Bell (2011), follows.

Mobility can be defined as the ability of a transport system to provide access to work, recreational activities, shopping, intermodal transfer points and other land uses. According to Kaparias and Bell (2011), mobility measures thus need to reflect the ability of people and goods to reach different destinations (by using different modes). Mobility measures also need to capture the density of the transport service within a given area and experienced from the user's perspective. In essence, mobility is mainly concerned with travel time.

Reliability expresses the ease of mobility. Reliability measures thus need to reflect the ease or difficulty of people and goods to perform their trips. In essence, reliability is mainly concerned with travel time variability, speed, system usage and -capacity. Therefore, Kaparias and Bell (2011) state that reliability measures originate from the perspective of the suppliers of the modes and the infrastructure.

Operational efficiency refers to the organisation of resources to produce an acceptable level of transport output. The quantification of the performance of operational efficiency is thus of particular interest to the suppliers of the transport services. The measures of operational efficiency typically evaluate the competency of systems from a financial-, operational-, time- and user perspective. According to Kaparias and Bell (2011), the most frequently used measures are: trip time, congestion-related attributes, transfer time at connecting facilities and mode share.

System condition and -performance refer to the physical condition of the transport infrastructure and -equipment. As stated in Kaparias and Bell (2011), this sub-category is seen as a vital directive by most practitioners. System condition and -performance measures can focus on the condition of the system itself (e.g. roadways with deficient ride quality) and/or on the efficiency of transport programs (e.g. cost to maintain roadways). The most common measures relate to roadway- and bridge conditions and age as well as maintenance by their management organisations.

TRAFFIC SAFETY

Despite considerable improvements in recent years, safety remains a key issue within transport planning. Many people are still involved in incidents every day and many of these people often suffer injuries or death. The improvement of traffic safety is a priority for city authorities. Therefore, the quantification of a city’s performance in this aspect is essential.

A variety of measures aiming to reduce incident occurrences has been introduced throughout the last decades. According to Kaparias and Bell (2011), these include in-vehicle fixtures and fitments (e.g. seatbelts, airbags and headrests) as well as on-road traffic engineering features (e.g. pedestrian crossings and traffic calming measures). ITS applications such as collision control systems and variable speed warning signs play a prominent role in both of these categories.

The level of safety associated with transport infrastructure (e.g. road section and intersection) can be defined by two measures. These are: 1) the number of incidents and 2) the impact of the incidents. Even though incident numbers are relatively easy to obtain and analyse, the quantification of the resulting impact is more complex. However, according to Elvik *et al.* (2009), the latter mentioned is mostly measured as the number of people with (light to severe) injuries or the number of fatalities.

The main factors influencing road injuries are: exposure (i.e. the amount of travel), incident rate (i.e. incident risk per unit of exposure) and incident severity (i.e. the outcome of incidents concerning injuries). Given these factors, Kaparias and Bell (2011) have identified four different ways to reduce the amount of injuries and fatalities. These are:

1. reducing exposure to the risk of incidents by reducing the amount of travel,
2. shifting travel to a means of transport with a lower level of risk,
3. reducing the incident rate for a given amount of travel, and
4. reducing incident severity by improving the protection and safety of road users.

Most policies (and ITS applications) aimed at improving traffic safety satisfy one or more of the aforementioned four requirements. Therefore, Kaparias and Bell (2011) recommend that, aside from safety’s direct quantification in terms of incident numbers, the measurement of the performance of policies and systems also need to be analysed. This can be done in terms of two categories: 1) policies and applications with a direct safety impact and 2) policies and applications with an indirect safety impact. The former mentioned includes policies (and ITS applications) that are put in place specifically for the avoidance of incidents and the improvement of safety. The latter mentioned includes policies and technologies implemented on the transport infrastructure that focus on the influencing factors of safety. These policies and technologies thus inherently imply a major fiscal investment.

SOCIAL INCLUSION AND LAND USE

According to Kaparias and Bell (2011), social inclusion through traffic management (and ITS) involves facilitating the participation of individuals in economic-, social- and cultural life. This is a complex issue that is influenced by numerous factors. The nature of these factors can be personal, geographical, institutional, economical, cultural or political. In this context, transport is not an independent activity; rather a supporting action. That is, an action that becomes necessary if the undertaking of vital activities is not possible within the individual's environment.

Land use generally describes the nature, intensity and spatial distribution of different functions or human activities in a certain area of consideration. According to Kaparias and Bell (2011), there is a strong bi-directional interdependency between transport and land use patterns. While changes in land use alter the spatial distribution and intensity of transport demand (by rearranging travel routes), changes in transport supply enhance the accessibility (and attractiveness) of certain locations which then possibly causes other locations to experience a decline in accessibility. The key factors influencing the relationship between transport and land use, as given in Kaparias and Bell (2011), are:

- access options (i.e. the variety of route options with which the activity can be reached),
- travel time (i.e. the average travel time with regard to free flow travel time),
- reliability of the transport service (i.e. delays due to congestion and parking search),
- access time between transport and activity (i.e. walking distances from parking spaces),
- access quality between transport and activity (i.e. user friendliness of access routes, safety of road users and access barriers), and
- capacity of the transport system (i.e. saturation of road infrastructure and availability of parking spaces).

POLLUTION REDUCTION

The environmental impact of a traffic management policy (and ITS application) usually consists of several elements. Examples include, among others, noise, visual intrusion as well as impact on flora and fauna. Nevertheless, the work in Kaparias and Bell (2011) only focused on the emission of pollutants from traffic.

According to Kaparias and Bell (2011), the influence of traffic management (and ITS) on vehicle fleet emissions is usually reflected by their effect on vehicle traffic activity and -demand. The former mentioned is mainly influenced by changes in traffic conditions and possibly also driving routes. Traffic conditions can be explained by the typical driving cycle where the typical speed of a vehicle is presented as a function of driving time. The main parameters describing a vehicle's driving cycle are:

average speed, maximum speed, number of stops and maximum acceleration/deceleration. The parameters of driving routes are length and topography (i.e. road gradients).

2.3.2 PERFORMANCE MEASURES

In Kaparias and Bell (2011), a collection of potential performance measures is presented. For the purpose required herein, only some of these measured are considered in more detail.

TRAFFIC EFFICIENCY

Numerous performance measures can be adopted for the evaluation of traffic efficiency. A list of some of these measures, as given per previously mentioned sub-category, follows.

MOBILITY

Examples of mobility measures, as given in Kaparias and Bell (2011), are:

- average travel time to relevant points of interest,
- average commuting distance,
- total roadway lane-kilometres, and
- total roadway lane-kilometres with ITS.

In Aztech (2011), the travel time index is also proposed as a valid measure for mobility. This index is computed by dividing the actual (measured) travel time by the free flow travel time along a roadway segment of interest. According to Aztech (2011), the actual (measured) travel time refers to the peak hour periods during the weekdays and is measured separately for (morning) inbound- and (evening) outbound directions.

The data required for the computation of such mobility measures can be obtained from, among others, probe vehicles, vehicle detectors, Geographical Information System (GIS) database, travel demand models, household travel surveys and maps of the road network.

RELIABILITY

Examples of reliability measures, as given in Kaparias and Bell (2011), are:

- Origin-Destination (OD) route travel time,
- total travel time,
- average travel time,
- vehicle-kilometres-travelled,

- delay, and
- modal split.

In Aztech (2011), travel time reliability is also proposed as a valid measure for reliability. This measure is used to indicate the longest travel time, corresponding to a certain roadway segment, that can be expected within 95% probability. That is, travellers can expect this travel time (or a shorter travel time) 95% of the time. According to Aztech (2011), this measure compliments the average travel time by providing additional information on the degree of variability in the travel time measures during the period of interest. An increase in this measure implies a greater degree of variability in the traffic; which generally translates into lower travel time reliability for the travellers.

The data required for the computation of such reliability measures can be obtained from, among others, cellular phone probes, probe vehicles, travel demand models, household travel surveys, video detection using Automatic Number Plate Recognition (ANPR), positioning systems (e.g. Global Positioning System: GPS), traffic detectors and surveys among travellers.

OPERATIONAL EFFICIENCY

Examples of measures pertaining to operational efficiency, as given in Kaparias and Bell (2011), are:

- public cost for transport,
- cost-benefit of existing facility versus new construction,
- average cost per constructed lane-kilometre,
- value of fuel savings, and
- customer satisfaction with completed projects.

In Aztech (2011), both the percentage of roadway kilometres congested and the percentage of time congested are also proposed as valid measures for operational efficiency. The former mentioned measure assesses the extent of recurring congestion by identifying the number of kilometres of a roadway segment that was congested during the peak periods. The latter mentioned measure represents the percentage of time during the peak periods a roadway segment is considered congested. According to Aztech (2011), these two measures allow one to gauge the extent of congestion - both in space and time.

The data required for the computation of measures pertaining to operational efficiency can be obtained from, among others, governmental offices, private transport companies, consultancy firms, vehicle probes, travel demand models, transport literature, expert opinions and surveys among travellers.

SYSTEM CONDITION AND PERFORMANCE

Examples of measures pertaining to system condition and -performance, as given in Kaparias and Bell (2011), are:

- percentage of roadway mainline pavement or bridges rated good or better,
- customer perception of the steps taken to improve the system,
- number of lane kilometres designated for capacity upgrade or resurfacing contracts,
- construction grants issued, and
- number of projects funded by the Government.

In Banks and Kelly (1997), equipment status is also proposed as a valid measure for system condition and -performance. This measure can be quantified as the fraction of equipment functioning properly, as opposed to that either not functioning or producing erroneous data. According to Banks and Kelly (1997), the measurement of equipment status requires the precise definition of the various equipment status categories, an equipment inventory and a logging system for keeping track of changes in equipment status.

The data required for the computation of measures pertaining to system condition and -performance can be obtained from, among others, governmental agencies, expert opinions and surveys among travellers.

TRAFFIC SAFETY

In order to evaluate the impact of a specific traffic management (and ITS application) on traffic safety and to select the appropriate performance measure, Kaparias and Bell (2011) recommend that a classification first be made. This classification entails that an application first be placed under one of the following four groups:

1. Infrastructure-based application with direct safety impact (i.e. application installed only to avoid incidents and to improve safety).
2. Infrastructure-based application with an indirect safety impact in urban environments (i.e. application in inner-city areas with a primary goal other than safety).

3. Infrastructure-based application with indirect safety impact on urban roadways (i.e. application on roadway to influence traffic flow).
4. Car-to-infrastructure-related application.

A more in-depth discussion on the aforementioned classification groups follows.

INFRASTRUCTURE-BASED APPLICATIONS WITH DIRECT SAFETY IMPACT

Only one of this group's relating applications, as identified in Kaparias and Bell (2011), is considered in more detail. That is, the use of feedback signs.

By using feedback signs, authorities have the opportunity to influence a driver's behaviour. For example: authorities can reduce the speed according to the current traffic conditions or adapt the spacing behaviour according to the current speed. The effects of the feedback signs can be measured by comparing the traffic situation immediately in front of and behind the location of the feedback sign.

Possible measures could then be speed and spacing. The data needed for the computation of these measures can be obtained from inductive loop detectors and radar.

INFRASTRUCTURE-BASED APPLICATIONS WITH INDIRECT SAFETY IMPACT IN URBAN ENVIRONMENTS

Only one of this group's relating applications, as identified in Kaparias and Bell (2011), is considered in more detail. That is, adaptive traffic signal control systems.

The objectives of adaptive traffic signal control systems include: the harmonisation of the traffic flow, the reduction of journey times on primary roads and the reduction or avoidance of congestion occurrences. With the aid of adaptive traffic signal control systems, authorities can directly influence the traffic flow according to the current traffic conditions. However, the effects these systems have, can only be analysed if the whole road network covered is considered. This can be accomplished by, for example, using an adequate fleet of vehicles that send their speed and position in the network or executing periodical driving inspections at roads with a high risk of congestion. In this way the reduction of congestion occurrences can, indirectly, reduce the risk of rear-end accidents.

Possible measures could then be the number of stops, number of congestion occurrences and queue lengths. The data needed for the computation of these measures can be obtained from probe vehicles, driving inspections and traffic models.

INFRASTRUCTURE-BASED APPLICATIONS WITH INDIRECT SAFETY IMPACT ON URBAN ROADWAYS

In this group, the application of roadway section control is considered (Kaparias and Bell 2011).

The objectives of section control include: the harmonisation of the speed (and spacing) in accordance to the current traffic volume, the reduction of the speed according to current weather conditions and the issuing of warning messages for congestion, road works and other dangerous situations. The operation of section control requires a widespread sensor infrastructure that collects the traffic data which, in itself, provides the necessary basis for the assessment. Section control can also reduce the number of congestion occurrences as well as their intensity. Since congestion is a major reason for rear-end-collisions, the system has a secondary effect on traffic safety. However, this influence is indirect which makes a reliable quantitative assessment very difficult.

In essence, possible measures could then be speed, spacing and the number of congestion occurrences. The data needed for the computation of these measures can be obtained from traffic detectors and radar.

CAR-TO-INFRASTRUCTURE-RELATED APPLICATIONS

Applications of car-to-infrastructure communication can include different systems. Examples include, among others, turning assistance, red-light assistance and collision warning. Nevertheless, since these systems all rely on the same technology, Kaparias and Bell (2011) considered them as one application.

The main aim of car-to-infrastructure communication is to influence the driver’s behaviour in specific situations. In order to validate these effects, a comparison of the driver’s behaviour with and without system support is necessary. However, this comparison is (mostly) only possible with the aid of additional data from the vehicles. Another aim of car-to-infrastructure-communication systems is to warn the driver of critical traffic situations. In order to measure the direct effects of such warnings, a pool of test drivers is needed. In this way the reduction of critical situations can, indirectly, reduce the number of incidents.

Possible measures could then be the number of red light violations and warnings, speed, brake pedal activations and number of conflict situations. The data needed for the computation of these measures can be obtained from traffic detectors, red light cameras, vehicle probe data and pool of test drivers.

SOCIAL INCLUSION AND LAND USE

A discussion of possible performance measures, as given per category, follows.

SOCIAL INCLUSION

Although social inclusion is a personal issue, it is not possible to evaluate its impact(s) for each individual citizen. Therefore, measuring social inclusion is a matter of approximation in terms of: a spatial unit (i.e. a reference zone that can represent a house, a house-block or a municipality), a target group (e.g. deprived and elderly) and/or a specific activity. According to Kaparias and Bell (2011), the result of this approximation is average values that indicate a general trend rather than the exact situation of all individuals.

Examples of measures pertaining to social inclusion, as given in Kaparias and Bell (2011), are:

- average travel time to basic everyday activities,
- average transport cost to basic everyday activities,
- percentage of population within “x” kilometres or minutes of basic everyday activities, and
- number of trips per day for specific population groups.

In Litman (2003), numerous other measures pertaining to social inclusion are also proposed. Examples include (transport) affordability and diversity. The former mentioned measure can be computed as the portion of household expenditures devoted to transport; particularly by people who are economically-, socially- and physically disadvantaged. According to Litman (2003), transport costs can, as a general reference, be considered unaffordable if they exceed 20% of a household’s income. The latter mentioned measure refers to the variety and quality of transport options available in a community. This can be computed by, for example, considering the modal split. That is, the portion of travel made by, among others, walking, cycling, ridesharing, public transport and taxi services.

The data required for the computation of measures pertaining to social inclusion can be obtained from, among others, GIS database, surveys among travellers and OD models.

LAND USE

Due to the slow development rate of land use patterns, it is more appropriate to survey the land-use-related impacts of traffic management (and ITS applications) over long periods of time rather than to measure their performance with respect to it (Kaparias and Bell 2011). Surveying the nature, quantity and distribution of human activities and other land functions is not only a basic means for monitoring the general economic-, social- and ecological development, but also a way of obtaining basic data for the evaluation of accessibility and social inclusion.

Examples of measures pertaining to land use, as given in Kaparias and Bell (2011), are:

- type and location of education facilities,
- type and location of public services,
- location and access procedure of parking facilities,
- number of parking spaces at parking facilities, and
- the number and width of lanes.

In Gudmundsson (2001), additional measures pertaining to land use are also proposed. Examples include land area occupied by roadways, land use mix (i.e. the proximity of residential-, commercial- and employment land uses) and the number of animal collisions with vehicles. Animal collisions typically occur in the vicinity of informal settlements and/or high-density areas.

The data required for the computation of measures pertaining to land use can be obtained from, among others, municipalities, on-site survey inspections, public service authorities, topographical maps, transport planning authorities and commercial digital network providers.

POLLUTION REDUCTION

In Kaparias and Bell (2011), the main performance measures needed for pollution reduction assessment have been identified. A discussion of these performance measures, as given in Kaparias and Bell (2011), follows.

- Fleet data.
  - The fleet composition by vehicle category and fuel type.
  - The age distribution for each vehicle category.
  - The total travelled distance, for each vehicle category, within a specific timeframe.
- Traffic conditions.
  - The traffic volume by time of day and by vehicle category.
  - The number of stops as well as the average speed for each of the vehicle categories.
  - The maximum allowed speed on each of the network's links concerned.
  - The average passenger load for each vehicle category.
  - The average parking time by vehicle category.
- Route data.
  - The number of signalised intersections.
  - The average gradient of all links in the network concerned.

- Vehicle data.
    - The weight, dimensions (i.e. height and width), passenger capacity, battery type, battery weight and maximum power of the Electric Vehicle (EV).
- Data on electricity production.
    - The total amount of electricity generated.
    - The total emissions due to electricity production.

Note: the last two mentioned performance measures are only applicable if the fleet under consideration contains a significant number of EVs.

In Gorham (2002), numerous other transport emission reduction measures are also proposed. A prominent example is the use of road pricing. Road pricing is used to relieve congestion in, especially, urban areas by placing a charge on the distance driven. According to Gorham (2002), the simplest form of road pricing is an odometer tax. However, an odometer tax does not adjust for where and when vehicles travel; instead it averages incremental vehicle costs over time and space. Road- or facility specific charges can be implemented through tolls or, in urban areas, increasingly through advanced technology.

The data required for the computation of measures pertaining to pollution reduction can be obtained from, among others, transport companies, vehicle manufacturers, transport service providers, Government organisations, field data collection, positioning systems, enforcement cameras and the city’s traffic control centre.

2.3.3 PERFORMANCE INDICATORS

Kaparias and Bell (2011) have developed Key Performance Indicators (KPIs) for each of the performance measures relating to each of the performance areas presented previously. However, since the construction of all of these KPIs is founded on similar principles, only one performance measure’s representative KPI per performance area is considered herein.

TRAFFIC EFFICIENCY

For the performance area, traffic efficiency, it has been decided to only discuss the index for mobility in more detail.

INDEX FOR MOBILITY

A mobility KPI can be composed of different elements. However, according to Kaparias and Bell (2011), it essentially consists of the average travel time (on the roadway) to reach different destinations. This travel time can be expressed in time units, normalised by the distance to the destinations and weighted by the importance according to the goals and objectives of the application under consideration. The weights have to be assessed with values from 0 to 1; with the target sum set to 1.

The mobility index I_{MOB} can be calculated with the aid of Equation 1 (Kaparias and Bell 2011).

Equation 1: Mobility Index

$$I_{MOB} = W_{PV} \cdot \frac{1}{|R_{PV}|} \sum_{r \in R_{PV}}^{|R_{PV}|} \frac{ATT_{PV}^{r}}{D_{r}}$$

Where:

r = a route (specific OD pair) among a set of selected R_{PV} on the road network.

ATT_{PV}^{r} = the average travel time for route r on the road network.

D_{r} = the length of route r.

W_{PV} = the weight representing the importance of the travel time on the road network.

The unit of the mobility index I_{MOB} is “travel time per kilometre”.

TRAFFIC SAFETY

For the performance area, traffic safety, it has been decided to only discuss the index for car-to-infrastructure communication systems in more detail.

INDEX FOR CAR-TO-INFRASTRUCTURE COMMUNICATION SYSTEMS

Car-to-infrastructure communication systems aim to (directly) warn drivers of dangerous situations and conflicts. According to Kaparias and Bell (2011), the number of sent-out warning messages can thus be used as a significant figure for evaluating their safety impact.

The proposed index I_{C2I} is defined as shown in Equation 2 (Kaparias and Bell 2011).

Equation 2: Car-to-Infrastructure Communication Index

$$I_{C2I} = \sum_{l \in L}^{|L|} W_{l} \cdot \frac{WARN_{l}}{DTV_{l}} + \sum_{j \in J}^{|J|} W_{j} \cdot \frac{WARN_{j}}{DTV_{j}}$$

Where:

$WARN_l$ = the number of sent-out driver warnings on link l on an average day, referring to a critical situation.

$WARN_j$ = the number of sent-out driver warnings on intersection j on an average day, referring to a critical situation.

W_l = the weight representing the importance of link l in the network.

W_j = the weight representing the importance of intersection j in the network.

DTV_l = the daily traffic volume on link l.

DTV_j = the daily traffic volume through intersection j.

The dimension of the car-to-infrastructure communication index I_{C2I} is “actions per vehicle”.

SOCIAL INCLUSION AND LAND USE

For the performance area, social inclusion and land use, it has been decided to discuss one index pertaining to social inclusion and one index pertaining to land use. The former mentioned includes a discussion the index for accessibility and the latter mentioned includes a discussion on the index for the proportionality of the covered area.

INDEX FOR ACCESSIBILITY

According to Kaparias and Bell (2011), the basic contribution of traffic management (and ITS) to social inclusion is the provision of access to basic activities of everyday life. In order to compute accessibility, the pre-defined spatial zones, their respective structural data and the quality of the transport system need to be considered.

The accessibility from location/zone z_1 to activity act in each zone $z_2 \in Z$, where Z is the set of all other zones, $ACC_{z_1,act}$ is defined as given in Equation 3 (Kaparias and Bell 2011).

Equation 3: Accessibility Index

$$ACC_{z_1,act} = \sum_{z_2 \in Z}^{|Z|} B_{z_2} \, . \, a_{z_2,act}$$

Where:

$a_{z_2,act}$ = the opportunities for activity act in zone z_2.

B_{z_2} = a binary value equalling 1 if zone z_2 is within a pre-determined threshold (e.g. a certain distance) and 0 otherwise.

The dimension of the accessibility index $ACC_{z_1,act}$ is "number of activities". For specific case studies, it can be used as a performance index. However, for the complete assessment of social accessibility the various $ACC_{z_1,act}$ values for different origin zones and activities need to be combined into a collective KPI. According to Kaparias and Bell (2011), this average accessibility KPI represents the average accessibility to all activities (set ACT) from all zones of origin (set Z). This results in the I_{ACC} KPI as shown in Equation 4 (Kaparias and Bell 2011).

Equation 4: Average Accessibility Index

$$I_{ACC} = \sum_{z_1 \epsilon\, Z}^{|Z|} \sum_{act \epsilon ACT}^{|ACT|} \frac{W_{act}\, .\, ACC_{z_1,act}}{|Z|}$$

Where:

W_{act} = the weight representing the importance of activity act among the set of all considered activities in the set ACT.

$|Z|$ = the number of elements in the set of zones Z (i.e. number of zones).

The dimension of the average accessibility index I_{ACC} is "number of activities".

INDEX FOR THE PROPORTIONALITY OF THE COVERED AREA

The main difficulty in assessing the additional value generated by traffic management (and ITS) with respect to land use is the large difference in the reaction times of both elements. Traffic management (and ITS) aim at short-term improvements of their targeted aspects. Land use, on the other hand, has long-term adaptation times to its boundary conditions. In order to demonstrate these effects at a macroscopic level, Kaparias and Bell (2011) propose that the proportionality of the covered area be used as the index.

According to Kaparias and Bell (2011), a direct calculation of land consumption is feasible through GIS data. That is, defining the relative growth in vehicle-kilometres over five years $\Delta\, VKM_5$ as follows:

Equation 5: Relative Growth in Vehicle-kilometres over 5 Years

$$\Delta\, VKM_5 = \frac{VKM_i - VKM_{i-5}}{VKM_{i-5}}$$

Where VKM_i and VKM_{i-5} are the total vehicle kilometres in years i and $i-5$ respectively. The relative growth of the total covered area by transport infrastructure over five years $\Delta\, TCA_5$ is defined as follows (Kaparias and Bell 2011):

Equation 6: Relative Growth of Total Covered Area over 5 Years

$$\Delta\, TCA_5 \frac{TCA_i - TCA_{i-5}}{TCA_{i-5}}$$

Where TCA_i and TCA_{i-5} are the total vehicle kilometres in years i and $i - 5$ respectively. The land use KPI of proportionality of area covered by transport I_{PCA} can be defined as shown in Equation 7 (Kaparias and Bell 2011).

Equation 7: Land Use Index

$$I_{PCA} = \frac{\Delta\, VKM_5}{\Delta\, TCA_5}$$

As stated in Kaparias and Bell (2011), the relative growths $\Delta\, VKM_5$ and $\Delta\, TCA_5$ can take any value. However, they would typically range between -1 and 1. Negative values indicate a decrease, positive values indicate an increase and zero indicates stagnation in the growth of the respective parameter. Their ratio I_{PCA} can also have positive- or negative values. Positive values indicate that traffic volume and total covered area have the same development trends and negative values indicate that the trends of the two indicators are contrary.

POLLUTION REDUCTION

For the performance area, pollution reduction, it has been decided to only discuss the index for the greenhouse gas (GHG) emission rate in more detail.

INDEX FOR THE GHG EMISSION RATE

Scenario analysis on road transport vehicles enables the analysis of fuels and emissions, including GHG. Since CO_2 is the dominant tailpipe GHG, the emissions during the vehicle's operation stage can be taken to only include CO_2. In Kaparias and Bell (2011), the GHG emissions rate E_{GHG} for a certain fuel type is derived using a carbon balance method. The heating value Q_{HV} for each specific fuel is known and normally measured in MJ/kg. Therefore, the mass of fuel required to produce 1 MJ of energy can easily be calculated. The carbon content by mass C_{mass} for this fuel (expressed as a percentage) can be assessed based on the known fuel type. If one assumes that all of the carbon introduced with a fuel to the engine is fully oxidised to CO_2, an appropriate GHG emissions rate can be calculated with the aid of Equation 8 (Kaparias and Bell 2011).

Equation 8: Greenhouse Gas Emission Rate

$$E_{GHG} = \frac{1000}{Q_{HV}} . C_{mass} \cdot \frac{M_{CO_2}}{M_C}$$

Where:

M_{CO_2} = 44 g/mol is the molar weight of CO_2

M_C = 12 g/mol is the molar weight of carbon

The unit of the GHG emission rate index E_{GHG} is g CO_2/MJ. The GHG emission rates for each fuel type are given in Ou *et al*. (2010).

2.4 FMS PERFORMANCE MEASUREMENT

2.4.1 TYPICAL ITS FUNCTIONS EVIDENT IN FMS

ITS not only play an important role in monitoring, controlling and managing freeway traffic more effectively, but also in providing the data needed for performance measurement purposes. A description, as given in Chan (2011), of some of the most prominent ITS functions present in a Freeway Management System (FMS) follows.

- Ramp control.
  - Entrance ramp control is the most widely used method of freeway traffic control. Its main objective is to limit the number of vehicles entering the freeway such that demand does not exceed capacity. The techniques for ramp control include ramp metering and ramp closure. Ramp metering limits the rate at which traffic can enter the freeway and ramp closure involves closing the ramp to traffic on a permanent- or a short-term basis.
- Freeway mainline control.
  - Freeway mainline control is the regulation, warning and guidance of freeway traffic in order to: achieve more uniform and stable traffic flow as demand for the facility approaches capacity; reduce the potential for rear-end collisions if congestion develops; facilitate incident management and recovery from congestion; divert freeway traffic to alternative routes to utilise corridor capacity; and to change the directional capacity of the freeway by use of reversible lanes.
- Dynamic roadway control.
  - Dynamic roadway control is mainly implemented through lane- and speed control. Reversible lane control is used to accommodate for peak directional traffic demands

by changing the directional capacity of a freeway. This is implemented when the peak period traffic volumes show a significant directional imbalance. Variable speed control is used to reduce the speed of traffic on a freeway to a level that corresponds to a maximum volume. As the peak flow demand increases, speed control can help improve the stability and uniformity of flow and reduce the occurrence of rear-end collisions. Moreover, lower speed limits could be used during hazardous driving conditions such as excessive rain or sunshine.

- Priority control for HOV (High Occupancy Vehicle) lanes.
    - Priority access control is used in conjunction with entrance ramp metering to give priority to HOV traffic (e.g. buses and carpools). The HOVs avoid any delay associated with ramp queues and enter the freeway with no disruption. This priority access is accomplished by using either bypass lanes on the ramps or exclusive ramps.
- Detection.
    - Electronic freeway detection systems provide real-time traffic information on volumes, speed and occupancy of each lane of the freeway. Since the traffic management agencies have accurate information at their disposal, they can improve the quality of operations in the traffic network by: implementing control strategies, detecting- and managing traffic during incident occurrences as well as activating traveller information systems.
- Traffic surveillance.
    - Traffic surveillance is the core of any effective ATMS. The traffic network is surveyed with the aid of CCTV (Closed Circuit Television) cameras. This surveillance footage assists in: accumulating accurate and reliable traffic information; identifying and verifying recurring- and nonrecurring congestion; identifying severity of problem areas; continual monitoring of traffic over a network; and evaluating the effects of traffic operational improvements.
- Variable Message Sign (VMS).
    - VMSs are traffic-control devices used for traffic warning, regulation, routing and management. They are designed to affect the behaviour of motorists (thereby improving traffic flow) by providing real-time traffic information. VMSs are the backbone of the traveller information system. They are also of cardinal importance to improving roadway operations and -safety. Three types of real-time signs exist. These are: 1) advisory, 2) guide and 3) advance.

- Highway Advisory Radio (HAR).
    - The HAR is intended to provide more specific traffic information, at key locations, more immediately than is possible through traditional commercially broadcast traffic reports. HAR uses either live messages, pre-selected taped messages or synthesised messages.
- Communications.
    - A FMS is comprised of many different elements. Examples include: field components (e.g. signal controllers, ramp meters and VMSs), surveillance hardware (e.g. detectors and cameras), central equipment (e.g. computers, peripherals and monitors) and the human-element (e.g. operators and maintainers). These components need to exchange information with one another. Moreover, information need to be transferred between the field equipment and the control centre. This information can, for example, be in the form of video pictures, voice messages or control- and surveillance data (i.e. low-speed data).

In summary, within the FMS environment, ITS applications can be used to: manage traffic flow, promote safe and stable traffic conditions, give priority to HOVs, provide real-time travel information to the motorists, improve the quality of operations in the traffic network, accumulate accurate and reliable traffic information as well as to facilitate communications exchange between the relating components.

2.4.2 PERFORMANCE AREAS, -MEASURES AND -INDICATORS

With so many performance measures to choose from, in addition to the incredible variety of applications where they can be used, it is difficult (or even impossible) to identify a comprehensive list of performance measures that are deemed compulsory for FMS-related evaluation. However, Brydia *et al.* (2007) have recommended a minimum set of freeway performance measures. Moreover, Payne (2015) has established a set of common road-related KPIs that can be adopted across Europe to assess the deployment and effects (i.e. benefits) of ITS applications. A discussion on the findings of both of these papers follows.

MINIMUM SET OF FREEWAY PERFORMANCE MEASURES

According to Brydia *et al.* (2007), agencies can consider the proposed minimum set of freeway performance measures as a starting point and can add or subtract measures as deemed appropriate to local needs and uses. Refer to Table 1 (Brydia *et al.* 2007).

In Table 1 (Brydia *et al.* 2007), the recommended performance measures are listed per corresponding geographic- and time scale. Moreover, the measures are stratified into several common areas of performance measurement. The performance areas identified are: congestion, reliability, incident management, work-zones, weather and general operations.

Table 1: Recommended Minimum Freeway Performance Measures

Performance Measure	Geographical Scale	Time Scale
CONGESTION FOCUS AREA		
Travel Time Index	Corridor, Area-wide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Total Delay (vehicle-hours and person-hours)	Corridor, Area-wide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Bottleneck ("Recurring") Delay (vehicle-hours)	Corridor, Area-wide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Incident Delay (vehicle-hours)	Corridor, Area-wide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Work Zone Delay (vehicle-hours)	Corridor, Area-wide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Weather Delay (vehicle-hours)	Corridor, Area-wide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Delay per Person	Corridor, Area-wide	Peak hour, AM/PM peaks
Delay per Vehicle	Corridor, Area-wide	Peak hour, AM/PM peaks
Percentage of Vehicle-Miles Travelled (VMT) with Average Speeds < 45 mph	Corridor, Area-wide	Peak hour, AM/PM peaks
Percentage of VMT with Average Speeds < 30 mph	Corridor, Area-wide	Peak hour, AM/PM peaks
Percentage of Day with Average Speeds < 45 mph	Corridor, Area-wide	Daily
Percentage of Day with Average Speeds < 30 mph	Corridor, Area-wide	Daily
HOV Lane Volumes	Corridor, Area-wide	AM/PM peaks
RELIABILITY FOCUS AREA		
Buffer Time Index	Corridor, Area-wide	Peak hour, AM/PM peaks, Midday, Daily
95th Percentile Travel Time Index	As needed	As needed
INCIDENT MANAGEMENT FOCUS AREA		
Detection Time	Corridor, Area-wide	AM/PM peaks (minimum)
Verification Time	Corridor, Area-wide	AM/PM peaks (minimum)
Response Time	Corridor, Area-wide	AM/PM peaks (minimum)

Performance Measure	Geographical Scale	Time Scale
Clearance Time	Corridor, Area-wide	AM/PM peaks (minimum)
On-scene Time	Corridor, Area-wide	AM/PM peaks (minimum)
Total Duration	Corridor, Area-wide	AM/PM peaks (minimum)
No. of Incidents by Type	Corridor, Area-wide	AM/PM peaks (minimum)
Reporting by (Citizens, Police, Other Agencies) per month	Corridor, Area-wide	AM/PM peaks (minimum)
Service Patrol Assists (Total and by Incident Type)	Corridor, Area-wide	AM/PM peaks (minimum)
WORK ZONES FOCUS AREA		
No. of Work Zones by Type of Activity	Corridor, Area-wide	Daily
No. of Lane-Miles Lost	Corridor, Area-wide	AM/PM peaks, Midday, Night
Lane-Mile-Hours of Work Zones	Corridor, Area-wide	AM/PM peaks, Midday, Night
Average Work Zone Duration by Work Zone Type by Lanes Lost	Corridor, Area-wide	Daily
Average Time Between Rehabilitation Activities	Area-wide	N/A
Average Number of Days Projects Completed Late	Area-wide	N/A
Ratio of Inactive Days to Active Days	Area-wide	N/A
WEATHER FOCUS AREA		
Hours Affected by (Rain, Snow, Ice, High Winds, Fog, Dust, Smoke)	Corridor, Area-wide	Daily
Lane-Miles Affected by (Rain, Snow, Ice, High Winds, Fog, Dust, Smoke)	Corridor, Area-wide	Daily
GENERAL OPERATIONS FOCUS AREA		
Service Patrol Vehicles per Mile	Corridor, Area-wide	Annually
Service Patrol Vehicles in Operation per Shift	Corridor, Area-wide	Annually

Performance Measure	Geographical Scale	Time Scale
Percentage Freeway Miles with (Electronic Data Collection, Surveillance Cameras, VMS, Service Patrol Coverage	Area-wide	Annually
Number of Messages Placed on VMSs	Corridor, Area-wide	Annually
Individuals Receiving Traveller Information by Source (511, Other Direct Means)	Corridor, Area-wide	Annually
Percentage of Equipment (VMS, Surveillance Cameras, Sensors, Ramp Meters, Roadway Weather Information Systems) in Good or Better Condition	Corridor, Area-wide	Annually
Percentage of Total Device-Days Out-of-Service (by Type of Device)	Corridor, Area-wide	Annually
Number of Devices Exceeding Design Life	Corridor, Area-wide	Annually
Mean Time Between Failure (MTBF) for Field Equipment (by Type of Device)	Corridor, Area-wide	Annually

SET OF COMMON ROAD-RELATED KPIs

In order to develop KPIs that will remain relevant in the foreseeable future, Payne (2015) aimed to achieve a balance between KPIs to deliver a minimum standard and KPIs to support future investment and deployment. As a result, 15 KPIs have been proposed - eight of these are deployment related and seven of these are benefit related. It should however be noted that, since many ITS applications incorporate elements of multimodality, multimodal KPIs were also (where relevant) included.

A brief overview of the recommended KPI shortlist, as given in Payne (2015), follows.

RECOMMENDED DEPLOYMENT KPIs

1. Length and percentage of road network covered by websites/over-the-air services offering traffic- and travel information. Report separately: travel information, traffic information, integrated traffic- and travel information as well as freight specific information.
2. Number and percentage of urban public transport stops for which traveller information is made available to the public.
3. Length and percentage of road network covered by the following. Report separately: information gathering infrastructures, traffic information services, traffic management plan(s) including cross border plans, traffic management- and control measures/equipment, infrastructure or equipment on the network that enable cooperative-ITS and intelligent safety services for disabled- and vulnerable road users.

4. Number and percentage of signal controlled road intersections using adaptive traffic control or prioritisation.
5. Length and percentage of road network covered by incident detection and -management.
6. Length and percentage of road network covered by automated speed detection.
7. Provision of intelligent services on the TEN-T (Trans-European Transport Networks) core and comprehensive networks that are compliant with the delegated regulations of the ITS Directive.
8. Number and percentage of new vehicles including the following intelligent vehicle features: safety readiness, automated operation, cooperative systems, public emergency call systems and private emergency call systems.

RECOMMENDED BENEFIT KPIs

1. The percentage change in peak hour journey time along routes where ITS has been implemented.
2. The percentage change in peak hour traffic flow along routes where ITS has been implemented.
3. The percentage change in journey time variability on routes where ITS has been implemented; as measured by coefficient of variation.
4. The percentage change in mode share on corridors where ITS has been implemented. Report percentage mode share separately for each mode.
5. The percentage change in number of reported accidents along routes where ITS has been implemented.
6. The percentage change in annual CO_2 emissions (expressed per tons) on routes where ITS has been implemented.
7. Time taken from the initiation of a public emergency call to the presentation of the content of minimum set of data[1] in an intelligible way at the operator's desk in the public safety answering point[2].

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[1] The information defined by the standard 'Road transport and traffic telematics (EN 15722)'.

[2] A physical location where emergency calls are first received under the responsibility of a public authority or a private organisation.

2.5 PUBLIC TRANSPORT PERFORMANCE MEASUREMENT

2.5.1 BACKGROUND

THE ROLE OF THE CUSTOMER

When considering the performance- and delivery of a transit service, the perspective taken is important. According to Eboli and Mazzulla (2012), many researchers consider the passenger's point-of-view to be the most relevant perspective when evaluating the performance of transit projects. As it happens to be, passengers evaluate services in many ways that may not necessarily be systematically associated with the extent of use of the transit service. This is due to the fact that the measures of efficiency and effectiveness, as aggregate indicators of total output, implicitly assume the homogeneity of transit service quality. Therefore, as stated in TRB (2003c), the perceived performance of a transit service from the passenger’s point-of-view needs to be evaluated by considering the indicators related to service quality.

MEASURE TYPES

According to Eboli and Mazzulla (2012), the aspects describing transit services can be divided into two categories. These are: 1) subjective measure and 2) objective measures. A discussion follows.

Subjective measures are based on passengers’’ perceptions and are thus dependent on customer tastes (e.g. comfort). These measures are evaluated on the basis of transit user judgements. User judgements can be expressed in terms of expectations (i.e. what they expect of the service) and perceptions (i.e. what they perceive to receive from the service). These judgements of service quality are generally derived from the well-known Customer Satisfaction Surveys (CSSs). A CSS allows the perceived performances of a given transit service to be analysed and thus assist transit operators in identifying which service quality factors customers deem most important. According to Eboli and Mazzulla (2012), the main disadvantages of this type of measure are the strong subjectivity of transit users’ judgements and the failure to take non-users’ perceptions into account. Furthermore, significant statistical errors could occur if respondents are not correctly sampled or if users’ judgements are too heterogeneous.

Objective measures categorised by characteristics that describe the service (e.g. frequency of runs). These characteristics are evaluated by a range of simple disaggregate performance measures. They are quantitative measures that are used for measuring the ability of a transit agency to offer services that meet or exceed customer expectations. A deterrent of such measures are that they provide no information by itself about how “good” or “bad” a specific result is and thus need to be compared with a fixed standard, target or past performance value (Eboli and Mazzulla 2012). As a result, the objective measurement process is often deemed tedious. Nevertheless, the comparison value required can, for example, be derived from the (manual) data provided by the operators, the dedicated trained checkers or the field supervisors. One particular method of manual data collection is the well-known Passenger Environment Survey (PES). PES uses a mystery rider to rate the transit system's performance.

Both of the aforementioned categories support transit agencies in monitoring, evaluating and implementing improvements in their service. However, intuitively, subjective measures are more difficult to measure and evaluate than objective measures.

2.5.2 PERFORMANCE AREAS AND -MEASURES

In Eboli and Mazzulla (2012) it is proposed that the quality of the transit service be evaluated by nine performance areas. These are: 1) service availability, 2) service reliability, 3) comfort, 4) cleanliness, 5) safety and security, 6) fare, 7) information, 8) customer care and 9) environmental impacts. A discussion of each of these performance areas and their possible relating performance measures follows.

<u>Service availability</u> describes the general availability of the service to all the transit users or the proximity to points of access (i.e. stops/stations) of the transit system. According to Eboli and Mazzulla (2012), the measures belonging to this performance area can thus be represented by the characteristics of the route of the transit line. That is, **the path and the coverage, the number of stops/stations, the distance between the stops/stations, the location of the stops/stations and the characteristics of the service** (e.g. service frequency, span of service, travel time and need for transfers).

<u>Service reliability</u> can be defined as the ability of the transit service to adhere to its schedule or to maintain regular headways and a consistent travel time. Lack of control, as caused by the uncertainty of arrival times, makes the service unreliable. An unreliable service may result in additional travel- and waiting time for passengers. Consequently, service unreliability can lead to loss of passengers, whereas improvements in reliability can lead to the attraction of more passengers. Public transit agencies have developed multiple measures to evaluate this performance area. However, according to TRB (2003a), the three most common measures are: **on-time performance, headway regularity and running time adherence**.

The transit users' comfort encompasses both the physical comfort on-board the vehicles and the comfort of the ambient conditions on-board the vehicles or at the stops/stations. Comfort on-board the vehicles entails having soft- and clean seats, comfortable temperature, not too many people in-transit, a smooth transit ride, low levels of noise and -vibrations as well as no unpleasant odours. According to Eboli and Mazzulla (2012), comfort on-board the vehicles is commonly evaluated by the **degree of crowding**. On the other hand, comfort at stops/stations is generally represented by the **function of the passenger amenities** provided at the stops/stations. Examples of amenities include: shelters, benches, vending machines, trash receptacles, lighting and phone booths.

Cleanliness not only refers to the physical condition of the vehicles and the facilities, but also to the cleanliness of the vehicle's interior and -exterior. For example: having transit vehicles and -shelters clean of graffiti as well as having clean seats and windows. Clean vehicles tend to promote a good public image and help to attract and maintain ridership. In Eboli and Mazzulla (2012) it is stated that this performance area can, for example, be measured by the **frequency of interior cleaning and -exterior washing**.

The safety of passengers relates to their freedom from hazards such as crime or incidents while in transit or while at stops/stations. Therefore, as stated in Eboli and Mazzulla (2012), safety during the transit journey can, for example, be measured by **the number of passenger incidences (e.g. severe injuries or fatalities) owing to the responsibility of the transit operator**. The security experienced by passengers relates to their actual- and perceived freedom from criminal activities and potential threats against them and their property. Therefore, Eboli and Mazzulla (2012) state that security against crimes on-board the vehicles and at stops/stations can, for example, be measured by **the number of complaints registered during a certain period of time**.

The fare of a transit service refers to the monetary cost of a passenger's journey. Possible measures for this performance area will thus relate to the characteristics of the monetary cost. Examples include, as given in Eboli and Mazzulla (2012), the cost of a **one-way ride**, the cost of a **transfer**, the availability of **discounted fares** (e.g. students, elderly people and people with disabilities), the availability of **volume discounts** (e.g. monthly passes) and the cost of **parking** at stops/stations such as at park-and-ride facilities.

Another service aspect affecting transit service quality is linked to the availability- and provision of information pertinent to the planning- and execution of a transit journey. Without adequate information, both current- and potential passengers might not be able to use the transit service effortlessly. Ideally, passenger information needs to be available at every stage of the transit journey.

Pre-trip information helps the passenger to plan routes and connections. This type of information consists of, for example, the location of the nearest stop/station; the routes that travel to the desired destination with transfer locations; the cost of fare; the time of departure and the approximate duration of the transit journey (Eboli and Mazzulla 2012). **In-transit information** assists the passenger at each decision point of the transit journey. This type of information consists of, for example, the identification of the correct transit vehicle to board at the applicable departure point; the identification of stops/stations for transfers or disembarking the vehicle; how to transfer to another route at transfer points; the fare, time limits and restrictions; the identification of the correct vehicle to board; the geography of the area (i.e. location of the final destination in relation to the stop/station) and information on the return trip provided at the destination (e.g. departure times and changes in route numbers) (Eboli and Mazzulla 2012). **Supportive/confirming information** repeats and reinforces data and decisions. This type of information needs to be provided at any point during the trip when the passenger might want to be reassured that he/she is progressing correctly and not getting lost. For the purpose of designing- and preparing information materials that will meet the needs of all the transit customers, TRB (1999) could be of interest to schedulers, transit planners and other applicable representatives.

The performance measures relating to customer care include those elements needed to make the journey easier and more pleasant. Therefore, as given in Eboli and Mazzulla (2012), possible measures are: the **courtesy- and knowledge of the drivers**, the **courtesy- and helpfulness of the ticket agents**, **personnel appearance**, other elements linked to the **ease of purchasing tickets or paying fare**, the presence- and condition of the **ticket issuing- and validation machines** and the effectiveness of the **ticket selling network**.

According to Eboli and Mazzulla (2012), there are two types of service aspects that influences the transit system's impact on the environment. The first type entails effects such as **emissions, noise, visual pollution, vibration, dust and dirt, odour and waste**. The second type entails effects such as the **vibrations on the road** and the **consumption of natural resources** in terms of energy or space.

2.5.3 PERFORMANCE INDICATORS

As mentioned previously, not all agencies use the same terms for performance measures and views of how indicators need to be calculated vary considerably. Examples of performance indicators found in transport literature follow.

TRB (2003a) proposes a classification that considers indicators of:

- cost efficiency (defined as the measure of service output compared to a unit of input in terms of cost),
- cost effectiveness (defined as the measure of outcome compared to unit of input in terms of cost), and
- service effectiveness (defined as the measure of outcome compared to unit of input in terms of service).

Litman (2009) states that there are three general types of performance indicators. These are:

1. measures of service quality - which reflect the quality of service experienced by the users,
2. indicators of outcomes - which reflect outcomes or outputs, and
3. indicators of cost efficiency - which reflect the ratio of inputs (i.e. costs) to outputs (i.e. desired benefits).

Vuchic (2007) proposes a relative comprehensive classification of performance indicators. These performance indicators include:

- transit vehicle quantity or -volume (e.g. the number of vehicles or the fleet size, the fleet capacity, the number of lines, the network length and the annual number of passengers),
- system- and network performance (e.g. the intensity of network service and the average speed on a transit system),
- transit vehicle productivity (e.g. the annual vehicle-kilometres, the annual space-kilometres and the annual passenger-kilometres)
- transit system efficiency (e.g. vehicle-kilometres per vehicle and year, passengers per vehicle-kilometres, daily passengers per employee and vehicle-kilometres per kilowatt-hour), and
- transit vehicle consumption rates and network utilisation (e.g. operating cost per passenger, operating cost per vehicle-kilometre and scheduled vehicles per fleet size).

Nevertheless, for consistency reason, a discussion of possible KPIs for some of the previously defined performance measures, per performance area, follows.

LINE PATH

TRB (1995a) proposes that the characteristics of the line path be evaluated by the route directness. Route directness is expressed in terms of the additional travel time for a one-way trip, or the additional travel time required in comparison to a car making the same trip, or a time limit increase in the average travel time per passenger, or an absolute limit to the total number of path deviations. For each of these indicators, TRB (2003a) suggests some standard limitations.

ROUTE COVERAGE

Route coverage can be considered as the spacing distance between adjoining routes. In TRB (1995a), target values for spacing between transit routes are suggested. These are a function of factors such as: the population density of an area, the proximity of an area to the Central Business District (CBD) and the type of transit services or routes in operation within an area (e.g. grid versus feeder and local versus express). Route coverage can however also be considered as a measure of the proportion of a metropolitan area, corridor or population served by transit. Moreover, TRB (2004) suggests the presence- or lack of a transit service within 400 metres as a rule-of-thumb indicator of coverage. In TRB (2003a), target values for the indicators of route coverage, when expressed in terms of route kilometres per square kilometre, are suggested.

STOP SPACING

Stop spacing is a route characteristic that can be regarded as the distance between the adjoining service stops/stations of a path. As part of transit operators' efforts towards balancing the trade-off between rider convenience (i.e. stops/stations within walking distance) and speed, numerous standards regarding stop spacing have been developed. Examples of target values for stop spacing are suggested in TRB (1995a). In addition, in TRB (2003a), more target values - related specifically to local bus, automated guide-way transit, light rail, heavy rail and commuter rail - are suggested.

STOP LOCATION

The time spent walking to reach the stop/station defines the level of accessibility to the transit service. In Eboli and Mazzulla (2011), it is thus suggested that the walking distance (or time) from home to access the stop/station can be taken as the indicator for the stop location. In general, stops/stations need to be located within walking distance and the pedestrian environment in the area should not discourage walking. As reported in TRB (2003c), about 80% of passengers prefer to walk 400 metres or less to access the stops/stations. If an average walking speed of 5 km/h is assumed, this is then equivalent to a maximum walking time of 5 minutes.

SERVICE CHARACTERISTICS

The characteristics of the transit service refer to the: service frequency, service span, travel time and need for transfers. However, the possible indicators for only the first two characteristics are considered herein.

The indicator regarding service frequency can be calculated as the average value of the number of runs scheduled for each hour of the day. In TRB (2003c), standard ranges for LOS are suggested as a function of the average headway (in minutes) among vehicles.

The span of the service refers to the number of hours during a day that the transit service is provided. This can vary by day, by route and even by stop/station. The length of the service in a day can impact the convenience of using the transit system and can also constrain the types of trips that the passengers are able to make. Therefore, the indicator regarding service span can be calculated as the average value of the number of hours per day, in different periods of the year (e.g. seasons), for different routes or stops/stations. The LOS thresholds reported in TRB (2003c) can be adopted as target values for the service span.

SERVICE RELIABILITY

ON-TIME PERFORMANCE

On-time performance can be evaluated by considering the percentage of transit vehicles departing from, or arriving at, a location on-time. The indicator is generally calculated as the ratio of the number of runs that arrive on-time to the total number of runs. TRB (1995a) suggests that on-time performance be considered as the runs up to 1 minute early and up to 5 minutes late. In addition, TRB (2003c) introduces an indicator for on-time performance as the percentage of trips departing from all scheduled time points, not including terminals, between 0 and 5 minutes after their scheduled departing time.

HEADWAY REGULARITY

Headway regularity can be defined as the evenness of intervals between transit vehicles. TRB (2003a) proposes an indicator for headway regularity that is calculated as the ratio of the average difference between the actual- and the scheduled headway to the scheduled headway (expressed as a percentage). Standard ranges for LOS, with regard to headway adherence, can be found in TRB (2003c). Reliability of runs that arrive on schedule can also easily be evaluated on the basis of the runs 'removed' from the daily schedule. A possible indicator could then be to calculate the ratio of the number of runs executed in the period of data gathering to the number of runs scheduled for this same period.

RUNNING TIME ADHERENCE

The indicator for running time adherence (expressed as a percentage) can be evaluated, analogously to the headway regularity, as the average difference between the actual- and the scheduled running times compared to the scheduled running time (Eboli and Mazzulla 2011).

COMFORT

LOAD FACTOR

In TRB (2003c), passenger load LOS thresholds for both bus and rail are provided. This LOS is based on two measures: 1) passengers per seat when all passengers can sit and 2) standing passenger area when some passengers are obliged to stand or when a vehicle is designed to accommodate more standees than seated passengers.

AVAILABILITY OF PASSENGER AMENITIES

Eboli and Mazzulla (2011) propose that the availability of passenger amenities be evaluated by the availability of furniture at stops/stations. With this approach, a score is assigned to each line stop/station on the basis of the various available amenities (e.g. shelter, benches or both). The indicator varies from a minimum value of 0 (i.e. stops/stations without any kind of furniture) to a maximum value of 10 (i.e. stops/stations with all of the relevant furniture).

CLEANLINESS

In TRB (1995b), specific recommendations regarding transit practice on cleaning functions are reported. These recommendations include standard values for periodic detailed cleaning, interior cleaning- and exterior washing services per week. In general, transit agencies (even if only to remove coarse refuse such as bottles and newspapers) need to perform the cleaning of vehicle interiors on a daily basis. With regard to a vehicle's exterior washing, a daily frequency is also needed. Detailed cleaning, depending on the agency, needs to be performed monthly, quarterly or annually. This type of cleaning functions are typically scheduled during off-peak hours (e.g. midday and late evenings).

The level of detailed cleaning required is dependent on how much is done daily as part of the service line function.

SAFETY AND SECURITY

In Eboli and Mazzulla (2011) the indicator concerning safety and competence of drivers is evaluated on the basis of the number of incidents. The number of incidents, for a certain year of analysis, is compared to the average number of incidents during the previous number of years. Moreover, in Eboli and Mazzulla (2011), the indicator of the service aspect regarding security against crimes on-board the vehicles and at stops/stations is calculated analogously to that of safety. That is, it is evaluated on the basis of the number of complaints registered during the year of analysis and compared to the average number of complaints registered during the previous number of years.

FARE

AVERAGE ONE-WAY TICKET COST

The average one-way ticket cost can be regarded as an indicator of the monetary cost of a ticket. Eboli and Mazzulla (2011) considered standard values corresponding to the average cost of tickets, for different typologies of service, adopted by transit agencies operating in similar territorial contexts and characterised by high standards of transit service quality.

INFORMATION

PRE-TRIP INFORMATION

In Eboli and Mazzulla (2011), an indicator for the attribute ‘availability of schedules/maps at stops/stations’ is evaluated on the basis of a score assigned to each stop/station of a line. This score ranges from a minimum value of 0 to a maximum value of 10. The minimum value is assigned to the stops/stations without any kind of information devices and the maximum value to the stops/stations with significant information display(s) of schedules and/or maps. The indicator is calculated as the average value of the scores assigned to all the stops/stations of all the transit lines. Similar indicators can also be calculated by distinguishing among information devices (i.e. information service media). TRB (1996) provides a useful review on the relative costs as well as the types- and tools of information devices probable to be at stops/stations.

IN-TRANSIT INFORMATION

In Eboli and Mazzulla (2011), an indicator for the attribute 'availability of schedule/maps and announcements on the vehicle' is calculated as the ratio of the number of vehicles with functioning information devices on-board vehicles to the total number of vehicles sampled in a certain time period. In order to ensure accuracy, it is recommended that a trained checker be used to verify the functioning nature of the information devices on different days of this time period.

CUSTOMER CARE

PERSONNEL HELPFULNESS

Eboli and Mazzulla (2011) evaluated personnel helpfulness by means of a mystery rider who verifies the behaviour of the personnel and assigns a score to each personnel unit. This score ranges from a minimum value of 0 to a maximum value of 10. A score of 10 signifies that personnel are helpful and a score of 0 that they are unhelpful.

PERSONAL APPEARANCE

Eboli and Mazzulla (2011) suggest that personnel appearance be evaluated by means of a trained checker who verifies personnel's adherence to uniform regulations. An indicator is proposed as the ratio of the number of staff wearing the appropriate uniform to the total number of staff.

EASE OF PURCHASING TICKET

Eboli and Mazzulla (2011) evaluated the ease of purchasing tickets by taking a passenger's (only) opportunity to purchase a ticket into account. The proposed indicator is calculated as the ratio of the number of vehicles and/or stops/stations with functioning automatic ticket machines to the total number of vehicles and/or stops/stations sampled in the period of data gathering. In order to ensure accuracy, it is recommended that a trained checker be used to verify the functioning nature of the automatic ticket machines on different days of this time period.

ENVIRONMENT

A considerable amount of models and procedures, which allow the effects of the transit systems to be quantified (especially in terms of pollution and noise), can be found in the literature. For a simplistic approach, Eboli and Mazzulla (2011) recommend that environmental protection be evaluated by considering the use of ecological vehicles. A possible indicator can then be the ratio of the number of vehicles in keeping with the vehicle noise- and pollution emission regulations to the total number of vehicles needed for the transit line.

2.6 IRT PERFORMANCE MEASUREMENT

2.6.1 TYPICAL ITS FUNCTIONS EVIDENT IN IRT

ITS not only play an important role in providing fast, safe and reliable Integrated Rapid Transit (IRT), but also in providing the data needed for performance measurement purposes. A description, as given in TRB (2003b), of some of the most prominent ITS functions present in an IRT system follows.

- Automated Vehicle Location (AVL) systems.
    - Vehicle tracking uses AVL systems to pinpoint a vehicle's location on the transit network. It allows for: real-time monitoring of a vehicle's movement (thereby improving vehicle dispatch), control of vehicle headways (thereby improving vehicle operations), closer schedule adherence (thereby obtaining more effective timed transfers) and the ability to direct maintenance crews in the event of a vehicle breakdown (thereby having quicker emergency response to service disruptions). In addition, AVL can assist agencies in realising and providing a Passenger Information Display System (PIDS). It can also facilitate two-way communications between vehicle drivers and central supervisors. Lastly, AVL allows transit agencies to monitor the mechanical condition of the vehicles on the road.
- PIDS.
    - PIDS can provide (real-time) information to passengers before trips, at stops/stations and at terminals and/or on-board the vehicle. Both the type of information available (i.e. static or dynamic) and how it is provided (i.e. service media used) are important since both affect the public's understanding and their ease of using the transit system. Examples of possible information service media are: timetable dispensing kiosks, telephones, displays for static information, Electronic Message Signs (EMSs), television broadcasts, hand-held computer devices, home computers and mobile phones.
- Traffic signal priority systems.
    - Traffic signal priority systems are used to provide vehicles with preference at signalised intersections. This can occur either when they arrive at an intersection or when certain conditions (e.g. when vehicles run late) are met. Signal prioritisation can reduce the mean- and variance of delays (thereby increasing reliability) while having minimum impacts on cross street traffic.

- Automatic Passenger Counter (APC).
    - An APC helps to track ridership by counting the passengers as they board and disembark a vehicle. APCs can thus be used to develop or refine transit schedules or to plan or support service changes. They can greatly reduce the cost of collecting ridership information by reducing or eliminating the need for manual checkers. APCs can also increase the amount or quality of information obtained and can permit continuous sampling of stop-by-stop ridership on each vehicle equipped fittingly.
- Electronic Fare Collection (EFC).
    - EFC methods can affect the overall success of an IRT system by increasing passenger convenience and efficiency of operations. Whereas the old cumbersome methods may inhibit ridership and impede vehicle operations, the new fare systems (enhanced with EFC) may serve to attract new passengers and retain existing passengers. EFC methods can also affect the vehicle driver directly. Some of the older methods can be time consuming, distracting and can lead to driver-passenger disputes. In SA, EFC is implemented with smart cards. By using smart cards, the need to carry exact cash is removed. This makes transit payments quicker and easier and also lessens the probability of fraud occurring. Moreover, with the aid of smart card technology, transit agencies are able to collect information about ridership that can be used for planning- and operations purposes. EFC can also, in general, reduce dwell times and fare collection costs as well as increase revenues.
- Vehicle guidance technologies.
    - Guidance technologies assist transit operators in driving their vehicles more safely and, in some cases, can control the vehicle’s lane positioning automatically. These technologies can be employed along the entire running way or only at the stops/stations where precision docking (i.e. the provision of a small separation between the vehicle and the platform) is important. Other guidance applications include tunnels and narrow running ways. Guidance can be mechanical, optical or magnetic.
- Collision avoidance systems.
    - Collision avoidance systems deal with the various ways of avoiding transit vehicles colliding with other vehicles. Collisions can be avoided in both the front and back of a transit vehicle. Radar can detect how the transit vehicle is approaching other vehicles. This information can then be used to either warn the driver or automatically reduce

the vehicle's speed to avoid the accident. Rear-end collisions can also be reduced with the aid of visual warnings at the back of the transit vehicle.

In summary, within the IRT environment, ITS applications can be used to: monitor vehicle operations, provide (real-time) information to passengers, cater for passengers with hearing- or visual impairments, provide priority for transit vehicles at signalised intersections, collect ridership information, facilitate effortless and safe fare payments, allow for precision docking at the stops/stations and avoid collisions.

2.6.2 PERFORMANCE MEASURES

In Diaz and Hinebaugh (2009), six key IRT system performance measures are identified. These are: 1) travel time, 2) reliability, 3) image and identity, 4) passenger safety and -security, 5) system capacity and 6) accessibility. A discussion of these measures and examples of how the IRT features may contribute to their performance follows.

TRAVEL TIME

Travel time refers to the amount of time the passengers spent traveling from the beginning to the end of their trips. There are several different travel time components that IRT systems impact. A discussion of these, as given in Diaz and Hinebaugh (2009) follows.

- Running time - The time spent in the vehicle while traveling from stop/station to stop/station.
- Station dwell time - This represents the time required for the vehicle to load- and unload passengers at the stops/stations.
- Waiting time - The time a passenger spends at a stop/station before boarding a particular transit service.
- Transfer time - The time a passenger spends transferring from one IRT service to another or to other transit services (e.g. local bus routes and rail).

Travel time is particularly important for non-discretionary recurring trips such as those made for work purposes. However, relatively high IRT running speeds and reduced stop/station dwell times make IRT services more attractive for all types of users; especially for choice riders. Waiting- and transfer times also have a particularly important effect on the attractiveness of IRT systems (Diaz and Hinebaugh 2009). Therefore, IRT service plans generally strive to feature a frequent, all-day, direct service with travel times varying accordingly for the different operating conditions.

RUNNING TIME

In Diaz and Hinebaugh (2009), it is stated that running times are dependent on traffic congestion, delays at intersections and the need to decelerate into- and accelerate from stops/stations. The main factors influencing running time are thus: the type of running way (e.g. bus-way or freeway HOV lane, arterial street bus lane or mixed traffic); the average stop-spacing; and the average dwell time per stop/station.

STATION DWELL TIME

According to Diaz and Hinebaugh (2009), dwell time depends on: *the number of passengers boarding- or disembarking per door channel* (higher passenger loads at stops/stations increase dwell times, while multiple places to board and disembark disperse these loads, thereby reducing dwell times); *the fare collection system* (processing fares directly upon boarding increases loading times, while pre-processing fares and/or reducing transaction times on vehicles can reduce loading times); and *vehicle occupancy* (congested vehicles require extra time to load- and unload passengers).

WAITING TIME

In Diaz and Hinebaugh (2009), it is stated that the primary determinants of waiting time are service frequency and -reliability. However, other factors such as the presence of a PIDS may also affect the perception of waiting time.

TRANSFER TIME

The primary factors affecting transfer time, as given in Diaz and Hinebaugh (2009), are: the physical design of both the stop/station and the transit route network. These factors not only influence a passenger's perception of transfer time, but also have an impact on the percentage of passengers obliged to transfer.

RELIABILITY

Reliability represents the variability of travel times and is affected by many IRT features. A discussion of the main aspects of reliability, as given in Diaz and Hinebaugh (2009) follows.

- Running time reliability - The ability of an IRT service to consistently maintain a high speed such that customers can be provided with consistent travel times.
- Station dwell time reliability - The ability of IRT vehicles to load passengers within a certain consistent dwell time such that the delay at stops/stations can be minimised. This consistency

needs to be maintained with varying loads of passengers, across varying levels of congestion and at different periods of a service day.

- Service reliability - The ability of a IRT system to provide a service that is consistent with its plans and policies as well as the expectations of its customers. Therefore, service reliability is influenced by: the availability of the service to the passengers, the ability to recover from disruptions and the availability of resources to consistently provide the scheduled LOS.

According to Diaz and Hinebaugh (2009), reliability is affected by a number of sources of uncertainty. These are: traffic conditions, route length, recovery times built into the route schedules, number of stops/stations, evenness of passenger demand (and the unpredictable use of wheelchair lifts/ramps) and vehicle breakdowns due to unforeseen mechanical- or non-mechanical problems. Even though some of these factors are not within the direct control of the transit operator, there are many features of an IRT service that can aid in improving its reliability. Examples include, among others, the utilisation of:

- a running way type that results in the least running way travel times,
- level platforms or raised curbs that facilitate consistent stop/station dwell times by reducing the need to step up to the vehicle, and
- significant distance spacing between stops/stations which allows vehicles to travel at a predictable, high speed for longer periods of time.

IMAGE AND IDENTITY

The creation of an image and identity, separate from conventional transit operations, is an important objective of an IRT service. In Diaz and Hinebaugh (2009), it is stated that if IRT is to attract choice riders it needs to not only offer competitive travel times and a high quality of service, but also be complemented by an attractive image.

Image and identity capture how an IRT system is perceived by both passengers and non-passengers. These attributes reflect the effectiveness of an IRT system's design in fitting it within the context of the urban environment. Image and identity are also important as both a promotional- and marketing tool for luring passengers as well as for providing information to non-frequent users regarding the location of IRT system access points (i.e. stops/stations) and route options.

A discussion of the key aspects of image and identity, as given in Diaz and Hinebaugh (2009), follows.

- Brand identity - The concept of brand identity captures both the qualities that affect identity (e.g. the passenger's overall perception of the style, aesthetics, compatibility of the system features and explicit branding) and marketing devices (e.g. logos and colour schemes). Effective design and integration of IRT features reinforce a positive and attractive brand identity. This then aids in attracting potential customers and making it easier for them to use the system.
- Contextual design - The aim of contextual design is to convey a singular- and attractive design aesthetic that both communicates the existence of the system and complements the physical urban environment. Quality of life is enhanced when systems are designed to: 1) harmonise with their context and 2) create a sense of place for the communities they serve. Designing IRT as an integrated part of the community can channel a wide spectrum of benefits. These benefits relate to, among others, the environment, economy, aesthetics, public health and -safety and civic participation.

PASSENGER SAFETY AND -SECURITY

Passenger safety and -security are distinct measurable attributes of a transit system. They impact service attractiveness, operating costs and overall performance.

SAFETY

Safety is the level of freedom from hazards as experienced by passengers, employees, pedestrians, other vehicle occupants and others who interact with the transit system. In general, two performance measures reflect the quality of a transit agency's safety management. These are: 1) accident rates and 2) the public's perception of safety (Diaz and Hinebaugh 2009). Investment in numerous IRT features can offer the potential to positively influence the system's safety performance relative to conventional transit operations. For example: as running way exclusivity increases, the frequency of sideswipe collisions between transit and non-transit vehicles decreases.

SECURITY

Security is the level of freedom from crime or other danger as experienced by transit employees, -property and system users. The objective of security is to minimise both the frequency- and severity of criminal activities impacting IRT systems and their passengers. Therefore, as stated in Diaz and Hinebaugh (2009), a transit agency's security management is generally measured as crime rates experienced on the transit system per unit of output (e.g. per service hour or per trip). Physical design elements, service characteristics, fare collection systems and other advanced technologies all contribute to the level of passenger security.

SYSTEM CAPACITY

System capacity refers to the maximum number of people or transit vehicles that can be moved past a point by an IRT line or -system. As passenger demand for a particular IRT line begins to meet or exceed capacity (especially at its critical points), the quality of service is most likely impacted negatively. That is, reliability may suffer, operating speeds may decrease and passenger loads may increase (Diaz and Hinebaugh 2009). Therefore, providing adequate capacity for IRT systems is essential.

There are three key elements that determine IRT system capacity. These are the: 1) IRT vehicle capacity (i.e. the number of passengers), 2) IRT station capacity (i.e. the number of vehicles and passengers) and 3) IRT running way capacity (i.e. the number of vehicles). However, LOS parameters may also affect system capacity. For example: the availability of the service (e.g. measured as frequency, span and coverage), the level of comfort (e.g. measured as standing density), travel time and service reliability.

ACCESSIBILITY

Accessibility describes the general availability of the transit service to all transit users and the transit system’s proximity to points of access. According to Diaz and Hinebaugh (2009), accessibility is measured in terms of whether programs, facilities and vehicles meet the regulatory requirements and guidelines as well as the extent to which transit systems have been designed to meet the overall mobility needs of all passengers; including people with disabilities and elderly people.

Many IRT features can promote accessibility. In Diaz and Hinebaugh (2009), it is stated that IRT features can enhance accessibility by improving:

- physical accessibility (if physical barriers are removed and physical entry into the stops/stations and vehicles are facilitated),
- accessibility of information (if information is made available to all passengers; especially to those with vision- and hearing impairments), and
- safety (if improved safety treatments are provided and susceptibility to hazards, through warnings and other design treatments, is prevented).

Based on the aforementioned, it is evident that the primary manner to measure accessibility is in terms of compliance with applicable regulations, standards and design guidance. Other ways of measuring accessibility, as given in Diaz and Hinebaugh (2009), involve both qualitative ratings and quantitative measures that suggest the impact of improved accessibility.

2.7 NETWORK PERFORMANCE MEASUREMENT

2.7.1 OVERVIEW

Transport systems typically span multiple jurisdictions, serve common markets and often provide overlapping services within regions and corridors. However, research has not sufficiently examined ways of integrating system-level programs for measuring the performance of multimodal and/or multi-jurisdictional transport networks. Therefore, TRB (2010a) has developed a guidebook that provides methods for integrating performance measures from individual transport modes and multiple jurisdictions.

2.7.2 INTRODUCTION

As performance measurement is becoming more common, there is increased recognition that individual agencies cannot address the transport systems they are responsible for in a vacuum. In TRB (2010), two factors that stimulate this recognition are given. Firstly, investments made on one mode or jurisdiction may affect the performance of other modes or jurisdictions. Secondly, limited resources are creating a need to invest transport resources as efficiently as possible.

Based on the aforementioned, agencies are starting to acknowledge that they need to coordinate and interact with other agencies to address the network performance implications of their decisions. As stated in TRB (2010), network performance measurement is an attempt to evaluate the transport system as a whole. That is, considering all modes of transport, all potential strategies (e.g. capital- versus operational investments) and all jurisdictions (e.g. state, regional and local). In essence, network performance measurement involves breaking down the silos between different investment approaches such that the trade-offs and efficiencies across systems can be taken into consideration.

2.7.3 FRAMEWORK

The guidebook developed in TRB (2010) is founded on a framework for implementing network performance measurement. The concept of this framework is portrayed in Figure 5 (TRB 2010). In this figure, the left side indicates the dimensions and the right side describes the basic process for considering network performance measurement.

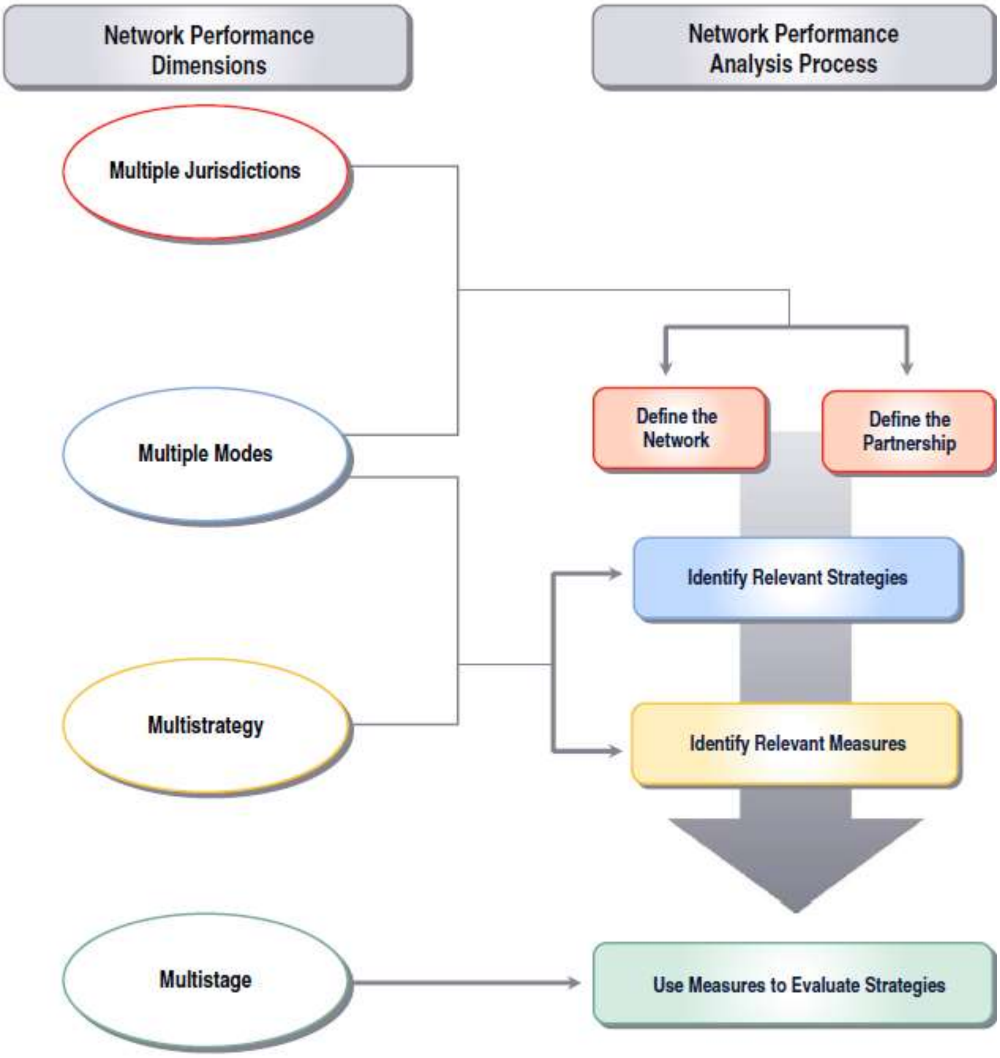

Figure 5: Network Performance Measurement Framework

2.7.4 COMPONENTS

In this section, an overview of the components pertaining to the framework shown in Figure 5 (TRB 2010) is given. The components identified for inclusion are:

- define the network,
- define the partnership,
- define network-level performance measures,
- define network performance strategies, and
- apply network performance measures.

DEFINE THE NETWORK

The network is the combination of: 1) the relevant agencies or jurisdictions that have existing or proposed infrastructure within the geographic area under consideration and 2) the relevant transport modes (TRB 2010). By including the full set of relevant agencies and modes that are applicable to the network, the decision maker inherently improves his/her understanding of the specific problem and the potential range of solutions.

DEFINE THE PARTNERSHIP

In laymen's terms, the definition of partnership is based on: "who is involved and who has a voice or control over decisions". More formally, partnerships refer to the forum used by a set of agencies for measuring network performance and making integral decisions. According to TRB (2010a), partnerships primarily exist since nothing else can happen without them. That is, until a set of agencies agrees on an approach and a forum to make decisions, network performance measurement cannot take place. The specific partnership arrangement will respond to the conditions and questions that the individual agencies have. TRB (2010a) has identified three basic types of partnerships. These are: 1) single region, 2) peer-to-peer and 3) intra-agency.

DEFINE NETWORK-LEVEL PERFORMANCE MEASURES

Although no specific definition of transport network-level performance measures exists, these measures encompass certain criteria and qualities. Examples of some of these criteria and qualities, as given in TRB (2010a), follows.

- They address the regional, state or multistate impacts of individual decisions.
- They are derived from a process that involves multiple actors working in collaboration.
- They may span multiple jurisdictions, modes, investment strategies as well as stages of the plan and project development process.
- They are connected with broader outcomes and system-wide performance objectives.
- They measure the performance of a transport network; not only individual facilities.
- They are supported by data and tools that provide a fair comparison of different types of investment strategies.

DEFINE NETWORK PERFORMANCE STRATEGIES

Like modal silos, performance measurement has often been conducted separately for different types of strategies. However, TRB (2010a) states that one of the key dimensions of network performance measurement is the consideration of multiple types of strategies. The significant cost and lack of physical space for new transport capacity have increased the interest in system operations solutions. The definition of the appropriate strategies will depend on the scale of the effort under consideration and the modes and jurisdictions involved in defining the network and partnership.

APPLY NETWORK PERFORMANCE MEASURES

Applying the network performance measures will depend on the context of the network considered. Nevertheless, examples of application may include the following (TRB 2010):

- corridor-level performance measures evaluate investment strategies across an entire corridor that spans jurisdictions (e.g. congestion measures, crash reduction and environmental impact),
- system-level performance measures evaluate the cumulative effect of investment strategies at the systems level (e.g. air quality measures for conformity analysis),
- a project selection process compares benefits and impact across multiple modes and investment strategies, and
- project development activities ensure that investment priorities are established using one set of metrics throughout the project development process.

2.8 PERFORMANCE-BASED MANAGEMENT

2.8.1 INTRODUCTION

OVERVIEW

Artley *et al.* (2001) define performance-based management as follows:

> *"Performance-based management is a systematic approach to performance improvement through an ongoing process of establishing strategic performance objectives; measuring performance; collecting, analysing, reviewing and reporting performance data; and using that data to drive performance improvement."*

In essence, performance-based management follows the Plan-Do-Check-Act (continuous improvement) cycle that was developed by Walter Shewhart of Bell Labs in the 1930s.

PERFORMANCE MEASUREMENT VERSUS PERFORMANCE MANAGEMENT

Performance-based management essentially uses the information from performance measurement to manage- and improve performance as well as to demonstrate what has been accomplished.

Performance measurement is thus not only a predecessor to, but also a critical component of, performance-based management.

BENEFITS

Performance-based management has many benefits. A discussion of some of the benefits, as given in Artley *et al.* (2001), follows.

- Performance management caters for a structured approach that is focused on strategic performance objectives.
- It provides a mechanism for accurately reporting performance to upper management and stakeholders.
- With the aid of performance management, all interested parties are incorporated into the planning- and evaluation of performance.
- Performance management can aid with linking performance and budget expenditures.
- It provides an excellent framework for accountability.
- With the aid of performance management, the responsibility for performance improvement is shared.

2.8.2 IMPLEMENTATION STEPS

In order to establish a performance-based management program, Artley *et al.* (2001) have identified six steps. Refer to Figure 6 (Artley *et al.* 2001). This figure presents an overview of the overall performance management process and portrays how the identified steps are interconnected with one another.

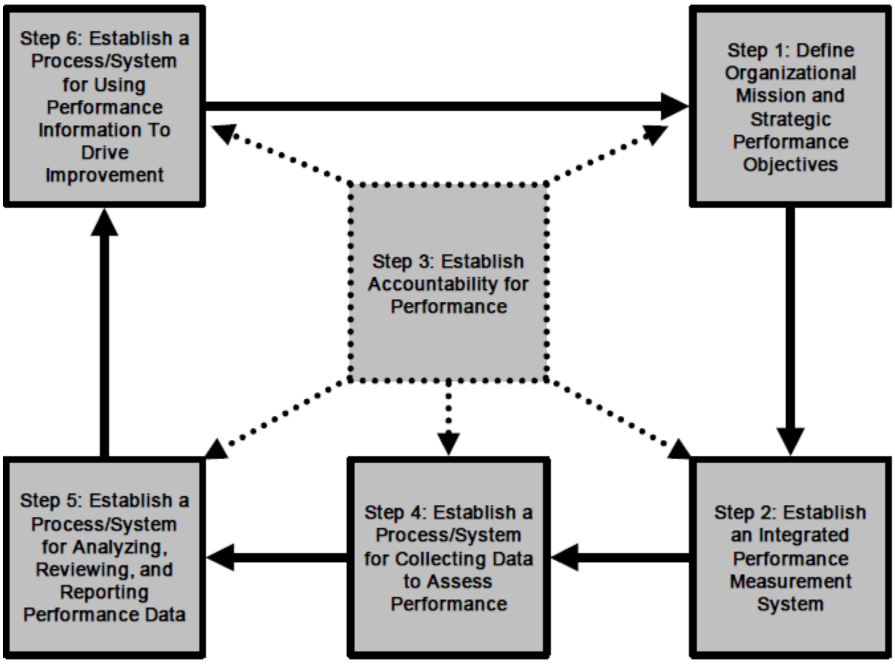

Figure 6: Six Steps to Establishing a Performance-Based Management Program

STEP 1

The first step to establishing a performance-based management program is to define the organisational mission and strategic performance objectives. This correlates to the strategic planning phase of performance-based management

STRATEGIC PLANNING

Artley *et al.* (2001) define strategic planning as follows:

> *"Strategic planning is a continuous- and systematic process where the guiding members of an organisation make decisions about its future, develop the necessary procedures and operations to achieve that future and determine how success is to be measured."*

As stated in Artley *et al.* (2001), the pivotal point in strategic planning is the point at which strategic direction is set. That is, the organisation's goals, objectives and strategies by which it plans to achieve its vision, mission and values. It is at this point that an organisation's knowledge and insights about its past, present and future converge and a path is chosen around which the organisation will align its activities and its resources.

However, as stated in Artley et al. (2001), strategic direction means nothing if it is not appropriately used and implemented. That is, strategic direction needs to be translated into action such that it can drive the organisation. In essence, organisation's strategy and performance measures need to be in alignment and senior managers need to convey the organisation's mission, vision, values and strategic direction to employees and external stakeholders.

STEP 2

The second step to establishing a performance-based management program is to establish an integrated performance management system. This can be accomplished with the aid of four sub-processes. These are:

1. understand the concept of an integrated performance measurement system,
2. choose a performance measurement framework,
3. develop performance measures, and
4. maintain an integrated performance measurement system.

UNDERSTAND THE CONCEPT OF AN INTEGRATED PERFORMANCE MEASUREMENT SYSTEM

From the developed strategic perspective, the major components of an integrated performance measurement system can then be established. A discussion of these components, as given in Artley and Stroh (2001), follows.

- Strategic plans set the foundation for effective performance measurement systems.
- Key business processes and their activities are the means to achieve the outcomes (i.e. the end results) of the strategic plan.
- Stakeholder- and customer needs, their expectations and their points of view need to be taken into account when developing strategic goals and -objectives.
- Senior management involvement and leadership commitment to the development and use of performance measures are critical activities in the success of the performance measurement system.
- Employee involvement is one of the best ways to create a positive culture that thrives on performance measurement.
- Accountability of measures ensures that the necessary responsibility is delegated.
- Conceptual frameworks can help in deciding what to measure.
- Communication is crucial for establishing and maintaining a performance measurement system.
- A sense of urgency gives impetus to move to a new or enhanced performance measurement system.

CHOOSE A PERFORMANCE MEASUREMENT FRAMEWORK

Conceptual frameworks helps to stimulate thought about what needs to be measured. As stated in Artley and Stroh (2001), the adoption of a framework helps to: 1) organise one's thoughts, 2) identify common vocabulary and 3) ensure appropriate coverage for the performance measurement system. Four of the most prominent reference models for performance frameworks are discussed in Section 4.2 of this research project. These range from the traditional performance scorecard approach to more modern approaches. A popular example of the latter mentioned is performance dashboards.

DEVELOP PERFORMANCE MEASURES

Performance measurement is required to understand the gap between actual- and expected levels of achievement as well as to know when corrective actions may be warranted. Artley and Stroh (2001) identified three approaches to developing performance measures. These are the: 1) United States of America (USA) Department of Energy (DoE) approach, 2) University of California approach and 3) Auditor General of Canada approach. However, for the application required herein, only the last mentioned approach is considered in more detail.

THE AUDITOR GENERAL OF CANADA APPROACH

This approach originates from a document produced by the Office of the Auditor General of Canada and the Commissioner of the Environment and Sustainable Development. The Auditor General of Canada approach consists of nine steps. A discussion of these steps, as given in Artley and Stroh (2001), follows.

1. Define the role of the program. WHY is the program relevant to the strategic objective(s)? Establish program standards or targets and performance measures with respect to the developed strategic objectives.
2. Identify the key program activities and -outputs. Ensure that program managers and staff (only) focus on the issues that contribute to the achievement of organisational strategy.
3. Identify program stakeholders and -issues. WHO do you want to reach? Identify whom program activities and -outputs are intended to serve, influence or target as well as who the other principal groups affected are and how they are affected.
4. Identify what the program aims to accomplish. WHAT results do you expect to achieve? Define the desired results in terms of outcomes such that they can become the focus for determining appropriate objectives, milestone targets and measures.

5. Identify responses and performance requirements. HOW are you going to achieve your objectives? Performance objectives need to be defined in operational terms such that they can be effectively managed.
6. Identify potential performance measures and -targets. The results indicated by a performance measure need to be compared with the expectations specified by its performance target. Performance targets can be based on a benchmark best practice, a technical standard or some specified progression from the baseline value.
7. Establish information capabilities and a baseline for each measure. Understand what information is currently available to the organisation as well as the organisation's capabilities for gathering- and analysing that information. Then, for each measure, establish baseline values that can be used to shed light on the organisation's information capabilities and gaps.
8. Assess the adequacy of performance measures. Select a set of performance measures (from the list of candidate performance measures developed) that is suitable for tracking performance towards specified objectives.
9. Establish accountability and resources for implementation. Formalise the accountability relationship between results, outputs, activities and resources such that people's performance expectations can be clarified.

MAINTAIN AN INTEGRATED PERFORMANCE MEASUREMENT SYSTEM

The management of a mature integrated performance measurement system can be accomplished by conducting a series of regularly scheduled maintenance checks. In Artley and Stroh (2001), five maintenance checks have been identified. A discussion of these checks follows.

1. Measure the system components. Annually re-evaluate the components to check for any changes that could impact the system.
2. Manage the performance measurement team. Periodically check for: 1) changes to the team members, 2) burn-out of the team members and 3) common understanding and agreement of the roles/responsibilities and tasks of the team members.
3. Be aware of new legal requirements/issues. The organisation needs to stay informed about new legal developments. This can be accomplished by incorporating the organisation's requirements into the performance measurement system and by thoroughly communicating these requirements to their employees and stakeholders.

4. Assess new developments/technologies. Consider the impact (both positive and negative) they could have, the value they could add and the expenditure they would demand from the organisation.
5. Ensure (continuous) feedback. In order to obtain new ideas that can breathe life into the system, feedback from employees, customers, stakeholders and a benchmarking partner is needed.

STEP 3

The third step to establishing a performance-based management program is to establish accountability for performance. This can be accomplished with the aid of two sub-processes. These are:

1. understand the concept of accountability, and
2. consider accountability tools.

UNDERSTAND THE CONCEPT OF ACCOUNTABILITY

Accountability refers to the obligation a person, group or organisation assumes for the execution of authority and/or the fulfilment of responsibility. According to Artley (2001), this obligation includes: answering (i.e. providing an explanation or justification) for the execution of that authority and/or fulfilment of that responsibility; reporting on the results of that execution and/or fulfilment; and assuming liability for those results.

CONSIDER ACCOUNTABILITY TOOLS

Since accountability requires reporting, the focus of accountability tools is on the reporting of performance. This reporting of performance needs to encapsulate both intentions and results. Artley (2001) has identified numerous accountability tools. A discussion of these tools follows.

- Strategic plans are the foundation for all planning, budgeting, execution, control and evaluation activities by an organisation.
- Performance plans are used to establish performance agreements and to make comparison with actual performance results.
- Performance agreements state expectations for each party signing the agreement and thus provide a process for measuring performance.
- Accountability reports integrate performance results, financial status and management controls such that a status report on performance measures can be provided.

- Performance-based contracts delegate responsibility by establishing accountability. The customer is held accountable for establishing clear performance expectations and the provider is held accountable for achieving those expectations.
- Self-assessment reports are used by the performing organisation (and other organisations in the chain of authority and responsibility) to evaluate and assess performance by providing a basis for continuous improvement.
- Performance reviews serve as formal documentation of performance and can aid with employee development and -promotion.
- Management controls are the policies and procedures used to ensure that: programs achieve their intended results; resources are used consistent with agency mission; programs and resources are protected from waste, fraud and mismanagement; laws and regulations are followed; and reliable and timely information is obtained, maintained, reported and used for decision making.
- Equity statements set out: who would benefit from what is proposed, how (both in the short- and longer term) and why they should benefit, who would bear what costs and risks from it (both in the short- and longer term) and why they should, and who would be accountable to whom, for what.
- Accountability meetings help to improve future performance by considering not only past lessons learned, but also understanding present limitations.

STEP 4

The fourth step to establishing a performance-based management program is to establish a process/ system for collecting data to assess performance. This can be accomplished with the aid of four sub-processes. These are:

1. determine data needs,
2. understand the components of a data collection plan,
3. examine data collection considerations, and
4. consider data collection methods.

DETERMINE DATA NEEDS

In order to determine data needs, Beschen *et al.* (2001) state that the developers of the data collection plan first need to identify the data that the decision makers use to operate the organisation. Then they need to conduct a survey on what data is already available. After this survey, the quality of the existing data need to be assessed. This assessment then facilitates the identification of the data limitations and their implications for assessing performance; thereby allowing the appropriate response- and rectification mechanisms to be set in place.

UNDERSTAND THE COMPONENTS OF A DATA COLLECTION PLAN

A data collection plan provides details to support decision-making by the users of the information. According to Beschen *et al.* (2001), when developing a data collection plan, attention needs to be given to numerous aspects. A discussion of these aspects follows.

- Statement of informational requirements. The data collection plan needs to clearly define the informational needs of the performance measurement program.
- Statement of information sources. For each identified measure, the data collection plan needs to specify a specific data source.
- Data collection process. It is important to establish: 1) the reason and process for the data collection, 2) the time period(s) for which the data is to be collected and 3) the form(s) of analysis that will be used with the collected data.
- Data collection and reporting frequency. The type of data being collected and the needs of the decision makers regarding the timing of the information dictate the collection and reporting frequency.
- Data collection costs. In general, both tight control of the reporting system development process and close attention to collecting only what is needed (not all that is available), is required.
- Data protection. Since protecting sensitive data is of paramount importance to every organisation, it needs to be the first aspect considered when designing a performance information system.

EXAMINE DATA COLLECTION CONSIDERATIONS

Before selecting a data collection method, a few aspects of the data collection process first need to be examined. Some of the most notable aspects to consider, as identified in Beschen *et al.* (2001), are:

- Sampling techniques.
    - The sampling method chosen can influence the statistical impact of the chosen sample and might place limitations upon extrapolating the results.

- Bias.
    - Bias may occur in quantitative- and qualitative data collection and is often the result of the collection of an incomplete or inaccurately weighted sample of data.
- Data reliability.
    - The data source used can influence its reliability
- Data validity.
    - Due to the imperfect nature of measurement, data validity is a matter of degree.
- Level of accuracy.
    - Each body of data collected may yield valuable information, but may also differ in its degree of accuracy.
- Level of detail.
    - Not all of the information that can be collected is necessarily valuable or usable.
- Response rate.
    - Response rate is important in determining the bias of the data received from the instrument.
- Speed.
    - Data that can be collected quickly may sacrifice one or more of the other necessary characteristics (e.g. level of detail and level of accuracy).

CONSIDER DATA COLLECTION METHODS

Beschen *et al.* (2001) have identified numerous data collection methods. These methods vary in their performance with respect to bias, cost, response rate, speed, level of detail, validity, reliability as well as usefulness with demographically diverse population. A discussion of these methods, as given in Beschen *et al.* (2001), follows.

- Agency- and program records.
    - Most agencies and programs routinely record data, for administrative purposes, on customers and/or transactions. Not only are these records a source of outcome information, but they are also the main data source on the inputs (both money and employee time) and outputs produced by the program.
- Site inspections/observations.
    - Trained observers are used to rate outcome conditions that can be perceived by the eyes or by other physical senses of the observer.

- Special technical equipment.
    - Special technical equipment is used to collect data for outcome indicators that require scientific measurements.
- Surveys and interviews.
    - Surveys provide a method of gathering information from stakeholders and other role players by questioning them. Questionnaires are used to gather data (qualitative, quantitative or both) and usually take the form of personal interviews, telephone interviews or mail questionnaires.
- Purchasing (or using) statistics from an outside source.
    - Statistics purchased (or used) from an outside source are often used in cost-benefit analyses and regression analyses.
- Peer review/expert panel evaluation.
    - A traditional approach to Research and Development (R&D) program evaluation has been peer reviews. These reviews can take the form of either highly structured- or unstructured processes.
- Quantitative methods for R&D activities.
    - The quantitative methods for collecting performance data need to include the use of indicators of input (e.g. funding and human resources) and indicators of output (e.g. publications, citations and patents).
- Economic methods.
    - The value of economic methods lies in estimating how much benefit (or return) the organisation receives from the initial investments in R&D. Examples of economic methods are, among others, rates of return, production functions, customer surplus and social rate of return.
- Case studies.
    - In case studies, a complex situation is studied in its context such that questions about the efficiency- and effectiveness of current programs can be answered.
- Content review.
    - Content attempts to, by coding and classifying the qualitative data sources, develop an understanding of the meaning of large volumes of qualitative analyses.
- File review.
    - File review aids in: 1) providing the information necessary and pertinent to the evaluation of the program and 2) minimising the need for additional data collection; thereby reducing the costs associated with that data collection effort.

- Focus groups.
  - Focus groups are small-group facilitated sessions that are designed to quickly gather in-depth information; while offering stakeholders a forum for direct participation. These sessions are usually facilitated by an outside third party and can yield invaluable information.

STEP 5

The fifth step to establishing a performance-based management program is to establish a process/ system for analysing, reviewing and reporting performance data. This can be accomplished with the aid of three sub-processes. These are:

1. understand the role of data analysis,
2. train the organisation in data analysis skills, and
3. conduct data analysis.

UNDERSTAND THE ROLE OF DATA ANALYSIS

According to Jordan *et al.* (2001), the purpose of data analysis and -review is to convert raw data into performance information and knowledge. During analysis, the data that has been collected is processed and synthesised such that organisations can make informed assumptions and generalisations about what has happened, why this might vary from what was expected and what corrective action might be required.

TRAIN THE ORGANISATION IN DATA ANALYSIS SKILLS

Training needs vary by the degree to which the person or organisation is involved in the analysis process. Some organisations provide data directly to the manager, some to the relevant business units and some use “cross talk” (i.e. vertical communication) between organisational levels. As stated in Jordan *et al.* (2001), analysis skills can thus either be centralised or decentralised; with the training needs varying accordingly.

CONDUCT THE ANALYSIS PROCESS

Jordan *et al.* (2001) have divided the analysis process into four main steps. These are:

1. question review,
2. data collection and -organisation,
3. data analysis, and

4. data presentation.

QUESTION REVIEW

In order for the analysis plan to help deal coherently with the where, who, how and what else issues pertaining to data collection, the following questions need to be reviewed (Jordan *et al.* 2001):

- How does actual performance compare to a goal or standard?
- If there is significant variance, is corrective action necessary?
- Are new goals or measures needed?
- How have existing conditions changed?

DATA COLLECTION AND -ORGANISATION

Since data needs to be collected from all possible sources, the analysis plan needs to clearly stipulate what data has been collected on the various aspects considered and/or from where to pull that data. Possible data collection sources, as given in Jordan *et al.* (2001), are: baseline data, performance measurements (e.g. self-assessments and on-site reviews), relevant in-depth evaluation studies (e.g. expert review) and status of assumptions about external influencing factors or other parts of the organisation, programs and facilities.

Once the raw data has been collected and verified, it is often necessary to further organise it before performance analysis can occur. Jordan *et al.* (2001) have identified methods that can help to prepare the foundation for performance measurement by organising, synthesising and aggregating the organisation's data. A discussion of these methods follows.

- Using a scorecard.
  - A (balanced) scorecard approach can help to minimise the problems of measurement that perturbs the system. It is often used to get a holistic view of the health of an organisation.
- Using expert judgment.
  - In situations where data is primarily qualitative and for purposes of validating self-assessments, experts or peers are often asked to combine data and describe/interpret the findings (in qualitative terms).
- Using meta-analysis and evaluation synthesis.
  - Synthesis methods use systematic- and comprehensive retrieval practices (e.g. accumulation of prior studies) to determine a common metric for the quantification

of results. If the collection of results is then statistically aggregated, it is possible to derive a more accurate and useful portrayal of what is known and not known about a given topic.

- Normalisation.
  - Normalisation, in this context, denotes the practice of creating a rate indicator that can be used to compare dissimilar organisations. This practice is then usually used to count errors or events.
- Performance indices.
  - Performance indices allow for multiple sets of information to be compiled into an overall measure; thereby providing a statistical measure of how performance changes over time.

DATA ANALYSIS

There are two categories of analysis tools: 1) those that analyse measurement data and 2) those that identify root causes and then design improvements. In Table 2 (Jordan *et al.* 2001), a list of different tools relating to each of these two categories is given.

Table 2: Two Categories of Analysis Tools

To Analyse the Measurement Data	To Identify Root Causes and Design Improvements
Check test	Affinity diagram
Run chart	Brainstorming/creative thinking
Statistical analysis	Cause and effect diagram
Statistical process control/control chart	Cost-of-quality analysis
Matrices, contingency tables	Criticality analysis
Flow charts	Failure mode and effect analysis
Decision trees, historical timelines	Fault tree analysis
Scatter plots of relationships between variables	Histogram
	Pareto analysis
	Story boarding
	Gap analysis
	Analytical hierarchy process

The information obtained from the data analysis has many uses. Primarily, the data provides management and individual performers with a view of current- and past levels of performance. The data can also provide an indication of future performance. According to Jordan *et al.* (2001), performance-related information provides management with the necessary clarity as to where an organisation (or individual performer) stands relative to its goals and aspirations. Therefore, it is incumbent on management to establish an appropriate method for presenting key information in a way that promotes and encourages the behaviours necessary to attain the organisation's objectives and -vision.

DATA PRESENTATION

The choice of which software to use for data presentation is often based on personal preference, company policy and -needs and/or the related financial expenditure (Jordan *et al.* 2001). Spreadsheet and database software can, for example, be used to generate Pareto charts, bar charts, pie charts and scatter diagrams. Software for more complex analyses and presentation, beyond that performed by common spreadsheet and database software packages, are more expensive and possibly difficult to find. The scarce and expensive nature of such software packages stimulates the proposition made herein and thus provide impetus for the research conducted.

STEP 6

The sixth step to establishing a performance-based management program is to establish a process/ system for using performance information to drive improvement. This can be accomplished with the aid of two sub-processes. These are:

1. benchmarking (including the use of performance data to accomplish benchmarking and the use of benchmarking data to drive improvement), and
2. change management through re-engineering, continuous improvement and process improvement.

BENCHMARKING

The single most important and valuable benefit of benchmarking is that it allows an organisation to see beyond its existing paradigms of process performance (Gee *et al.* 2001). Benchmarking essentially allows an organisation to improve its likelihood of seeing tomorrow's solutions to today's problems. Even though these truly new ideas are often wholly different from the processes observed from the benchmarking efforts, they are inspired therefrom.

The simplest and most successful model available for adopting benchmarking is designed by the American Productivity and Quality Centre (APQC). A discussion of the APQC's four-phase model, as given in Gee *et al.* (2001), follows.

1. Plan. Prepare the benchmarking study plan, select the team, select partners and analyse the process.
2. Collect data. Prepare and administer questions, capture the results and follow-up with partners.
3. Analyse. Analyse performance gaps and identify best practices, methods and enablers.
4. Adapt and improve. Publish findings, create an improvement plan and execute the plan.

RE-ENGINEERING

Many business processes are so complicated that only a few people in the organisation actually understand them. However, according to Gee *et al.* (2001), re-engineering can be used to simplify these evident complex processes.

The simplification inherent to re-engineering leads to a high payback in terms of cost and time saved (Gee *et al.* 2001). Firstly, it makes the business processes more understandable to the employees. If the processes are more understandable, safety can be dramatically improved. Simplification can also improve processes such that the quality of work-life of the employees is increased. Moreover, by educating the participants as to what the process is and what it is intended to accomplish, the flexibility of the organisation's business processes is increased. With this increased flexibility, an organisation can more easily respond to unexpected events in the business environment. Lastly, by improving the responsiveness to customers and stakeholders, a lasting positive attitude can be fostered.

There are four phases to re-engineering. A discussion of these phases, as given in Gee *et al.* (2001), follows.

1. Organising the organisation. Decide what process(es) will be re-engineered.
2. Analysing the current processes. Understand how each process works and what the cycle times are.
3. Developing new concepts. Define the new model by "thinking out of the box".
4. Moving from the current organisation to the new model. Develop a strategy to deploy the new concept(s).

CONTINUOUS IMPROVEMENT

In general, most work is accomplished through repeatable processes that consist of many steps. The concept of continuous improvement is that a small improvement in the cost and/or time to complete one cycle of the process, when multiplied by the many times the cycle is repeated, can lead to great savings over time (Gee *et al.* 2001). Each improvement of the process reduces the excess time and cost in the process by reducing the waste or those portions of a process that do not contribute to the end result.

The most commonly used technique to perform continuous improvement is by implementing the Plan-Do-Check-Act cycle. This cycle constitutes the following steps. First, plan the process or the change. Then implement the process or the change. After the process or change is completed, check the results (usually by taking measurements). Based on the results of the measurements, take action accordingly. That is, continue with the process or change that was developed or re-enter the cycle and improve on the initial change by repeating the cycle.

PROCESS IMPROVEMENT

Process improvement uses as a set of management techniques to control and improve the effectiveness- and efficiency of the process. According to Gee *et al.* (2001), the main goals of process improvement is to achieve a stable process, reduce the variation and to increase the conformance with regard to customer expectations.

After management has identified the primary customer(s) and the core process(es) to be improved and controlled, they can commence with the seven phases of process improvement. A discussion of these phases, as given in Gee *et al.* (2001), follows.

1. Organise the team. The process improvement team needs to be organised according to the types of skill-mix the team needs to have.
2. Analyse the current process. Construct a process flowchart of current processes such that a systematic map of the activities, actions and decisions that (actually) occur can be generated.
3. Simplify the process. The team needs to remove redundant or unnecessary activities.
4. Develop outcome indicators. For each valid requirement in the process, a measurable indicator needs to be identified.
5. Determine if the process is stable. Team members need to look for, and be aware of, seasonal- or periodic variation caused by other processes.
6. Determine if the process is capable. In order to determine how frequently the process outcome conforms to the client's expectations (as measured by the outcome indicator), the team needs to use one or more statistical technique.

7. Determine if further improvement is feasible. The team leader needs to be alert of two possibilities. Firstly, further process improvement may not justify the work of the team. Secondly, the process itself may not be adequate to achieve the required and/or desired results.

3. STATUS QUO

3.1 TECHNOLOGY APPLICATIONS

In order to investigate and elucidate the need for the provision of a performance management approach, a typical transport environment needs to be considered. An example of such a representative transport environment is the City of Cape Town (CoCT). The CoCT is deemed appropriate for reflecting the status of the nation's current transport situation and technology implementations with regard to ITS applications.

The next sections provide a discussion on the City's transit- and traffic operations, the extensive recent implementation of technology systems and their relating ITS-aspects as well as the long-term viability of the advanced transport systems.

3.1.1 MANAGEMENT FACILITY WITH RESULTANT TRANSPORT DATA REPOSITORY

The Transport Management Centre (TMC) of the CoCT was officially opened in May 2010 and is situated in Goodwood. It is the first integrated public transport, traffic and safety-and-security management centre in SA and it is also viewed as one of the finest state of the art facilities in the world (CoCT 2010). Since the realisation of this centre, extensive deployment of technology and the relating supporting ITS devices have been implemented.

MAIN FUNCTIONAL AREAS

According to CoCT (2010), the TMC has five main functional areas. These are:

1. Freeway Management System (FMS).

The TMC uses CCTV cameras to monitor the traffic flow and VMSs to provide feedback to the travellers. These VMSs have been placed throughout the City. Some of them use renewable energy sources such as wind turbines and solar panels.

2. Arterial Management System (AMS) and Urban Traffic Control (UCT).

The TMC uses traffic signal controls, in conjunction with the CCTV cameras, to ensure the seamless movement of the traffic in the City.

3. Incident Management System (IMS).

The TMC facilitates faster emergency- and incident responses by detecting incidents quickly and notifying relevant role players immediately via an advanced modern dispatching system.

4. Integrated Rapid Transit (IRT).

The TMC is seen as the operational hub for the City's IRT system. It accommodates for central processing, vehicle monitoring, computer-aided dispatch, vehicle scheduling, database and reporting, information management, digital video management, communication-monitoring, emergency management and maintenance control.

5. Transport Information Centre (TIC).

The TMC has a 24 hour, 7 day a week service that provides information to citizens and visitors on general enquiries of (mostly) public transport. They support: Cape Metrorail, Golden Arrow Bus Services (GABS), park-and-ride facilities, dial-a-ride public transport and kerbside parking management.

TRANSIT- AND TRAFFIC OPERATIONS

In Figure 7, the general transit- and traffic operations of the TMC are portrayed. These are represented under the groups of: 1) input, 2) information processing, 3) action and 4) output.

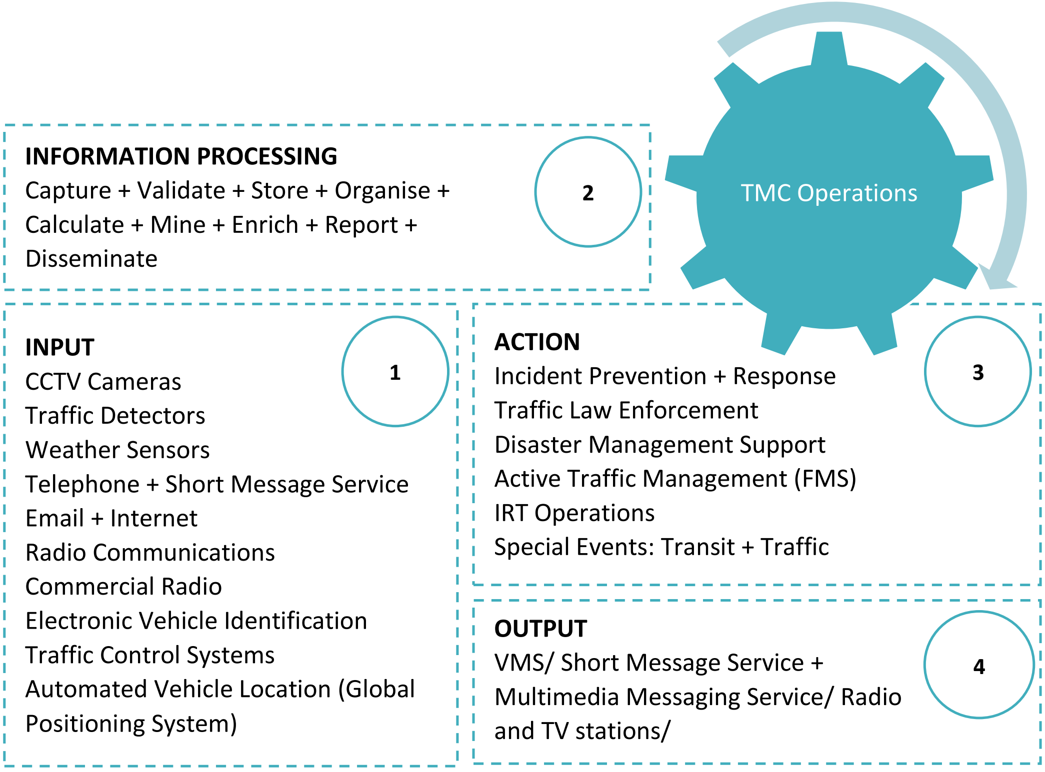

Figure 7: TMC Operations

3.1.2 ADVANCED TRAFFIC MANAGEMENT SYSTEMS

ATMS utilise ITS functions such as: traffic control systems, lane- and incident management, ramp metering, navigation- and warning systems, adaptive signal management and electronic toll collection. These ITS functions rely on information technologies to connect sensors, roadside equipment, vehicle probes, cameras, message signs and other devices together to create an integrated view of the network operations and to detect incidents, dangerous weather events and/or other roadway hazards (Ezell 2010). The information retrieved from the real-time traffic monitoring is portrayed to drivers on output devices such as VMSs and HAR. These ATMS procedures are currently managed by the CoCT's TMC and assist with FMS, AMS, UTC and IMS.

SA'S FREEWAY MANAGEMENT SYSTEMS

In September 2006, SANRAL launched its first FMS project in Gauteng (SANRAL 2012). Subsequently, FMS has been deployed in the metropolitan areas of Johannesburg, Tshwane and Ekurhuleni in Gauteng, eThekwini and Pietermaritzburg in Kwazulu-Natal and Cape Town in the Western Cape.

CAPE TOWN'S FREEWAY MANAGEMENT SYSTEM

SANRAL together with the Provincial Government of the Western Cape and the CoCT Municipality have funded the implementation of the Cape Town Freeway Management System (CT FMS). The CT FMS has been operational since the beginning of May 2010. As stated in SANRAL (2012), for the period 1 May 2010 to 30 July 2011, the CT FMS responded to over 13 800 incidents on the major freeways in Cape Town.

The freeways covered by the CT FMS include (SANRAL 2012):

- the N1 from the CBD to the Huguenot Toll Plaza,
- the N2 from the CBD to the top of Sir Lowry's Pass,
- the R300 between the N1 and the N2,
- the M5 between the N1 and N2, and
- the N7 between the N1 and Potsdam Interchange.

In total, approximately 150 km of the busiest freeways in Cape Town are under surveillance. According to SANRAL (2012), CT FMS comprises over 200 CCTV cameras and 48 VMSs.

The (live) footage from the CCTV cameras are mainly meant to be used by road- and security authorities. The latter mentioned includes traffic authorities and the South African Police Service (SAPS). However, some of the still footage (i.e. images that are not incident-related) from the CCTV cameras are shown on the website: www.itraffic.co.za. The VMSs are only used to convey real-time and relevant information to the motorists.

3.1.3 ADVANCED PUBLIC TRANSPORT SYSTEMS

APTS utilise ITS functions such as: electronic ticketing, navigation- and warning systems, parking guidance, fleet management, cruise control and priority systems. These ITS functions rely on information technologies to connect GPS and AVL, EFC and other devices together to create a real-time view of the position and status of all the assets and the movement of all the commuters in the APTS (Ezell 2010). The information retrieved from the real-time monitoring is portrayed to the commuters on output devices. Examples of output devices include: PIDSs (e.g. EMSs) shown at the stops/stations and Advanced Traveller Information Systems (ATISs) (e.g. journey planners) portrayed on websites and applications. These APTS procedures facilitate IRT and are also currently managed by the CoCT's TMC.

SA'S INTEGRATED RAPID PUBLIC TRANSPORT NETWORKS

As mentioned previously, IRPTNs have been developed and are being developed in the 12 main metropolitan areas of SA. These are (SA DoT 2007):

1. The CoCT Metropolitan Municipality.
2. The City of Tshwane Metropolitan Municipality.
3. The City of Johannesburg Metropolitan Municipality.
4. The Ekurhuleni Metropolitan Municipality.
5. The eThekweni Transport Authority.
6. The Nelson Mandela Bay Metropolitan Municipality.
7. The Buffalo City Local Municipality.
8. The Msunduzi Local Municipality.
9. The Mbombela (Nelspruit) Local Municipality.
10. The Polokwane Local Municipality.
11. The Rustenburg Local Municipality.
12. The Mangaung Local Municipality.

The current three flagship Bus Rapid Transit (BRT) systems, as components of IRT, are those of the CoCT (referred to as MyCiti), the City of Johannesburg (referred to as ReaVaya) and Rustenburg (referred to as RRT: Rustenburg Rapid Transport).

MyCiti has shown good progress. It is well established with regard to both its infrastructure and the technologies accompanying IRPTN deployment. Moreover, even though MyCiti's magnitude may differ from the other rollouts, it makes use of the same ITS functions and is largely similar in nature. Due to this comparability, MyCiti's is thus seen as a good precursor to consider as baseline.

CAPE TOWN'S BUS RAPID TRANSIT SYSTEM

OVERVIEW OF THE MYCITI SERVICE

In October 2010, the MyCiti Business Plan for the implementation of phase 1A was adopted by the Council (Martheze and Grimbeek CoCT 2011). Phase 1A is the City's starter phase of its IRPTN. It runs between the CBD and Table View and consists of residential services on feeder routes[3] in the areas around Table View, a trunk route on a special red busway between central Cape Town and Table View, and a feeder route around the CBD.

In September 2012, the MyCiti Business Plan was extended to include phase 1B and the N2 Express service (CoCT 2012). Phase 1B is a relatively small extension to the initial phase and entailed the completion of the logical set of services around phase 1A. The N2 Express service was implemented as a short-term intervention to relieve pressure on the existing transit services, especially rail, between the Metro South-East and the central city. According to CoCT (2012), it will also allow certain innovations and lessons learned from phase 1A to be tested prior to their adoption as part of phase 2.

Phase 2 will encompass all areas of the Metro South-East (including Khayelitsha and Mitchells Plain) and will extend to the Southern Suburbs. Phases 3 and phase 4 will extend the system to the Northern Suburbs, the Delft and Blue Downs areas as well as the Helderberg areas (CoCT 2012). All four of the phases pertaining to the MyCiti service have been designed in such a way that the need for integration with other modes, especially with rail (the backbone of public transport in Cape Town), is inherently emphasised. As stated in CoCT (2012), the completion of these four phases can be expected within the next 15 to 20 years.

MYCITI'S TEETHING PROBLEMS

Certain routes of the MyCiti service have faced mismatches with regard to their forecasted- and actual passenger demand numbers. Even though these mismatches in supply and demand are not unusual

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[3] A feeder route is a route that provides access to a trunk route (aka a main route).

for such a newly deployed system, the MyCiti service still has to confront and deal with the consequences of the underutilised routes.

In the hope of counteracting this underutilisation, the MyCiti service revised their timetables and made changes to (re)optimise their routes (CoCT 2014). Some may argue that these amendments have been satisfactory, others not. Regardless of the aforementioned, recent cost figures (as obtained from an employee at TCT: Transport for Cape Town) indicate that the MyCiti service is currently running at a loss. As stated in Lewis (2014), the MyCiti service has, to date, cost R4.6 billion to roll out. Moreover, even though incidences such as strikes are out of the control of the service provider, the MyCiti users still sometimes view the service as being unreliable. According to Lewis (2014), overcrowding, long queues and services that do not run to schedule are some of the complaints concerning the MyCiti service.

3.1.4 THE LONG-TERM VIABILITY OF THE ADVANCED TRANSPORT SYSTEMS

In order to assess the long-term viability of the advanced transport systems in a developing country like SA, it has been deemed necessary to evaluate them against the four production factors. These are: 1) land, 2) labour, 3) capital and 4) technology. A discussion follows.

1. Land.

Land is relatively affordable in SA. This is an advantage to the project, since dedicated transit routes and new roads require additional land. However, there is also a disadvantage in that an overabundance of land results in the spreading out of people over larger areas. The aforementioned results in less densely populated urban areas (compared to the densely populated cities in Europe, America, South America and the East). The implication is that more extensive infrastructure over longer distances is required. Moreover, with regard to the private transport environment, the transit vehicles need to travel much longer distances with a lot fewer passengers per vehicle. The aforementioned factors cause the cost, relative to the revenue, to escalade drastically.

2. Labour.

Labour has become expensive in SA. Frequent strikes and higher wage demands (of for example: bus drivers) cause the input costs to escalade. Labour in SA is not, when compared to the cost of labour in many of SA's trade partners (especially in the East), competitive any more. Besides abnormally escalating labour costs at lower employment levels, the cost of technologically skilled labour to operate an advanced transport system also needs to be taken into consideration. When comparing the number of engineers per 100 000 of the population in SA with many other countries, the acute shortage of technologically skilled labour becomes evident. This shortage results in abnormally high cost of technologically skilled labour; exactly the type of labour that is required to design, build, operate and maintain an advanced transport system.

3. Capital.

Capital is scarce and expensive in SA. The cost of capital is extremely high in SA, yet the development as well as the eventual maintenance- and operation of an advanced transport system is capital intensive. The capital cost of developing- and maintaining an advanced transport system in SA is considerably higher than in first world countries; where capital is less scarce and less costly.

4. Technology.

Although there are some areas in the South African economy where the levels of technology is relatively high, in general, the nation does not have a noteworthy competitive advantage in technology as a production factor. Due the shortage of technologically skilled labour, the technology needed for the advanced transport systems is mostly imported. Moreover, due the deteriorating exchange rate, importing the technology is very expensive.

3.2 PERFORMANCE EVALUATION

As mentioned previously, no consistent or holistic performance management approach for measuring the technology-related aspects of the ITS deployments in the South African transport environment is currently available. Nevertheless, with the evolvement of Information Technology (IT), immense scope for growth in the utilisation of information systems has been created. Several initiatives within the transport industry serve as testimony of this fact.

The next sections provide a discussion on some of the emerging performance measurement developments and their applications evident in Cape Town.

3.2.1 THE TRANSPORT REPORTING SYSTEM

In March 2010, the CoCT put out a tender seeking assistance with the collection, capture, analysis and presentation of the transport data for the update of the 2007 ITP (Springleer *et al*. 2012). In order to be best positioned to produce data for inclusion into the Transport Register, the CoCT's Transport Department initiated the development of the Transport Reporting System (TRS).

Before the initiation of this tender, the City experienced a number of problems. The existence of these problems were linked to the fact that the transport data was housed in many separate sub-systems.

According to Springleer *et al*. (2012), the City experienced difficulty in handling and managing the transport data due to differing levels of technology and database platforms, difficulty in extending these existing systems to accommodate new functionality and reporting abilities as well as difficulty in integrating, reporting and consolidating the information in these systems for management review.

After a public tendering process, a team of consulting engineers, along with their specialist GIS subcontractor, were appointed on a three year contract to commence with the development of the TRS as of 1 July 2010 (Springleer *et al*. 2012).

After initial assessment, the tender team linked the City's problems to the following setbacks: the vintage of the data, the availability of the data, the storage of the data and the integrity of the data. (For example: the data that was previously recorded was only captured after some time had elapsed. This caused the relevance of the data to come into question.) Springleer *et al*. (2012) identified the main reason for the inefficiencies in the data to be related to the fact that both the survey and capturing were often carried out by the same staff. Furthermore, capturing was carried out on various spreadsheets that needed to be combined, cleaned and managed. This then often led to files getting lost, overwritten or captured more than once.

With the development of the TRS, the CoCT aims to mitigate these inefficiencies by allowing online capturing of data onto a web-based database. In order to make the data and the reports easily accessible to people within the City's Transport Department, this database facilitates the TRS with integrating and consolidating the transport survey data into a central database (Springleer *et al*. 2012). The key benefit of implementing the TRS is thus the creation of automatic reports and the quick access to information. Springleer *et al*. (2012) defined the main types of reporting abilities (available within the TRS) to be the following:

- raw survey data extractions for ad-hoc use (e.g. modelling),
- custom text and graph reports for various metrics (e.g. supply and demand, modal usages and vehicle occupancies), and
- spatial or GIS-based reports that filter vast amounts of data into easy to interpret map-based views.

The summary of the system improvements, which have so far resulted from the implementation of the TRS, can be seen in Table 3 (Springleer *et al*. 2012).

Table 3: Summary of System Improvements by the TRS

CONCERNS	ADVANCEMENTS	SHORTCOMINGS
Vintage of data	Data is recorded and uploaded on a web-based database from which it is immediately available for extraction and analysis by the user. Certain modes are available instantly (such as the bus module). These make use of portable electronic GPS enabled storage devices.	Currently, not all recorded data is captured at the same rate. However, a possible future consideration for the improvement thereof is to research the possibility of automating data collection and capturing as much data as possible.
Availability of data	Once captured, data is immediately available to various users. Depending on the public transport mode, the data output is made available in at least one of the following formats: automatic report, pdf, Microsoft Word and Microsoft Excel.	The current availability of captured raw data is excellent. However, certain public transport modes require an internal (i.e. within the CoCT) validation. For example: the cleaning and matching process of the minibus taxi module. Nevertheless, when compared to the way it was previously done, this process has been automated to a large extent. Notwithstanding this, if the legislative requirements are to be fulfilled, the process will have to be undertaken by a City official and cannot be outsourced.
Storage of data	Data is stored on a central server running Microsoft SQL Server as the database platform.	Access to the data is currently only available via an internet connection. However, the connectivity and internet speed within the City's IT infrastructure are continuously improving. Consequently, within the near future, the sufficiency of this access type will undoubtedly improve.
Integrity of data	Electronic data trails are available for all inserts, extractions, printing of permits, and so on. Furthermore, all modifications or alterations can be detected and isolated for auditing purposes. Since the raw data capture sheets are uploaded to the TRS, scans can also be downloaded for reference purposes.	Unfortunately, checks and balances for a system like the TRS will never ensure 100% integrity. However, when compared to what was previously done to ensure data integrity, this issue is indeed addressed to a large extent.

According to Springleer *et al*. (2012), within only one year of employment, the TRS has aided the City's Transport Department to achieve numerous of their desires. A discussion of some of these achievements follows.

- The City officials have gained the ability to both improve the management of their data as well as to respond quicker and more efficiently to various enquiries.

- In addition to the data being protected and controlled in a transparent and auditable manner, the City is now also capable to make survey data and reports available within a week of field surveys being completed.
- Data is now easily accessed via the internet and automatic reports are generated to assist with the compilation of the Current Public Transport Records (CPTRs).

3.2.2 PRIVATE TRANSPORT

As part of the procurement of a national ITS framework, the Government funded agency SANRAL (South African National Roads Agency Limited) has developed a measurement framework for managing contract performance.

SANRAL'S PERFORMANCE MANAGEMENT REGIME

INTRODUCTION

SANRAL has pursued a KPI approach towards establishing the performance of the FMSs in Gauteng, Kwazulu-Natal and the Western Cape. SANRAL, as the "employer" of this performance management regime, has the primary objective of delivering both regionally- and nationally integrated ITS functions at a consistently high quality level. The developed regime is derived from a number of key components. A list of these components, as given in SANRAL (2011), follows.

- Employer's requirements.
- Principles of governance.
  - Employer's procedure for project governance.
  - Formal change control process.
- Performance measurement.
  - Measurable service levels.
  - An approach to scoring the attained service levels.
  - Programs of independent auditing by the employer.
  - Automated measurement and data aggregation where possible.
- Payment mechanism.
  - Fixed- and variable items based on the payment schedule.
  - Adjustments based on groups (i.e. performance areas) of performance indicators; as determined by the relationship to critical success factors.

For the purpose required herein, only the performance measurement component is considered in more detail.

OVERVIEW

The concept of the developed performance measurement process can, essentially, be represented through Figure 8. This figure is adapted from the work in SANRAL (2011).

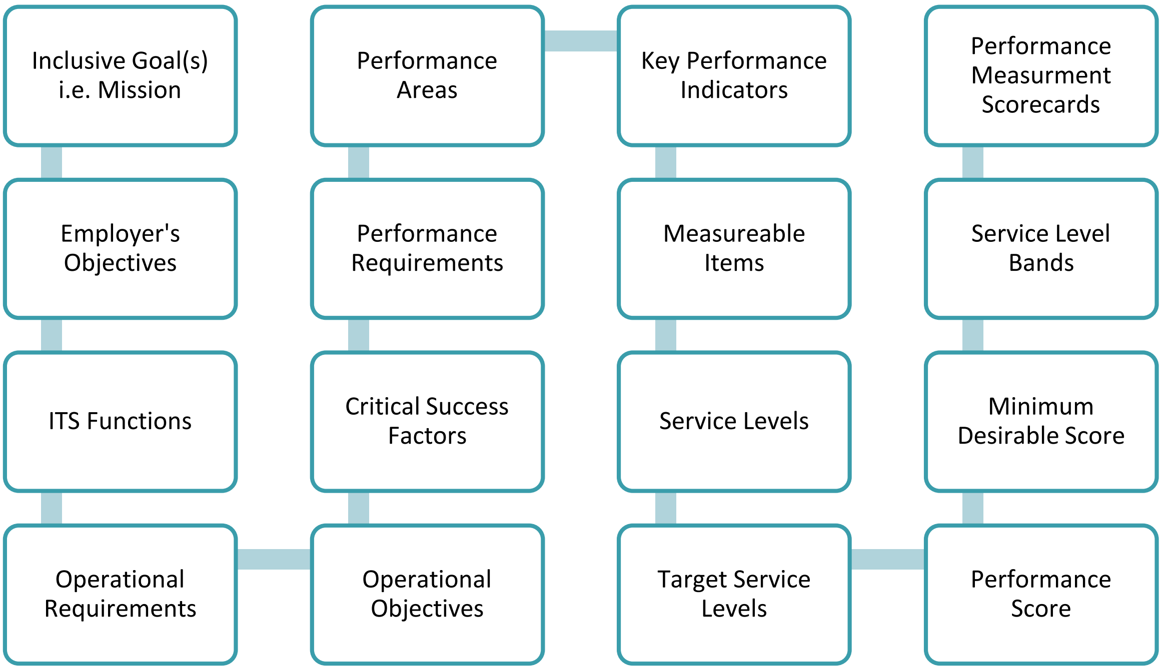


Figure 8: SANRAL Contract Performance Measurement

As can be seen in Figure 8, SANRAL aims to align, from the beginning to the end of the performance measurement contract, the operations of the main contractor with their objectives. Some of the important components of this contract and their relationship to one another are discussed in the following sections.

ITS FUNCTIONS

SANRAL wishes to procure the identified ITS functions (including their design, delivery and operations elements) in such a way that they support the delivery of their ITS service objectives. This relationship is portrayed in Figure 8 through the linkage between the employer's objectives and the ITS functions.

In SANRAL (2011), the following eight ITS functions are identified:

1. freeway management,
2. maintenance management and asset management,

3. incident management,
4. fleet management,
5. law enforcement support,
6. research and development,
7. advanced traveller information dissemination, and
8. public communications.

All of the aforementioned ITS functions are subject to the provisions in SANRAL (2011). The first six listed are the regionally provided ITS functions and the last two listed are the nationally provided ITS functions.

CRITICAL SUCCESS FACTORS

From the aforementioned, it is clear that SANRAL's objectives are translated into ITS functions. The operational requirements and -objectives are then linked to each ITS function. Moreover, as seen in Figure 8, the operational objectives of the ITS functions are achieved by meeting the identified critical success factors. In SANRAL (2011), five critical success factors are given. A discussion of these factors follows.

1. Operational performance relates to whether the relevant business processes and staff activities are executed as they should (i.e. in a timely manner and to the required quality standard) by only using the available tools.
2. System availability relates to the protection of asset health and whether the maintenance regime of the business is aligned to meet the operational demands.
3. Cooperative relationships relate to both the measurable level of cooperation among all parties involved and, where there are common data sources, to the relationships between the ITS functions.
4. Flexible- and scalable operations ensure that the ITS functions are, during their lifetime of operation, responsive to major foreseeable changes.
5. Public awareness and -understanding relate to all the aspects of the project that may have an impact on public perception, -behaviour and their interaction with the scheme.

SANRAL believes that the performance requirements they aspire to can adequately be expressed through these identified critical success factors. Their desired performance requirements (as per critical success factor) can easily be traced back to their (original) objectives. With this as the point of reference, they can ensure that the contractor adheres to their overall mission.

PERFORMANCE AREAS

As seen in Figure 8, the performance requirements are translated into the performance areas. The critical success factors are, with the aid of the performance requirements, mapped to the performance areas. The performance areas identified in SANRAL (2011), as given per critical success factor, can be seen in Table 4.

Table 4: SANRAL Performance Areas

CRITICAL SUCCESS FACTORS	PERFORMANCE AREAS
Operational Performance	Quality control Effectiveness Accuracy Timeliness
System Availability	System availability
Cooperative Relationships	Reporting Governance
Flexible- and Scalable Operations	Responsiveness
Public Awareness and -Understanding	Channel availability Customer relations Marketing support

MEASUREABLE ITEMS

The measurement process is facilitated by assigning the indicators to the performance area(s) of each critical success factor. For each KPI, items that are measureable are identified. Some of the identified measurable items in SANRAL (2011), as given per performance area, are shown in Table 5.

Table 5: SANRAL Measureable Items

PERFORMANCE AREAS	MEASUREABLE ITEM EXAMPLES
Quality Control **Effectiveness** **Accuracy** **Timeliness**	Incident records Maintenance scorecard VMS and HAR posting Service dispatching
System Availability	ITS equipment (e.g. CCTV cameras, traffic detectors, VMSs and HAR transmitters) ATIS interface Interfaces with other centres (e.g. municipal traffic control centre) and media Weather monitoring systems Communications backbone equipment (e.g. fibre optic cables)

PERFORMANCE AREAS	MEASUREABLE ITEM EXAMPLES
Reporting **Governance**	Performance management scorecard
Responsiveness	Incident detection, verification and notification (e.g. incident logs, call logs and footage) Vehicle dispatching and -tracking system
Channel Availability **Customer Relations** **Marketing Support**	Tactical marketing scorecard

PERFORMANCE SCORE

Within each performance area, each of the service levels is assessed in each region and for all centrally provided ITS functions. In order to calculate the performance score of each KPI, the measured service level is compared to both a minimum value and to the agreed target service level. The performance score is then, in layman's terms, recorded in points and weighted according to its relative contribution to meeting SANRAL's objectives. This recorded score, as derived from the service level band it belongs to, is then used to execute the payment procedure. In essence, this score identifies the performance-related adjustment that needs to be made to the payment certificate of each contractor (SANRAL 2011).

PERFORMANCE MEASUREMENT SCORECARDS

In SANRAL (2011), three scorecards are defined. The first is the facilities maintenance scorecard. This scorecard is used to determine the extent to which the main contractor demonstrates ownership, capacity and capability of the maintenance regime for the employer-provided (or main contractor-provided) facilities. The second is the public communications (i.e. index of quality of service) scorecard. This scorecard is used to determine the extent to which the main contractor demonstrates ownership of its marketing obligations. Examples of obligations are, among others, the level of knowledge of customer service representatives, the availability of tactical marketing material and the conformance to brand specification as agreed upon by the main contractor and the employer. The third is the contract performance scorecard. This scorecard is used to determine the extent to which the main contractor demonstrates ownership of the performance management cycle. The three basic stages are: 1) planning, 2) monitoring and 3) action.

THE SCORING- AND REVIEW PROCESS

A description of the steps associated with the scoring- and review process, as stipulated in SANRAL (2011), follows.

- If a score greater than zero is claimed, the main contractor needs to submit completed scorecards along with the supporting evidence.
- The performance review committee assesses the submissions and convenes a regional meeting (as determined by SANRAL) to discuss the scoring. Common topics discussed include:
    - whether the main contractor is generally meeting target service levels across critical KPIs solely for the purposes of the performance review,
    - whether proposals for improving performance have been submitted and are deemed effective, and
    - whether the main contractor has any overdue remedial measures (including those detailed in any prevailing recovery plan) that have not been adequately addressed in the period under review.
- The performance review committee may agree with the scores and thereby endorse the score associated with the score. If this is not the case, they may disprove the scores and thereby move to "re-score" the relevant section. While executing the latter mentioned, evidence in support to the new score needs to be cited.

3.2.3 PUBLIC TRANSPORT

The CoCT currently has two approaches available that can assist in managing the performance of the public transport system. While the first one discussed is privately owned, the second one is funded by the Government.

NON-RAPID PUBLIC TRANSPORT

WHERE IS MY TRANSPORT

The newly developed WhereIsMyTransport application is an all-encompassing web platform that spans across and caters for three interest groups. These are: 1) the operator, 2) the commuter and 3) the advertiser.

WhereIsMyTransport offers operators a complete operational environment toolset. With this platform they can, in real-time, manage their fleets, assign routes, create schedules and monitor their drivers. As for the commuters, WhereIsMyTransport gives them the ability to not only find out the estimated time of arrival of their awaited transport, but also to find out the fastest or cheapest way to get to their destination (WhereIsMyTransport 2012). Within the imminent future, WhereIsMyTransport will also launch a self-service advertisement portal that can deliver custom advertisements onto transit information screens. This can help to keep the application ajar and may also foster integration- and coordination among transport modes.

Based on the purpose of this research project, the aspect of the WhereIsMyTransport application that is deemed most important is the operational environment toolset provided to the operator. That is, the allowance for vehicle tracking, asset protection as well as fleet- and personnel management. The aforementioned, in essence, ensures safety and security while improving productivity and bringing discipline.

RAPID PUBLIC TRANSPORT

MYCITI'S PERFORMANCE MEASUREMENT TOOLBOX

The performance of the MyCiti system is, to varying degrees, being measured and monitored. A review of the current measurement tools used by the MyCiti system can be found in Table 6. This table has been composed with the help of the CoCT's IRT department.

Table 6: MyCiti's Performance Measurement Toolbox

NO.	PERFORMANCE AREA	NAME	TYPE	SUPPLIER	AGE
1	Base System Planning	Diva	Computer Software	MDV Limited	2012
2	Vehicle Tracking	Lio		Trapeze Group	
3	Schedule Adherence				
4	Operational Performance	BI (Business Intelligence) Analysis	Business Objects	Microsoft/ SAP (Systems, Applications and Products)	
5	Financial Performance	AFC Financial Analysis	Microsoft Excel	ICT Works	
6	Driver Behaviour Risk Management	Drivecam	Equipment/ Web-based	Drive Report	2013
7	Asset Maintenance/ SLA (Service Level Agreement) Management	Forcelink	Web-based & Mobile Interface	Acumen Soft	
8	Public Relations	Marketing	Service Promotion (Media)	TCT	2011
9	Customer Care	Customer Interaction	Service Provision (Social Media)	TIC	2010
10	Quality Assurance	Performance and Quality Monitoring	Performance Evaluation and Quality Assurance Checks	TCT	
11	Event Management	Special Events	Operational Deviation		

A description of the performance areas per number listed in Table 6 follows.

1. System planning tool used to create the (optimised) base model.
2. Controlling software used to monitor real-time vehicle movement.
3. Real-time analysing software used to review and (re)optimise system with regard to schedule adherence.
4. BI objects used from a cost cutting perspective for post-analytic purposes (e.g. conducting trend analysis and reviewing routes).
5. The use of validators on-board vehicles and turnstiles at stops/stations to provide data on the number of taps/stop/route as well as load- and OD data.
6. The use of equipment to monitor inter alia harsh braking, swirling, aggressive acceleration and sharp cornering with the aim of reducing risky driver behaviour.

7. Real-time workforce, workflow, fault reporting and SLA monitoring system.
8. Marketing the MyCiti service to maintain a favourable public image.
9. Attending to inquiries, queries, complaints and compliments.
10. Monitoring the performance of operators and/or contractors and verifying the quality of the data with on-site survey inspections.
11. In the case of special events, certain operational deviations are implemented with respect to route schedules and fare management.

3.3 THE MAIN CONSIDERATIONS DRAWN FROM THE STATUS QUO

The main considerations drawn from the status quo analysis and their associated contribution towards the proposition made herein are discussed in this section.

3.3.1 THE GENERAL CHALLENGES INDENTIFIED

TECHNOLOGY APPLICATIONS

LONG-TERM VIABILITY

Based on the review provided on the current ITS measurement trends and movements, it is evident that SA is embracing a technology-driven setting. Numerous technology applications are already in place and imminent expansion and enhancement among the major metropolitan areas are expected. However, the long-term viability of the advanced transport systems might not be a definite. When these systems are evaluated against the four production factors, it is evident that, if not adequately managed, they could have a negative impact on the nation's Gross Domestic Product (GDP) growth. In essence, there is a most definitive risk that these systems could have a potential risky nature in terms of their eventual value added output.

IMPLEMENTATION OBSTACLES

Even though we live in a technology-driven world, the concept of ITS has only been around for roughly 15 years in SA. At the moment, SA has no common ITS architecture and thus no common technical standard, for the technologies underlying the ITS applications, exists. As a result, there are many challenges that deter the implementation of ITS projects. These challenges are supported by the work done in Ezell (2010). A discussion of the main challenges identified follows.

Firstly, the vast majorities of ITS functions are subjected to system interdependency challenges; require system coordination to deploy, and at the same time, the adoption by the individual users;

and should operate at scale to be effective. Secondly, the uncertain marketplaces for ITS functions (due to the higher risk associated with new systems) impede its development. Thirdly, ITS face a range of institutional barriers, and these organisational challenges determine how the performing organisations, often across jurisdictions, establish and maintain common plans and schedules; how they allocate funding priorities; and how information is shared. Other ITS challenges include the lack of expertise within local- and regional transport agencies with regard to the technologies underlying the ITS functions and the implementation thereof. Lastly, the lack of technical standards for ITS technologies also inhibits the integration of ITS functions pursued by different organisations.

3.3.2 THE GENERAL SHORTCOMINGS IDENTIFIED

PERFORMANCE EVALUATION

PRIVATE TRANSPORT

SANRAL's measurement framework for managing contract performance has not yet achieved full functionality. In the Western Cape, only certain KPIs in some of the identified performance areas are currently being measured. These areas include: 1) system availability, 2) incident responsiveness and information dissemination and 3) contract performance management. The measurement is also done on an ad-hoc basis and is not yet fully automated. It is believed that future functionality will enable the necessary automation. Nevertheless, it needs to be noted that the exhaustive framework behind the measurement process is viewed by some transport role players as being too complex and perhaps even tedious.

PUBLIC TRANSPORT

The WhereIsMyTransport application is still at the early stages of its deployment and hence full functionality has not yet been attained. The same applies to MyCiti's performance measurement toolbox. Even though the measurement tools currently used by the MyCiti system may appear to be relatively all-inclusive, there is still room for improvement. Not only is the monitoring done by a modular- and possibly inconsistent performance measurement approach, but also insufficient attention is given to the monitoring of the IRT system's inherent technology-related aspects. Moreover, with their current disintegrated approach, it is difficult (or even impossible) to attain an idea of the overall system health. Therefore, if the sustainability of the MyCiti system is to be ensured, additional measures (might) need to be put in place.

3.3.3 THE FOUNDATION FOR THE RESEARCH PROPOSITION

Through the promotion of ITS applications, SA is embracing a technology-driven setting. Several initiatives with regard to the implementation of information systems within the nation's transport environment support this statement. The CoCT's TMC is an example of this. Since the realisation of this transit- and traffic operations' facility, extensive deployment of technology and the relating supporting ITS devices have been implemented.

Moreover, the South African transport industry at large seems to be aware of the need for measuring performance. Numerous attempts at measurement systems (although none have yet achieved full functionality) serve as testimony of this fact. SANRAL has developed a KPI approach towards measuring the performance of FMS, the WhereIsMyTransport application provides an operational environment toolset to the transport operator and the MyCiti system has pursued a performance measurement toolbox approach.

At this stage, however, the emphasis on a consistent and holistic performance measurement approach still lacks. Furthermore, insufficient attention is given to the measuring and monitoring of the technology-related aspects of the ITS applications. The aforementioned, in conjunction with the scepticism around the sustainability of the newly deployed advanced transport systems, give stimulus and provide further incentive for changing the current state of affairs.

An all-inclusive and easy-to-understand measurement framework that can stimulate the achievement of the ultimate performance management regime is needed. It is believed that the performance measurement framework and its associated performance management tool, as advocated herein, serve as the foundation for such a regime and hence also foster the development of a national ITS architecture.

4. RESEARCH DESIGN

4.1 OVERVIEW OF RESEARCH DESIGN

In order to realise the proposition made herein, it was necessary to consider (and ultimately integrate) three diverse and unrelated research fields. Firstly, all of the concepts pertaining to transport performance measurement needed to be assessed such that a viable set of performance measures (applicable to ITS projects) could be established. Secondly, the most prominent reference models needed to be considered such that a viable (conceptual) performance framework (which is to act as the reference point for performance evaluation) could be identified. Thirdly, the vast field of MCDM needed to be investigated such that a decision-making model for assessing the overall performance of the ITS projects (by collectively considering the proposed set of measures) could be identified.

Refer to Figure 9.

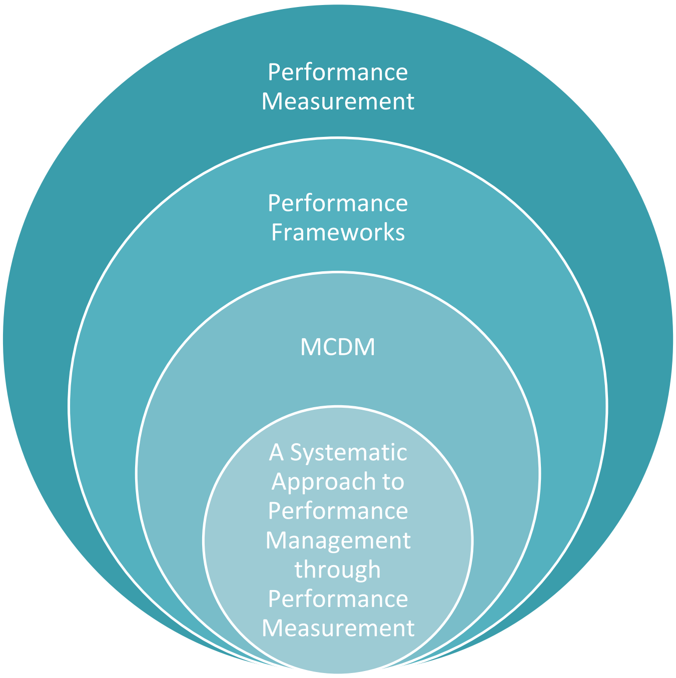


Figure 9: Overview of Research Design

Each of the research fields depicted in Figure 9 originates from different disciplines, encompasses different aspects and is based on unique considerations and foundations.

At this stage, all of the portraying aspects needed for assessing the performance of transport projects and -plans have been elucidated. This entailed a discussion of performance measurement and managing performance measurement. This chapter includes a discussion on the prominent performance frameworks and decision-making models. Following each of these discussions, the exerted choice is motivated and then considered in more detail.

4.2 INTRODUCTION TO PERFORMANCE FRAMEWORKS

As stated in Artley and Stroh (2001), when developing a performance measurement system for the first time or when updating the scope of the current performance measures being implemented, it is essential to take an appropriate conceptual framework into consideration. As mentioned previously, such a framework can be used to help: 1) organise one's thoughts, 2) identify common vocabulary and 3) ensure appropriate coverage for the performance measurement system. Moreover, the adoption of a performance framework can help to prioritise organisational activities such that they are aligned with the corporate objectives. In essence, performance frameworks provide organisations with the ability to ensure that efforts are focused on what matters the most.

The four most prominent reference models for performance frameworks are the: 1) Balanced Scorecard (BSC), 2) critical few method, 3) performance dashboard and 4) Total Quality Management (TQM) approaches.

4.2.1 THE BALANCED SCORECARD

In 1992, Robert Kaplan and David Norton introduced the BSC concept as a way of motivating and measuring an organisation's performance (Kaplan and Norton 1992). The developed concept takes a systematic approach to assessing internal results, while probing the external environment, and focuses on corporate strategy in four perspectives. These four perspectives can be explained by asking the following questions (Kaplan and Norton 1992, 1997, 2001):

1. Financial. How do we look to our stakeholders?
2. Customer. How well do we satisfy our internal- and external customers' needs?
3. Internal business processes. How well do we perform at key internal business processes?
4. Learning and growth. Are we able to sustain innovation, change and continuous improvement?

In essence, the BSC provides a way for management to look at the well-being of their organisation. Each of the aforementioned perspectives is directly tied to the organisational strategy. That is, strategically linked performance objectives and -measures flow from these perspectives. Refer to Figure 10. This figure is adapted from the work in Kaplan and Norton (1992, 1997, 2001).

Figure 10: Balanced Scorecard

In Figure 10, the sub-headings of “objectives”, “measures” and “targets” are self-explanatory. The “initiatives” heading, however, may cause confusion. Initiatives are programs designed to help the organisation achieve its targeted value(s). Examples of possible initiatives include programs such as: preventative maintenance, quality management, CSSs and employee training programs. Moreover, in Kaplan and Norton (1997), a distinction between lagging- and leading indicators is made. Lagging indicators and long-term strategic objectives are formulated for the strategic core issues of each perspective derived from the strategy of the business unit. These indicators thus indicate whether the strategic objectives in each perspective were achieved. Leading indicators, in contrast, are very organisation specific. They express the specific competitive advantages of the organisation and represent how the results (reflected by the lagging indicators) need to be achieved.

The BSC as an instrument for performance measurement has been further developed beyond its original conception. Numerous variation of the BSC exists. For example: since the BSC has high potential to integrate environmental- and social aspects into the general management system, the BSC has been combined with sustainable parameters to provide a meaningful instrument to the sustainability management field (Chai 2009). This variation of the BSC is referred to as the Sustainability Balanced Scorecard (SBSC). The SBSC is discussed in Section 4.3.2.

4.2.2 THE CRITICAL FEW METHOD

If an organisation has too many measures, a large amount of (unnecessary) routine data would be generated and management’s focus could be distracted from those measures that are the most critical to organisational success. The selection of a critical few set of performance measures highlights the need for a balance between internal- and external requirements as well as financial- and nonfinancial measures. According to Artley and Stroh (2001), best practice companies typically have a working number of measures of between three and 15 (depending on the complexities of the organisation) at each level of the organisation.

As with the BSC, the critical few framework develops strategically focused business perspectives and then identifies performance objectives and -measures for each of these perspective. While some organisations develop a working number of measures for each perspective, others develop performance indices to report performance levels for a particular perspective. These indices take data from many measurement sources and "roll them up" into a single, meaningful and reportable number. An example of the critical few framework can be seen in Figure 11 (Davies 2005).

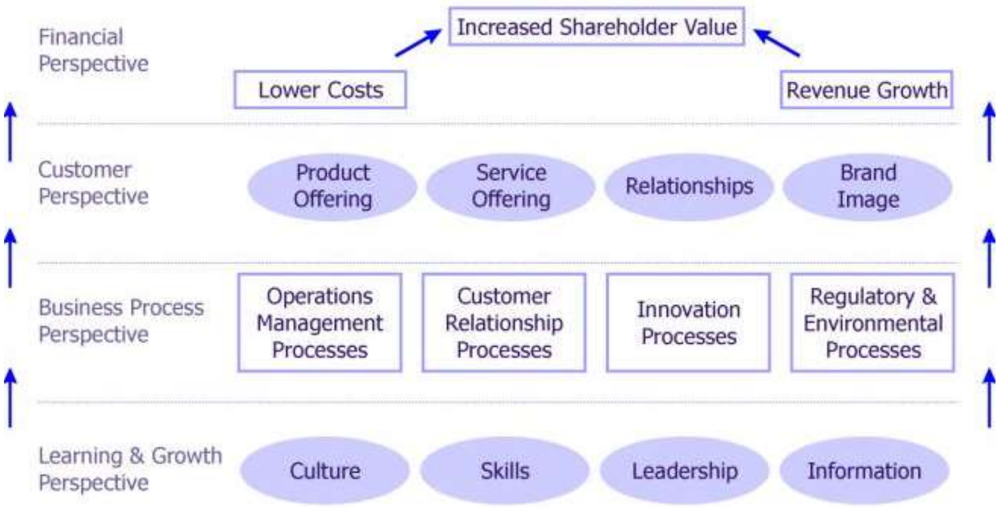


Figure 11: Example of a Critical Few with Performance Indices

As can be seen in Figure 11 (Davies 2005), each perspective is broken down into a few performance indices. All of the other relating performance measures are encapsulated within these performance indices. In essence, by utilising performance indices, the critical few method allows for a simplified and all-encompassing view of the overall organisational performance.

4.2.3 THE PERFORMANCE DASHBOARD

A performance dashboard is an executive information system that captures financial- and nonfinancial measures as indicators of successful strategy deployment. In France, companies have developed and used the Tableau de Bord for more than two decades (Artley and Stroh 2001). The Tableau de Bord is a dashboard of key indicators of organisational success that is designed to help employees "pilot" the organisation.

As with the critical few method, performance dashboards use index measures that “roll-up” performance in a weighted manner to a few selected gauges based on many measures or inputs. Moreover, a dashboard can deliver information to users (in layers) as they need it. This layered approach gives users self-service access to information and conforms to the natural sequence in which users want to handle that information. As stated in Eckerson (2006), this sequence is to: monitor, analyse and manage. The aforementioned is referred to as the three main applications of a performance dashboard. An discussion of these application, as given in Eckerson (2006), follows.

A performance dashboard:

1. <u>monitors</u> critical business processes and activities using metrics that trigger alerts when performance falls below pre-defined targets,
2. <u>analyses</u> the root cause(s) of problems by exploring relevant and timely information from multiple perspectives at various levels of detail, and
3. <u>manages</u> people and processes to improve decisions, optimise performance and steer the organisation in the right direction.

An example of a performance dashboard is shown in Figure 12 (Sonderman 2011).

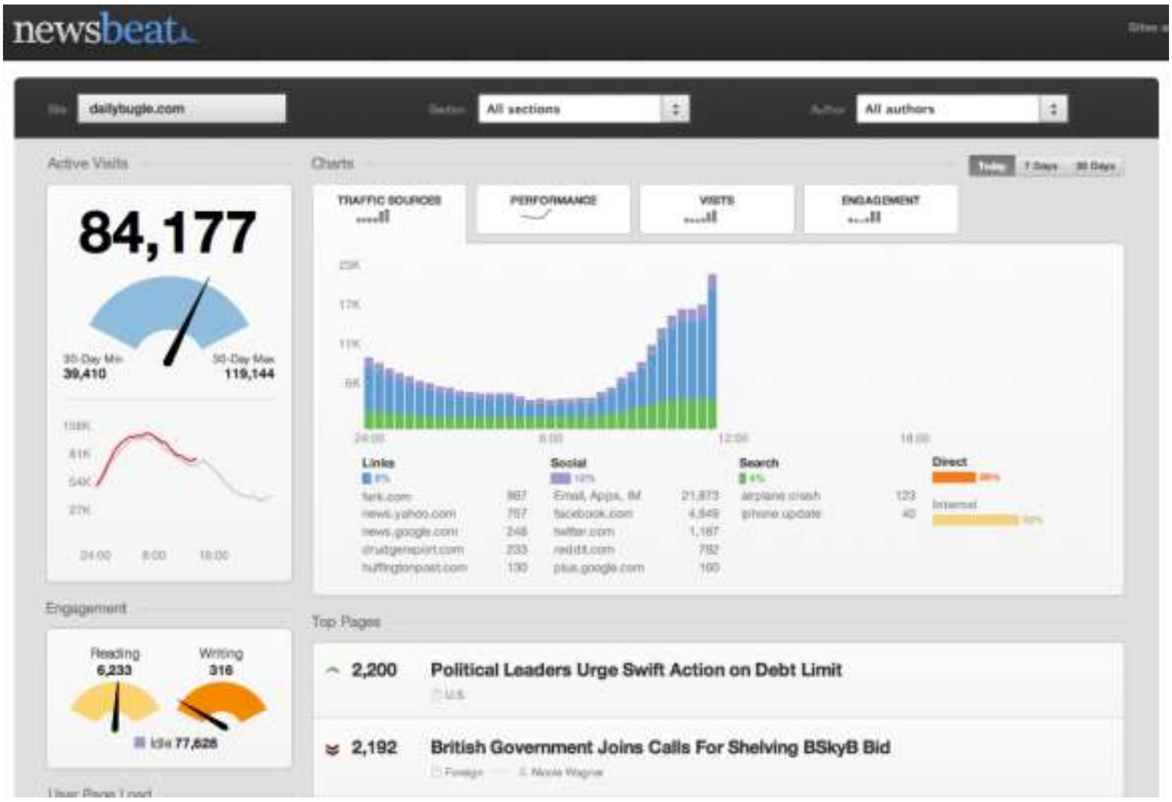


Figure 12: Example of a Performance Dashboard

This dashboard is specifically designed for an online news publisher (called Newsbeat) to aid them in understanding their web-traffic. With the aid of this dashboard, Newsbeat can view real-time charts about the number of visitors (and where they are coming from) for every article and/or page on their website. This dashboard thus provides handy analysis of data such as whether stories are trending up or down or whether they are getting significant social media referrals. Moreover, this dashboard can determine, algorithmically, when a particular story is seeing an unusual traffic spike. If such a scenario is identified, Newsbeat is alerted via email.

4.2.4 TOTAL QUALITY MANAGEMENT APPROACHES

Two TQM approaches have been identified for inclusion. These are the: 1) Malcolm Baldrige National Quality Award and 2) European Foundation for Quality Management (EFQM) excellence model.

THE MALCOLM BALDRIGE NATIONAL QUALITY AWARD

In 1988, the Malcolm Baldrige National Quality Award (MBNQA) was instituted to promote TQM (Artley and Stroh 2001). Since then, TQM has gone through many changes and is now generally referred to by other names such as: “continuous improvement” or “re-engineering”.

The Baldrige standards call for a balance among customer satisfaction, employee satisfaction and business results. The award is based on criteria created through a public-private partnership and is focused on three business factors. A discussion of these factors, as given in Artley and Stroh (2001), follows.

1. Approach. The processes used to run an organisation.
2. Deployment. The execution of an approach.
3. Results. The deployment and outcome of the approach.

Based on a 1000-point scale, the award criteria are divided into seven categories. These are: 1) leadership, 2) strategic planning, 3) customer focus, 4) measurement, analysis and knowledge management, 5) workforce focus, 6) operations focus and 7) business results. Refer to Figure 13 (US DoC NIST 2013).

Figure 13: MBNQA Model

In Figure 13 (US DoC NIST 2013), the horizontal arrow in the centre of the framework links the leadership triad to the results triad. This arrow not only illustrates the central relationship between leadership and results, but also emphasises the importance of this linkage to organisational success. The two bold one-headed arrows indicate that all actions point towards results. That is, the results triad is a composite of product- and process outcomes, customer-focused outcomes, workforce-focused outcomes, leadership- and governance outcomes as well as financial- and market outcomes. The two-headed arrows indicate the importance of feedback within an effective performance management system. The vertical arrow in the centre of the framework illustrates that measurement, analysis and knowledge management serve as the foundation for a performance management system.

The seven categories of the MBNQA model are further subdivided into both items and areas. There are 17 process- and results items. Each item focusses on a major requirement and consists of one or more areas. Organisations need to address their responses to the specific requirements of these areas. More information on these items and the point values used in the scoring system of the award criteria can be found in US DoC NIST (2013).

THE EUROPEAN FOUNDATION FOR QUALITY MANAGEMENT

The EFQM excellence model was created in 1991. It was developed as a framework against which applicants for the European Quality Award could be judged and to aid in the recognition of organisational excellence among European companies. Nowadays, as stated in Bou-Llusar *et al.* (2009), EFQM brings together more than 700 members located in many countries across the world.

The EFQM excellence model is made up of nine elements. These elements are grouped under five enabler criteria and four result criteria. The enabler criteria are: 1) leadership, 2) employees, 3) politics and strategy, 4) partnerships and resources and 5) processes. The result criteria are: 1) employee results, 2) customer results, 3) corporate results and 4) key performance (i.e. business) results. The enablers represent the way the organisation operates and the results concentrate on the achievements desired by the organisational stakeholders (Bou-Llusar *et al.* 2009). Refer to Figure 14. This figure is adapted from EFQM (2003).

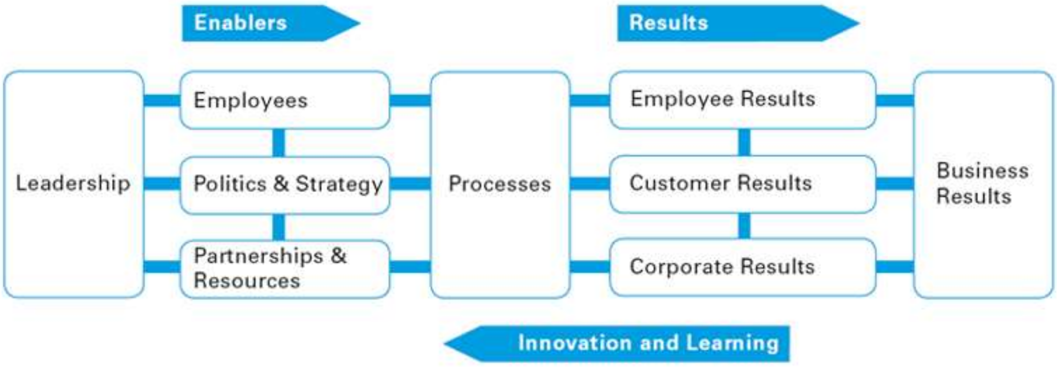


Figure 14: The EFQM Excellence Model

As with the MBNQA model, each criterion is broken down into several sub-criteria and each sub-criterion is illustrated with various ‘‘guidance points’’ exemplifying what the organisation has to do to develop the criteria. The RADAR scoring matrix, also based on a 1000-point scale, is used to evaluate the organisational performance. The RADAR logic consists of the following elements: **R**esults, **A**pproach, **D**eployment, **A**ssessment and **R**eview. The reader can refer to EFQM (2003) for more information regarding the RADAR scoring matrix.

4.3 THE PERFORMANCE FRAMEWORKS IDENTIFIED FOR INCLUSION

4.3.1 MOTIVATION FOR THE EXERTED CHOICE

The comprehensiveness of transport performance measurement demands that the performance framework be representative of all interested parties, while being understandable for implementing agencies and decision makers in a participative context. Therefore, due to the popularity and simplicity of the BSC, it has been decided to utilise a balanced approach to performance measurement. Moreover, since transport has immense economic-, social- and environmental effects, these three pillars of sustainability need to be integrated within the core management of the ITS projects. Following from the aforementioned, it has thus been decided to implement the SBSC variation of the traditional BSC. It is believed that the SBSC can help facilitate effective transport performance management, among the implementing agencies and decision makers, by changing their preferences towards more consensus-orientated measures for performance appraisal. However, in order to promote the wider use and application of a performance driven approach, it has been decided to represent the proposed scorecard as a performance (GUI) dashboard. This dashboard is to act as the management tool for assessing the effective development and maintenance of ITS applications as well as for evaluating the feasibility of continuous investments in transport technology.

4.3.2 THE SUSTAINABILITY BALANCED SCORECARD

OVERVIEW

The SBSC augments the traditional BSC by integrating the management of the environmental- and social aspects into the mainstream business activities. This is accomplished by explicitly taking the relation among all three performance dimensions of sustainability into account (Figge *et al.* 2002). These dimensions are the environmental-, social- and economic performance of the organisation. In essence, the SBSC helps to implement soft factors (which cannot be monetarised) within the core management of businesses.

According to Figge *et al.* (2002), there are three possibilities for integrating the three pillars of sustainability into general business management. Firstly, the environmental- and social aspects can be incorporated within the existing four standard perspectives of the BSC. Secondly, an additional perspective that specifically considers environmental- and social aspects can be added. (Kaplan and Norton (1997) also pointed out that the firm-specific formulation of a BSC may involve a renaming or adding of perspectives.) Thirdly, a specific environmental- and/or social scorecard can be formulated. Based on the application required herein, the second approach is considered in more detail.

EXPANDING THE BSC TO THE SBSC

Figge *et al.* (2002) propose that an additional non-market perspective be introduced. However, this additional perspective can only be justified if the successful execution of the strategy of the company is still considered. That is, the environmental- and social aspects from outside the market system need to explicitly represent the strategic core aspects.

As stated in Figge *et al.* (2002), strategically relevant environmental- or social aspects from outside the market system can impact an organisation’s performance in all four perspectives of the traditional BSC. That is, they can be relevant both directly (i.e. with regard to the financial perspective) and indirectly (i.e. with regard to the other perspectives). Therefore, an additional non-market perspective can also affect all four conventional perspectives.

The SBSC is formulated analogously to the traditional BSC. With the SBSC, the strategic core aspects and the leading indicators of the non-market perspective also need to be identified and reproduced through respective measures. According to Figge *et al.* (2002), these measures are then linked to the financial perspective by means of hierarchical cause-and-effect chains. Therefore, strategy-linked management is guaranteed for the strategically relevant non-market aspects too.

IMPLEMENTING THE SBSC

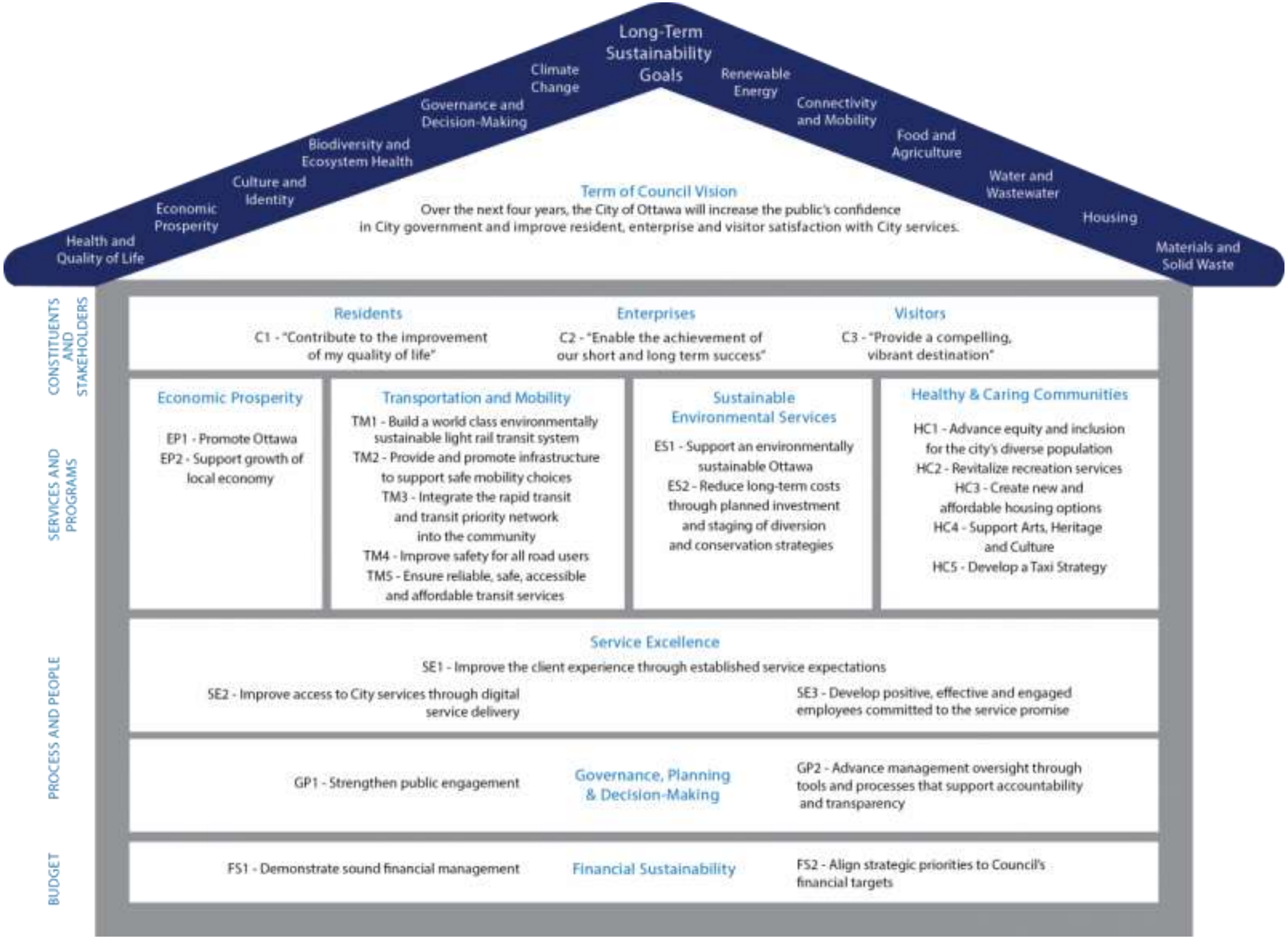
In order to implement the SBSC, Figge *et al.* (2002) recommend that three steps be executed. Firstly, the strategic business unit has to be chosen. This step assumes that a strategy of the business unit exists. Secondly, the environmental- and social aspects of concern have to be identified. Thirdly, the relevance of these aspects for the specific business unit's strategy has to be determined.

EXAMPLE

Figure 15 (CoO 2011) represents the strategy map developed for the City of Ottawa's strategic plan.

The top of the strategy map (i.e. the roof) depicts the City's 12 long-term sustainability goals. Immediately below the roof is the Term of Council vision: "Over the next four years, the City of Ottawa will increase the public's confidence in City government and improve resident, enterprise and visitor satisfaction with City services." Underneath the Term of Council vision are three stakeholder groups (i.e. residents, enterprises and visitors) who are the main focus of the City's strategic plan. Along the left wall are the perspectives of the SBSC. These perspectives are intended to be read from the bottom up; thereby illustrating how each perspective builds its success on the one below. The eight Term of Council priorities appear in the five lowest levels of the house. Each priority is associated with a series of strategic objectives (e.g. EP1, SE1, GP1, etc.).

For more detail, refer to CoO (2011).



Term of Council Vision

Over the next four years, the City of Ottawa will increase the public's confidence in City government and improve resident, enterprise and visitor satisfaction with City services.

Residents

C1 - "Contribute to the improvement of my quality of life"

Enterprises

C2 - "Enable the achievement of our short and long term success"

Visitors

C3 - "Provide a compelling, vibrant destination"

Economic Prosperity

EP1 - Promote Ottawa
EP2 - Support growth of local economy

Transportation and Mobility

TM1 - Build a world class environmentally sustainable light rail transit system
TM2 - Provide and promote infrastructure to support safe mobility choices
TM3 - Integrate the rapid transit and transit priority network into the community
TM4 - Improve safety for all road users
TM5 - Ensure reliable, safe, accessible and affordable transit services

Sustainable Environmental Services

ES1 - Support an environmentally sustainable Ottawa
ES2 - Reduce long-term costs through planned investment and staging of diversion and conservation strategies

Healthy & Caring Communities

HC1 - Advance equity and inclusion for the city's diverse population
HC2 - Revitalize recreation services
HC3 - Create new and affordable housing options
HC4 - Support Arts, Heritage and Culture
HC5 - Develop a Taxi Strategy

Service Excellence

SE1 - Improve the client experience through established service expectations

SE2 - Improve access to City services through digital service delivery

SE3 - Develop positive, effective and engaged employees committed to the service promise

Governance, Planning & Decision-Making

GP1 - Strengthen public engagement

GP2 - Advance management oversight through tools and processes that support accountability and transparency

Financial Sustainability

FS1 - Demonstrate sound financial management

FS2 - Align strategic priorities to Council's financial targets

Figure 15: SBSC Example

4.3.3 THE SCORECARD AS THE PERFORMANCE DASHBOARD

EXAMPLE

As an example, refer to Figure 16 (Artley and Stroh 2001). This figure shows how the BSC might be presented as a performance dashboard.

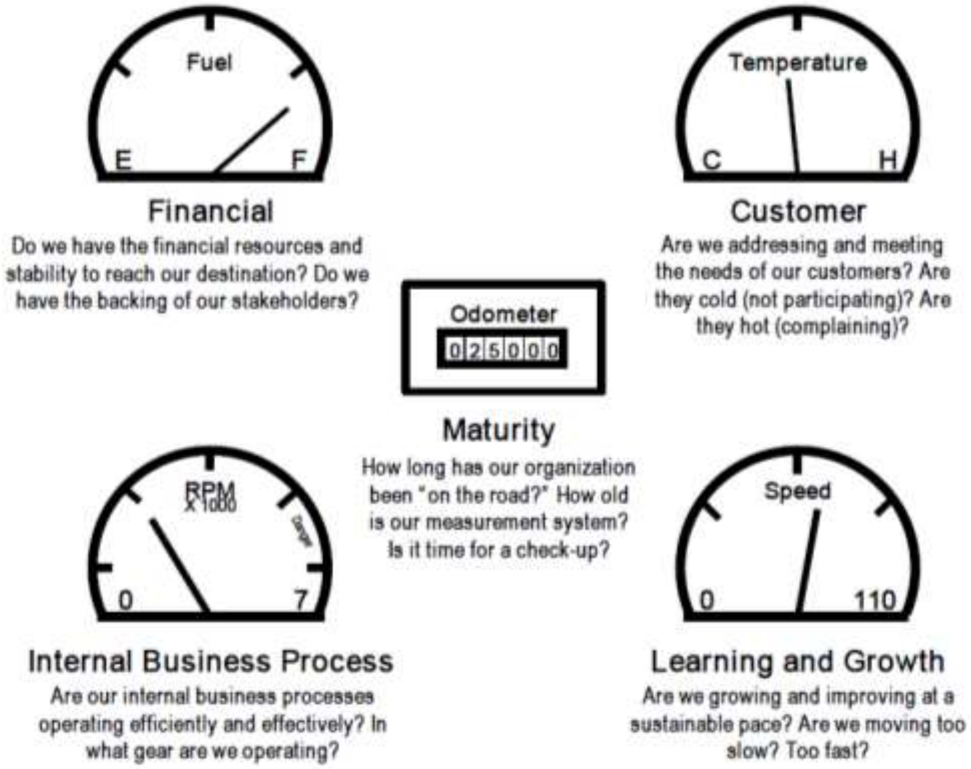


Figure 16: The Balanced Scorecard As A Performance Dashboard

Each of the gauges depicted in Figure 16 (Artley and Stroh 2001) could, for example, represent a "roll-up of measures" to give an overall indicator of performance. For example: the temperature gauge could represent customer satisfaction. This gauge could be an index made up of several components such as complaints, repeat customers, new customers and reputation.

BENEFITS

A discussion of some of the benefits of a performance dashboard, as given in Eckerson (2006), follows.

- Communicate strategy.
    - Performance dashboards translate corporate strategy into measures, targets and initiatives that are customised to each group in an organisation (and sometimes to every individual).

- Increase motivation.
    - The use of performance dashboards aids in motivating employees to excel in the areas being measured.
- Increase visibility.
    - Performance dashboards give managers greater visibility into daily operations and future performance by collecting relevant data in a timely fashion and forecasting trends based on past activity.
- Reduce costs and redundancy.
    - By standardising information, performance dashboards eliminate the need for redundant silos of information.
- Increase coordination.
    - Performance dashboards not only encourage members of different departments to start working more closely together, but they also foster a healthy dialogue between managers and staff.
- Empower users.
    - Through layered delivery of information, structured navigation paths and guided analysis, performance dashboards make it easier for (average) business people to access, analyse and act on information.

In essence, performance dashboards can be used to deliver the right information to the right users at the right time to optimise decisions, enhance efficiency and accelerate bottom-line results.

CONTEXT

Performance dashboards play an important role in the discipline called Business Performance Management (BPM). BPM provides a framework that takes the long-standing task of measuring performance to the next level. That is, managing performance. As stated in Eckerson (2006), BPM provides the business context in which performance dashboards operate. Refer to Figure 17. This figure is adapted from Eckerson (2006).

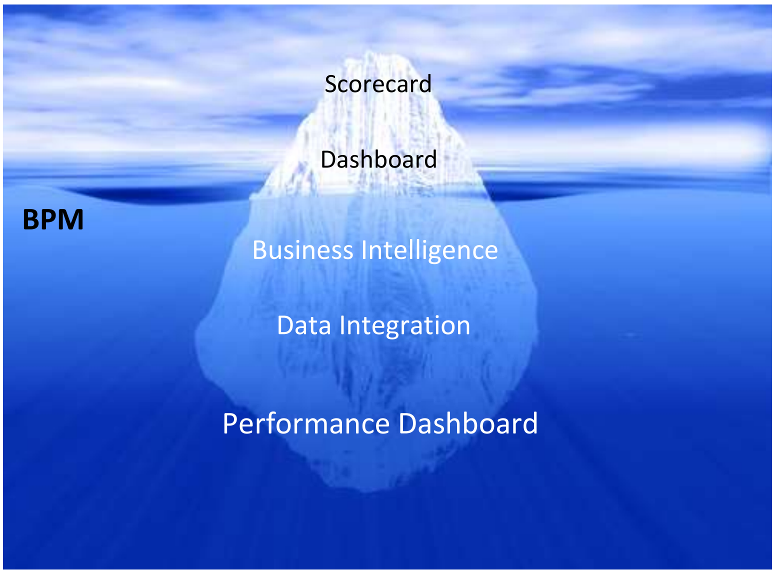


Figure 17: Context for Performance Dashboards

COMPOSITION

APPLICATIONS

As mentioned previously, a performance dashboard has three applications (i.e. monitor, analyse and manage). These applications are woven together in a seamless fashion. Each application provides a specific set of functionality that is delivered through a variety of means. Refer to Table 7 (Eckerson 2006).

Table 7: Performance Dashboard Applications

	MONITORING	**ANALYSIS**	**MANAGEMENT**
Purpose	Convey information at a glance	Let users analyse exception conditions	Improve alignment, coordination and collaboration
Components	Dashboard Scorecard BI portal Right-time data Alerts Agents	Multi-dimensional analysis Time-series analysis Reporting Scenario modelling Statistical modelling	Meetings Strategy maps Annotation Workflow Usage monitoring Auditing

LAYERS

Besides having three applications, a performance dashboard also consists of four views or layers of information. This layered approach starts at high-level views of information and works down into a more detailed view. With the aid of this approach, the users can get to the root cause of issues quickly and intuitively. Refer to Figure 18. This figure is adapted from Eckerson (2006).

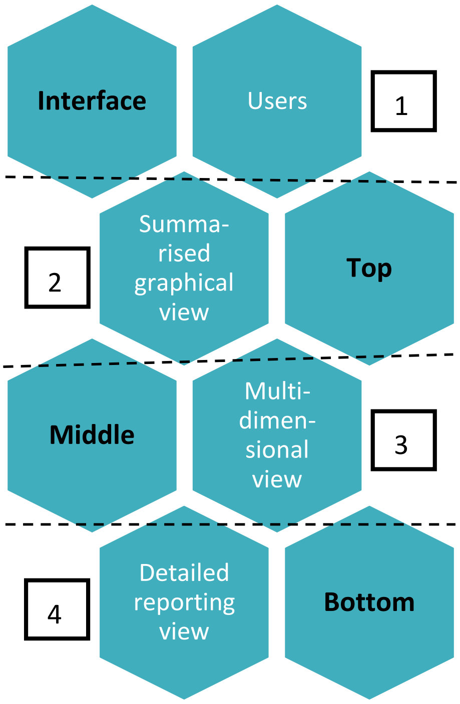


Figure 18: Performance Dashboard Layers

A description of the four layers given in Figure 18 follows (Eckerson 2006).

1. The interface layer connects the user with the (GUI) dashboard.
2. The second layer provides a summarised view, usually graphical, of the status of the key performance indicators and exception conditions. When performance exceeds the thresholds that are applied to each metric, the dashboard interface alerts users of these exception conditions.
3. The third layer provides the data behind the (graphical) metrics and alerts. Using the multi-dimensional analysis tools, users can navigate the data by dimensions (e.g. customer, geography and time) and hierarchies (e.g. country, region and city).
4. The last layer allows users to view detailed reports and transaction records (e.g. invoices, shipments and trades).

TYPES

According to Eckerson (2006), there are three main types of performance dashboards. Each type of performance dashboard emphasises the four layers and the three applications (as described previously) to different degrees. A description of these types, as given in Eckerson (2006), follows.

1. Operational dashboards monitor core operational processes and are used primarily by the people who deal directly with the customers or manage the creation or delivery of the organisation's products and services. This type of dashboard mainly delivers detailed information that is only lightly summarised. In essence, operational dashboards thus emphasise monitoring more than analysis and management.
2. Tactical dashboards track departmental processes and -projects that are of interest to a segment of the organisation or a limited group of people. Managers can use this type of dashboard to compare the performance of their areas or projects, to budget plans, forecasts or to the previous period's results. Tactical dashboards are usually updated daily or weekly and contain both detailed- and summary information. They tend to emphasise analysis more than monitoring and management.
3. Strategic dashboards monitor the execution of strategic objectives and are frequently implemented using a BSC approach. The goal of this type of dashboard is to align the organisation around its strategic objectives and to get every group "marching" in the same direction. Strategic dashboards encapsulate various scorecards. These scorecards are customised to every group in the organisation and are usually updated weekly or monthly. They give executives a powerful tool to communicate strategy, gain visibility into operations and to identify the key drivers of performance and business value. Strategic dashboards thus, essentially, emphasise management more than monitoring and analysis.

4.4 INTRODUCTION TO MULTI-CRITERIA DECISION MAKING MODELS

4.4.1 OVERVIEW

Simpson (1994) states that MCDM is, in a non-theoretical sense, commonly practised. That is, people often make decisions involving a number of conflicting objectives; both in a personal- and a work environment. However, humans can only consider a limited amount of information at once. Therefore, as decisions become more complex, the need for more formal approaches grows. MCDM models have been developed to assist humans in undertaking a structured approach towards assessing such complex decisions.

The MCDM is a field of operational research that is founded on numerous (quantitative) decision-making models. These models can be used to evaluate multiple- and usually conflicting criteria when making a decision among alternatives. According to Olyazadeh *et al*. (2014), there are three phases to the MCDM decision-making process. These are the: 1) intelligence phase, 2) design phase and 3) final phase. A brief overview of these phases, as given in Olyazadeh *et al*. (2014), follows.

In the intelligence phase, the decision maker recognises the decision problem(s) and then identifies the corresponding objectives. In the design phase, the decision maker establishes the protruding criteria and the viable alternatives. In the final phase, the optimal choice among the alternatives is evaluated. This entails the definition of the indicators, the assignment of importance weights to each indicator and then the comparison of the alternatives.

4.4.2 BACKGROUND

MCDM models comprise two general research streams. These are the: 1) American School and 2) European School. The American School requires that all alternatives be comparable and rank-ordered and forces decision makers to reach an explicitly hierarchical structure among the alternatives. In contrast, the European School accepts that alternatives may not always be comparable and that decision makers may not always want to explicitly rank priorities or even determine a best decision (Bentes *et al.* 2012). Well-known decision-making models of the American School include, among others, Analytic Hierarchy Process (AHP) and MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique). Prominent European School models include, among others, ELECTRE (Elimination et Choix Traduisant la Réalité) and PROMETHEE (Preference Ranking Organisation Method for Enrichment Evaluations).

4.4.3 POPULAR MODELS

Although there is much agreement on the role of decision analysis, there is disagreement on how to reach these aims (Simpson 1994). A number of models have been researched, refined and developed over the last couple of decades; with even small variations to existing models resulting in new branches of research. In Velasquez and Hester (2013), a literature review on popular MCDM models was conducted. The observed advantages, disadvantages and the areas of application of each model are summarised in Table 8 (Velasquez and Hester 2013).

Table 8: Popular MCDM Models

MODEL	ADVANTAGES	DISADVANTAGES	AREAS OF APPLICATION
Multi-Attribute Utility Theory (MAUT)	Takes uncertainty into account; can incorporate preferences.	Needs a lot of input; preferences need to be precise.	Economics, finance, actuarial, water management, energy management and agriculture.
AHP	Easy to use; scalable; hierarchy structure can easily adjust to fit many sized problems; not data intensive.	Problems due to interdependence between criteria and alternatives; can lead to inconsistencies between judgment and ranking criteria; rank reversal.	Performance-type problems, resource management, corporate policy and strategy, public policy, political strategy and planning.
Case-Based Reasoning (CBR)	Not data intensive; requires little maintenance; can improve over time; can adapt to changes in environment.	Sensitive to inconsistent data; requires many cases.	Business, vehicle insurance, medicine and engineering design.
Data Envelopment Analysis (DEA)	Capable of handling multiple inputs and outputs; efficiency can be analysed and quantified.	Does not deal with imprecise data; assumes that all input and output are exactly known.	Economics, medicine, utilities, road safety, agriculture, retail and business problems.
Fuzzy Set Theory	Allows for imprecise input; takes into account insufficient information.	Difficult to develop; can require numerous simulations before use.	Engineering, economics, environmental, social, medical and management.
Simple Multi-Attribute Rating Technique (SMART)	Simple; allows for any type of weight assignment technique; less effort by decision makers.	Procedure may not be convenient considering the framework.	Environmental, construction, transport and logistics, military, manufacturing and assembly problems.
Goal Programming (GP)	Capable of handling large-scale problems; can produce infinite alternatives.	It is difficult to weigh coefficients; typically needs to be used in combination with other MCDM models to weigh coefficients.	Production planning, scheduling, health care, portfolio selection, distribution systems, energy planning, water reservoir management, scheduling and wildlife management.
ELECTRE	Takes uncertainty and vagueness into account.	Its process and outcome can be difficult to explain in layman's terms; outranking causes the strengths and weaknesses of the alternatives to not be directly identified.	Energy, economics, environmental, water management and transport problems.

MODEL	ADVANTAGES	DISADVANTAGES	AREAS OF APPLICATION
PROMETHEE	Easy to use; does not require assumption that criteria are proportionate.	Does not provide a clear method by which to assign weights.	Environmental, water management, business and finance, chemistry, transport and logistics, manufacturing and assembly, energy and agriculture.
Simple Additive Weighting (SAW)	Ability to compensate among criteria; intuitive to decision makers; calculation is simple - does not require complex computer programs.	Estimates revealed do not always reflect the real situation; result obtained may not be logical.	Water management, business and financial management.
Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS)	Has a simple process; easy to use and program; the number of steps remains the same regardless of the number of attributes.	Its use of Euclidean distance does not consider the correlation of attributes; difficult to weigh and keep consistency of judgment.	Supply chain management and logistics, engineering, manufacturing systems, business and marketing, environmental, human resources and water management.

Most of the models mentioned in Table 8 (Velasquez and Hester 2013) have seen a common pattern of improvement and evolution. Examples include the transition from Multi-Attribute Value Theory (MAVT) to MAUT and, to an extent, AHP to Analytic Network Process (ANP). Outranking methods, like ELECTRE and PROMETHEE, which were prevalent early on in the development of the MCDM field, have been overtaken by the use of value measurement approaches such as AHP, ANP and MAUT. These decision-making models, however, share common characteristics such as: the presence of multiple, non-commensurable and conflicting criteria; different units of measurement among the criteria; and the presence of quite different alternative policies (Apperl *et al*. 2015). Therefore, based on the aforementioned and due to advancing technologies, it has become commonplace for the models to be used together. That is, combining different MCDM models into one model. These new hybrid models are capable of addressing the deficiencies inherent to certain (singular) models.

4.4.4 APPLICATIONS

The field of MCDM has many applications. Examples of applications follow.

In Bentes *et al*. (2012), the organisational performance of a telecommunications company was evaluated by integrating two methodologies. That is, the BSC method and the AHP method. This integrated model has proven to be quite efficient in providing a fine-grained view of performance and overall assessment. Rabbani *et al*. (2014) also developed an integrated model for assessing organisational performance. However, their model integrated the SBSC method with the ANP method and was used to evaluate the performance of oil producing companies. This integrated model has proven to be especially effective in assisting companies in maintaining their competitiveness.

Hassan *et al*. (2013) adopted a multi-level framework to assess the performance of the public transit service. The proposed framework uses the TOPSIS model. According to Hassan *et al*. (2013), the proposed model can be quite efficient in depicting deficiency areas in the transit system and can help decision makers to identify the necessary mitigation actions.

Nakanishi and Falcocchio (2004) evaluated the public sector's investments in ITS technologies by using the DEA method. The feasibility of the DEA model was tested on an incident management example in which the different TMCs acted as the Decision-Making Units (DMUs). The proposed model has proven to be an effective tool for measuring the efficiency and productivity of public agencies and other DMUs investing in ITS projects.

4.5 THE MCDM MODEL IDENTIFIED FOR INCLUSION

4.5.1 MOTIVATION FOR THE EXERTED CHOICE

Based on the aforementioned introduction to the field of MCDM, it is evident that the decision-making models are often technically oriented, intricate and difficult to understand for laymen. Moreover, decision-making within the context of the transport performance environment is a complex matter. This complexity arises from the existence of, among others, many portraying consideration aspects, varied interests among implementing agencies and decision makers, multiple objectives, different policies and numerous implementation strategies.

These complexities demand a decision support tool that can be used to establish the optimal course of action by assessing the trade-offs among the economic-, social- and ecological objectives. More specifically, a tool that can: 1) assist the implementing agencies in obtaining the necessary knowledge to easily make day-to-day informed decisions regarding the (overall) performance of their respective systems and 2) aid decision makers in the continuous assessment of their investment in transport technology. As a result, the challenge exists in finding a decision-making model that can meet these demands, while adequately representing the complexities of the transport performance environment.

In MAVT, the decision problem is formulated with multiple criteria (i.e. consideration aspects) and these criteria are used to evaluate the decision options (i.e. implementation strategies). This is accomplished by using a value measurement model, in which numerical scores are constructed, to represent the degree to which one decision option may be preferred over another (Apperl *et al*. 2015). According to Belton and Stewart (2002), MAVT is one of the oldest (i.e. originated in the late 1960's) and most widely applied MCDM models. Moreover, in Karjalainen *et al*. (2013) it is stated that MAVT has proven to provide a systematic and transparent framework to analyse (complex) decisions with multiple criteria, many decision options and numerous interested parties. Lastly, Gal *et al*. (1999) state that, since MAVT rests on simpler elicitation procedures, it is more widely accepted by the general practitioners.

Therefore, it has been decided to use MAVT to model and assess the performance of ITS applications. This author believes that this decision-making model can facilitate the adequate derivation of the overall values for the respective decision options by including the preferences of all the interested parties and the many portraying consideration aspects in a comprehensible manner.

4.5.2 MULTI-ATTRIBUTE VALUE THEORY

VALUE VERSUS UTILITY

While MAVT is based on value theory that makes use of value functions, MAUT is based on utility theory that makes use of utility (probability) functions. MAVT is thus a simplification of MAUT in that, unlike MAUT, MAVT does not seek to model the decision maker's attitude to risk. That is, in MAVT, there is no uncertainty.

MODEL FORMULATION

The general procedure to be followed when executing MAVT can be denoted by twelve steps. These steps are:

1. identify the decision maker(s),
2. define the problem and formulate the objective(s),
3. identify the alternative courses of action,
4. identify the relevant attributes (also referred to as criteria),
5. determine the attribute ranges,
6. assign values to each attribute and standardise these values,
7. define scaling factors to estimate the attribute weights,

8. normalise the initial attribute weights,
9. choose an aggregation rule,
10. synthesise the elicited information to give an overall value per alternative course of action,
11. conduct sensitivity analysis to evaluate the accuracy and robustness of the model, and
12. evaluate alternatives and make decisions.

The main procedures pertaining to the aforementioned steps are discussed in the next sub-sections.

PROBLEM STRUCTURING

VALUE TREE BUILDING

In value tree building, the attributes are organised as a value tree (also referred to as an objectives hierarchy or a decision hierarchy) where the groups of attributes represent the objectives. Figure 19 (Pöyhönen 1998) shows an example of a value tree that was used in Pöyhönen (1998) to evaluate traffic plans in Helsinki metropolitan area.

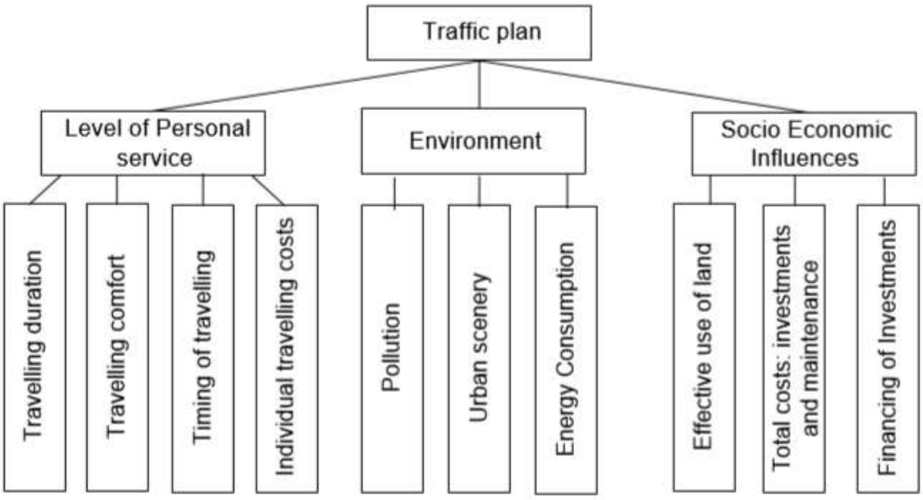


Figure 19: Value Tree Example

In order to build a value tree, Gal *et al.* (1999) recommend that one starts off with an idea generation phase. This stage of the analysis involves a brainstorming session among the elected decision makers. Brainstorming helps to define the problem and to formulate the objective(s). The next stage of the analysis is to build a value tree. A value tree helps to identify the attributes (criteria) to be considered. The tree needs to capture the issues that have emerged from the idea generation process. Moreover, the tree needs to reflect the decision makers' values (or objectives); rather than simply being a means of discriminating between decision options.

In Gal *et al.* (1999), the desirable characteristics of a value tree are identified. A discussion of these characteristics follows.

- Complete - all of the important aspects of the problem are captured.
- Operational - it can be used with reasonable effort.
- Decomposable - allowing different parts of the tree to be analysed separately.
- Non-redundant - to avoid double counting of impacts.
- Minimal or concise - keeping the level of detail to the minimum required.
- Measureable - possible to specify (in a precise way) the degree to which objectives are achieved through the association of appropriate attributes.
- Understandable - to facilitate generation and communication of insights.

It should however be noted that, in practice, it is unlikely that the initial value tree will "survive" the whole analysis. As the analysis proceeds, it may, for example, emerge that certain attributes do not satisfy the preferential independence requirement. If the latter mentioned is the case, restructuring will be required. Furthermore, certain aspects may, for example, have been elaborated in too much detail; others in not enough detail. As stated in Gal *et al.* (1999), value tree building is an iterative process.

VALUE ELICITATION

OVERVIEW

The purpose of the value elicitation is to model and describe the importance and desirability of achieving different performance levels for the given attributes. In practice, a single attribute value function has to be determined for all attributes. However, in some cases it suffices to determine the values for the attribute levels associated with the alternatives only (i.e. value scores).

HUT SAL (2005) states that when assessing a value function two main phases can be identified. These are: 1) choosing the range and 2) deciding on the value measurement technique.

CHOOSING THE RANGE

The end points of the range have to be fixed prior to value measurement. In HUT SAL (2005), possible options for the value ranges of an attribute have been identified. A discussion follows.

- The actual range is determined by the alternatives with the largest- and the smallest numbers.

- The acceptable range is determined by the objects that the decision maker is willing to consider.
- In the available range, all available options, not necessarily included in the decision alternatives, need to be within the end points.
- The theoretical range includes all of the feasible numbers.

For example: all of the possible ranges for the attribute "number of working hours per day" are depicted in Figure 20 (HUT SAL 2005).

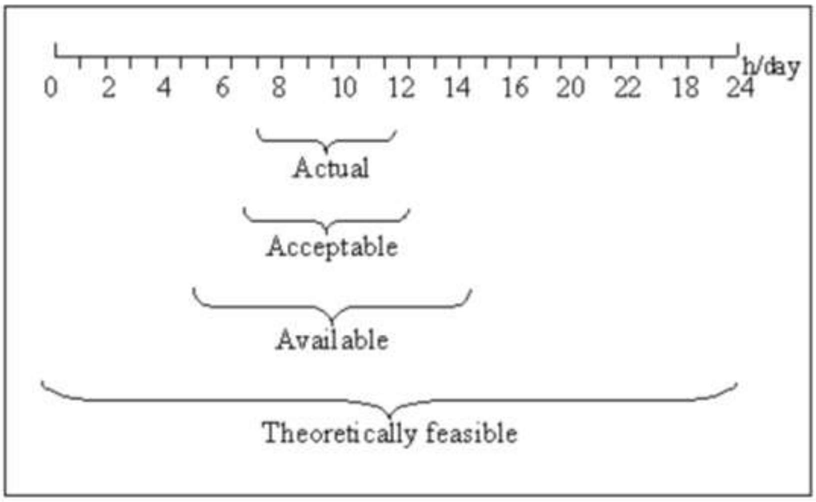


Figure 20: Possible Ranges of the working hours attribute

An advantage of a larger range is that it can accommodate new decision alternatives more easily if these lie outside the original set. However, the extremes of such a large range may require additional judgements. Such judgements may be neither relevant nor helpful for the current decision problem. Moreover, with a large range, the objects are more likely to lie close to one another in the middle of the range. This may make the discrimination among them difficult.

VALUE MEASUREMENT TECHNIQUES

Once the end points of each attribute have been established, there are a number of different methods that can be used for value elicitation. Table 9 (HUT SAL 2005) lists the main value measurement techniques and divides them into two main classes. These are: 1) numerical estimation methods and 2) indifference methods.

Table 9: Value Measurement Techniques

NUMERICAL ESTIMATION	INDIFFERENCE METHODS
Direct rating Category estimation Ratio estimation Assessing the form of the value function	Difference standard sequence Bisection

In numerical estimation methods, the decision maker is presented with an anchored scale and asked to numerically estimate the attractiveness of the given level of an attribute relative to the anchors. Indifference methods are based on the assessment of the strength of the value difference. The decision maker compares pairs of real- or hypothetical evaluation objects to each other and revises them until the strength of preference for value differences is equal for both pairs.

In the next sub-sections, an overview of the methods listed in Table 9 (HUT SAL 2005) is given.

DIRECT RATING

The direct rating method is commonly used with attributes that cannot be represented by easily quantifiable variables. An example of such an applicable attribute is "office image" (Goodwin and Wright 2004). With direct rating, the worst- and the best consequences with respect to a certain attribute are associated with values of 0 and 100, respectively. Values of the intermediate attribute levels are then determined only to the alternatives under consideration. According to Goodwin and Wright (2004), this method usually results in an interval value scale. Such a scale entails that only the intervals between the points in the scale are compared. The relative spacing between the alternatives thus reflects the strength of the preferences for one alternative to another.

CATEGORY ESTIMATION

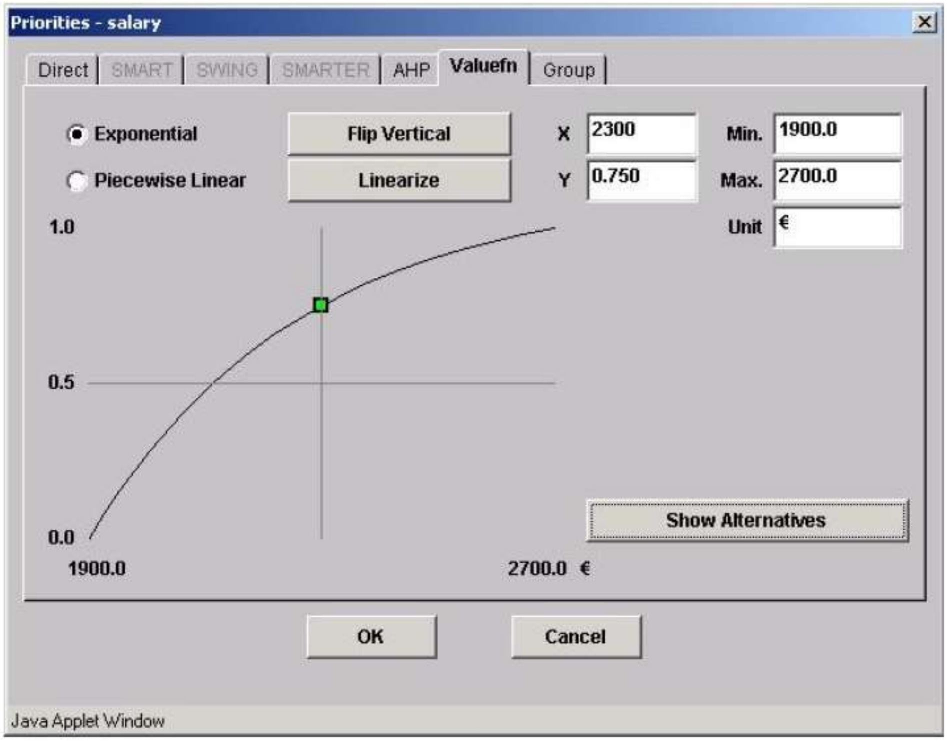
Category estimation is a variation of the direct rating technique in which the possible responses of the decision maker are reduced to a finite number of categories. The end points of the categories are mostly defined qualitatively. This enables variation in the end points across subjects. For each category, the decision maker then assigns a single value from 0 to 100. As stated in HUT SAL (2005), the advantage of categorisation is that relatively few preference estimates are needed. The downside of the method is, however, that some fine distinctions may get lost.

RATIO ESTIMATION

In ratio estimation, one of the alternatives is presented as a standard and the decision maker is asked to compare all of the other alternatives with this standard. That is, the decision maker is asked to state (in a ratio sense) how much more or less valuable an alternative is than the standard. If no standard alternative exists or if such an alternative cannot be created, ratios of value differences can be compared. HUT SAL (2005) state that the ratio estimation method is, in most cases, more demanding than the category estimation- or direct rating method.

ASSESSING THE FORM OF THE VALUE FUNCTION

If an attribute has a numerical scale, one option for the value measurement is the direct assessment of the form of the corresponding (single) attribute value function. In Figure 21 (HUT SAL 2005), the assessment of an attribute value function for the "money" objective is illustrated with the aid of the Web-HIPRE software.



● Exponential
○ Piecewise Linear

X 2300
Y 0.750
Min. 1900.0
Max. 2700.0
Unit €

Figure 21: Assessing a Single Attribute Value Function

As stated in HUT SAL (2005), the direct assessment of the form of a value function is likely to be difficult and, in most cases, also require expertise or prior knowledge on the subject.

DIFFERENCE STANDARD SEQUENCE

In a difference standard sequence method, the decision maker defines attribute levels x_0, x_1, ..., x_n in such a way that the increments in the strength of preference from x_i to x_{i+1} are equal for all i = 0, ..., n-1. The resulting sequence of attribute levels, equally spaced in value, is called a standard sequence.

Since all of the value steps in the standard sequence are equal, Equation 9 (HUT SAL 2005) can be deducted.

Equation 9: Positive Constant Value Step

$$\boldsymbol{v(x_i + 1) - v(x_i) = k}$$

$$\forall i = 1, \dots, n - 1$$

The (positive) constant k can be chosen freely by taking a corresponding positive affine transformation form v; which is by definition strategically equivalent to the original v. Let $k = \frac{1}{n}$ and $v(x_0) = 0$. Refer to Equation 10 (HUT SAL 2005).

Equation 10: Positive Affine Transformation Form

$$v(x_i) = \frac{1}{n}$$

For all i = 0, …, n

In Figure 22 (HUT SAL 2005), the different standard sequence method is illustrated with an arbitrary value measurement problem.

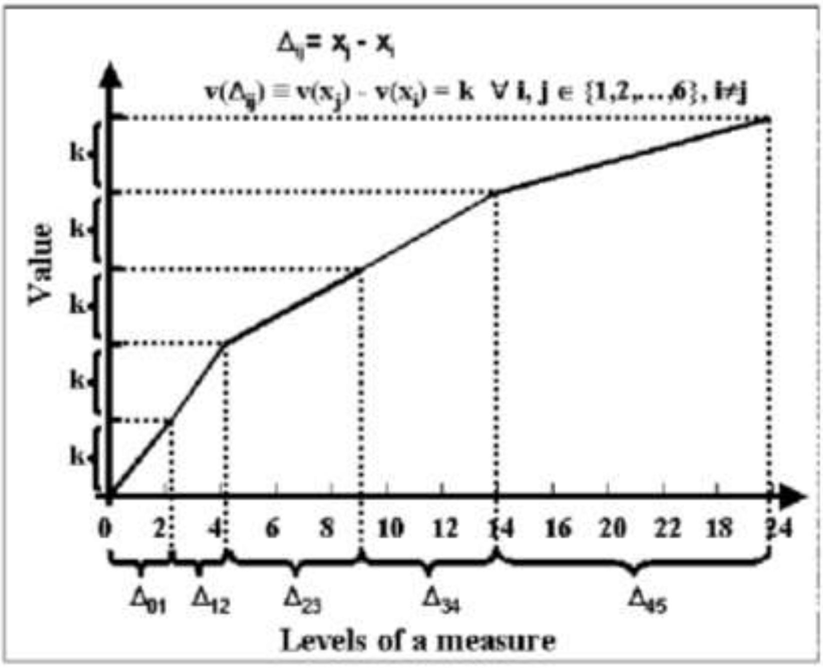


Figure 22: Difference Standard Sequence

BISECTION

In the Bisection method, the decision maker is presented with two objects and asked to define the attribute level that is halfway between the objects in respect to the relative strengths of the preferences.

First, the two extreme points (i.e. the least preferred evaluation object x_{min} and the most preferred evaluation object x_{max}) are identified and associated with the values in Equation 11 (HUT SAL 2005).

Equation 11: Two Extreme Points

$$v_{min} = 0$$

$$v_{max} = 1$$

Then, the decision maker is asked to define a midpoint m_1 for which $(x_{min}, m_1) \sim (m_1, x_{max})$; where (x_i, x_j) indicates the value difference between x_i and x_j, and ~ indicates the decision maker's indifference between the changes in the value levels. While m_1 is in the middle of the value scale, Equation 12 (HUT SAL 2005) holds.

Equation 12: First Midpoint

$$v(m_1) = \frac{1}{2}v(x_{min}) + \frac{1}{2}v(x_{max}) = 0.5$$

For the midpoint m_2 between x_{min} and m_1, and midpoint m_3 between m_1 and x_{max}, Equation 13 (HUT SAL 2005) holds.

Equation 13: Second and Third Midpoints

$$m_2 = \frac{1}{2}v(x_{min}) + \frac{1}{2}v(m_1) = 0.25$$

$$m_3 = \frac{1}{2}v(m_1) + \frac{1}{2}v(x_{max}) = 0.75$$

Additional midpoints can be determined in a similar manner until the value scale is defined with the desired accuracy.

In Figure 23 (HUT SAL 2005), the bisection method is illustrated for an arbitrary value measurement problem.

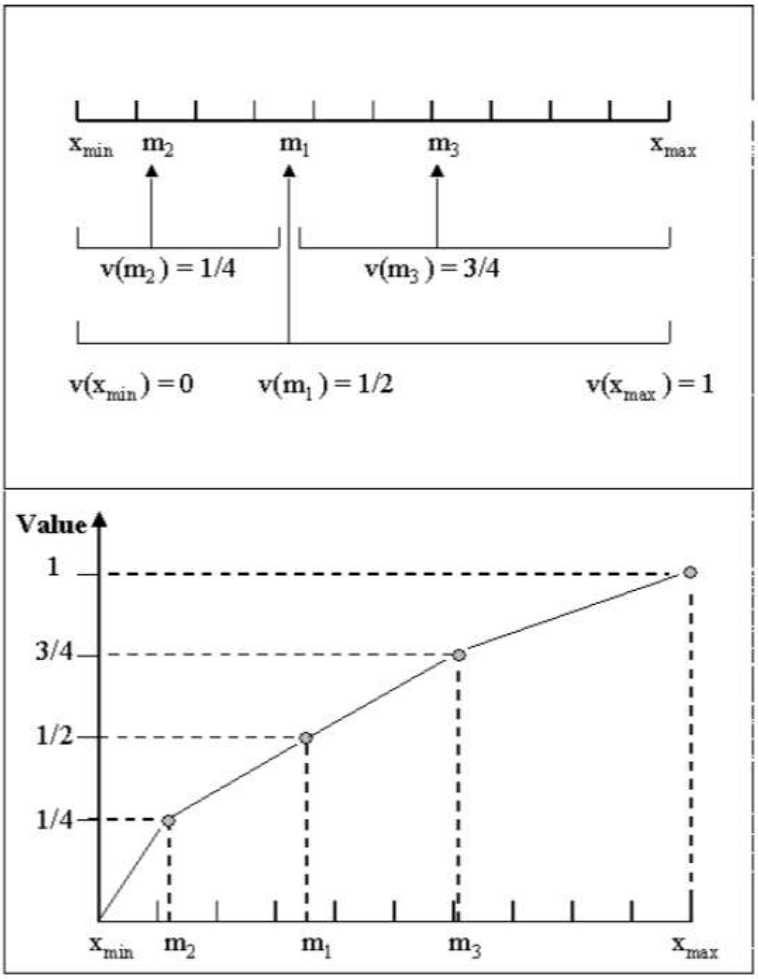


Figure 23: Bisection Method

WEIGHT ELICITATION

OVERVIEW

It is apparent that, in any evaluation, not all attributes carry the same weight. Therefore, it is desirable to incorporate an assessment of the relative importance of the attributes. According to Belton and Stewart (2002), the weight assigned to an attribute is essentially a scaling factor which relates scores on that attribute to scores on all other attributes.

WEIGHTING HIERARCHY

According to HUT SAL (2005), there are two ways to determine the weights in a value tree. A discussion follows.

1. Non-hierarchical weighting: The weights are defined for the attributes only.

2. Hierarchical weighting: The weights are defined, separately, for each hierarchical level and then multiplied down to get the corresponding lower level weights.

Examples of these two weighting hierarchies can be seen in Figure 24 (Pöyhönen 1998).

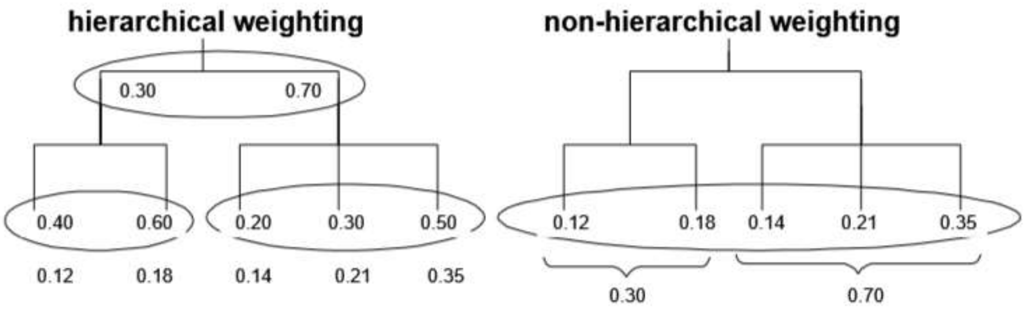


Figure 24: Weighting Hierarchy

In non-hierarchical weighting, the decision maker is not asked to weigh the objectives (i.e. upper level attributes). These weights are not required since the weight of an objective at the upper level is by definition the sum of the attribute weights below it. A problem with non-hierarchical weighting, as stated in Pöyhönen (1998), is that in real applications the total number of attributes presented to a decision maker, at once, may be very large. Hierarchical weighting, however, overcomes this problem. In hierarchical weighting, the decision maker is asked to weigh all of the attributes at each level of the value tree.

DEFINING WEIGHTS

Barfod and Leleur (2014) recommend that weights be defined as relative- and cumulative weights.

Relative weights are assessed within families of attributes (i.e. attributes sharing the same parent) and are normalised to sum to 1 (or 100). The **cumulative weight** of an attribute is the product of its relative weight in comparison with its siblings and the relative weights of its parent, parent's parent, and so on to the top of the tree. The cumulative weights of all bottom-level attributes also, by definition, sum to 1 (or 100) and the cumulative weight of a parent attribute is the total of the cumulative weights of its descendants.

Refer to Figure 25 (Barfod and Leleur 2014). In this figure, the relative weights are represented by the numbers in bold and the cumulative weights by the numbers in italics.

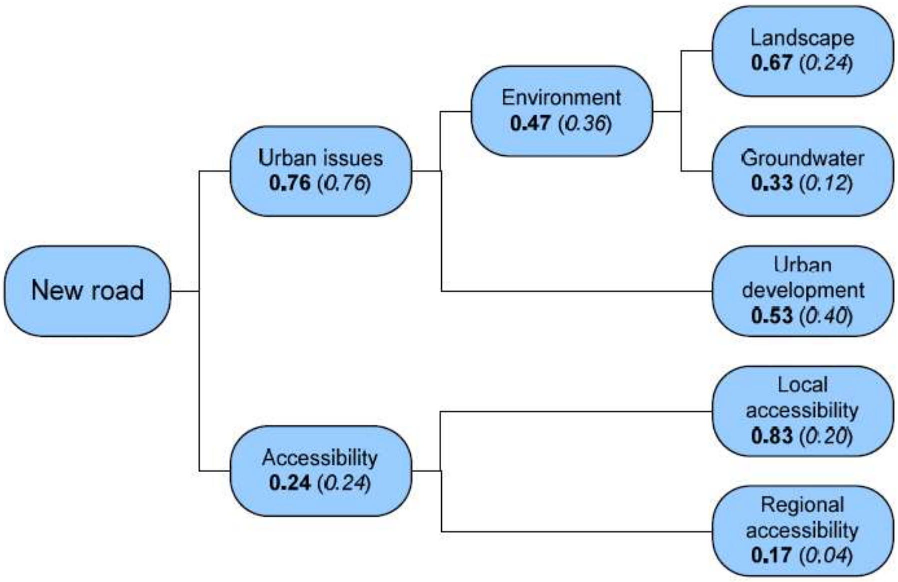


Figure 25: Explanation of Weight Definition

ASSESSING WEIGHTS

For large models, Barfod and Leleur (2014) recommend that the relative weights within families of attributes first be assessed. The weights at higher levels of the value tree can then be assessed either top-down or bottom-up.

As the name suggests, the **top-down approach** assesses the relative weights within families of attributes by working from the top of the value tree downwards. However, as stated in Barfod and Leleur (2014), the analyst needs to be aware of the difficulty associated with interpreting weights at higher levels of a value tree. That is, the weight of a higher-level attribute is the sum of the cumulative weights of all its sub-attributes. As a result, when comparing two higher-level attributes, the analyst needs to be thinking in terms of all the sub-criteria relating to the two higher-level attributes. Moreover, the analysts needs to carry out cross family checks on the cumulative weights of the bottom level attributes.

According to Barfod and Leleur (2014), the **bottom-up approach** begins by assessing the relative weights within families that contains only bottom level attributes. Then cross family comparisons are carried out by using one attribute from each family (e.g. the most highly weighted attribute in each family) and any unitary bottom level attribute. This process results in the cumulative weights of the bottom level attributes; which can be aggregated to obtain the higher-level weights.

WEIGHTING TECHNIQUES

Different multi-criteria models employ different methods for extracting weightings from the decision makers. According to Argyrous (2010), weighting techniques can be classified as either direct (i.e. precise weight elicitation) or indirect (i.e. imprecise weight elicitation). Direct estimation includes those methods that ask the decision maker to explicitly weigh the items; either as an ordinal ranking of properties or as some cardinal measure of each attribute against one another. This is designed to give the exact worth of each attribute compared to another attribute. Methods pertaining to indirect estimation include, for example, information on a ranking of similar options and rankings that are elicited in an iterative or interactive way (Argyrous 2010).

Methods adopting the direct estimation approach range from quite simple rating procedures, like the frequently used direct rating and point allocation methods, to somewhat more advanced procedures, such as the often used SMART, swing weights and trade-off method (Riabacke *et al*. 2012). A popular example of the indirect estimation approach is rank-based methods.

All the available weighting methods differ in their procedures during the extraction phase. In the direct rating method, the decision maker is asked to rate each attribute on a scale from 0 to 100. In the point allocation method, the decision maker is asked to distribute a total of 100 points among the attributes. The rest of the procedures mentioned (except for the trade-off method) are discussed in the following sub-sections.

SMART

SMART was first introduced by Edwards (1997). The steps of the SMART method, as given in HUT SAL (2005), can be summarised as follow:

- first ask the decision maker to give 10 points to the least important attribute,
- then ask the decision maker to compare the other attributes with the least important one and to give them points greater than 10, and
- then, when all of the comparisons have been executed, normalise the points obtained.

In order to normalise the points, the weight of the attribute i need to be calculated as given in Equation 14 (HUT SAL 2005).

Equation 14: Weight Normalisation

$$w_i = \frac{p_i}{\sum_{j=1}^{n} p_j}$$

In Equation 14 (HUT SAL 2005), p_i represents the points given to the attribute (objective) i and n the total number of the attributes (sub-objectives).

SWING WEIGHTS

The swing weight method was first described by von Winterfeldt and Edwards (1986). As stated in Guinto (2008), this method is a variant of direct rating that forces consideration of the range of an attribute. With the swing weight method, the decision makers are presented with all objectives and the respective ranges of the attribute values. Each decision maker then considers the hypothetical situation of all objectives being at their worst values. Then the decision makers are given the opportunity to "swing-up" from their worst to their best values; until of the attributes have been ranked.

In more formal terms, let x_i^* be the best and x_i^0 the worst outcome of the attribute X_i, $i \in (1, \dots, n)$. Furthermore, let $a^0 = (x_1^0\ ,\ x_2^0, \dots, x_n^0)$ be the worst possible alternative. By considering the alternative a^0, the decision maker is then asked to choose one attribute, say x_i, to be shifted to the highest level, say x_i^*. The attribute x_i is then allocated 100 points. Therefore, Equation 15 (HUT SAL 2005) holds.

Equation 15: Swing Weights

$$V(a_0) = 0$$

$$a_i = (x_1^0, x_2^0, \dots, x_{i-1}^0, x_i^*,\ \ x_{i+1}^0, \dots, x_n^o\ )$$

$$V(a_i) =\ w_i v_i\,(x_i^*) =\ w_i\ = 100$$

Next, the decision maker is asked to choose another attribute to be shifted to the best level and then to allocate it points relative to the first attribute. This procedure is continued until the weights of all attributes have been assessed. Finally, the given weights w_i, $i\ \in (1, \dots, n)$ are normalised.

Refer to Table 10 (Guinto 2008). This table shows an example of a questionnaire that used the swing weight method.

Table 10: Swing Weights Questionnaire Example

ATTRIBUTE	BENCHMARK (WORST CASE)	BEST VALUE	CONSEQUENCE TO RANK AND RATE	RANK (1 - 5)	RATE (0 - 100)
Agricultural Land	70%	100%	Change from 70% to 100% (all other attributes at lowest levels)		
Everglades National Park	40%	80%	Change from 40% to 80% (all other attributes at lowest levels)		
Flood Damage Reduction	95%	100%	Change from 95% to 100% (all other attributes at lowest levels)		
Lake Okeechobee	60%	90%	Change from 60% to 90% (all other attributes at lowest levels)		
Water Supply Reliability	70%	100%	Change from 70% to 100% (all other attributes at lowest levels)		

The rating points obtained from the questionnaire in Table 10 (Guinto 2008) were then used to calculate the swing weights as shown in Table 11 (Guinto 2008).

Table 11: Swing Weight Calculation Example

ATTRIBUTE SWUNG FROM WORST TO BEST	CONSEQUENCE TO COMPARE (WORST TO BEST VALUE)	RANK	RATE	WEIGHT	WEIGHT CALCULATION
Agricultural Land	70% - 100%	3	50	0.19	= 50 / 260
The Estuaries	10% - 90%	2	75	0.29	= 75 / 260
Everglades National Park	40% - 80%	1	100	0.38	= 100 / 260
Flood Protection	95% - 100%	6	0	0.00	= 0 / 260
Lake Okeechobee	60% - 90%	4	20	0.08	= 20 / 260
Water Supply Reliability	70% - 100%	5	15	0.06	= 15 / 260
	Total		260	1	

RANK-BASED METHODS

In rank-based methods, the decision maker is only asked to define the ranking of the attributes. These ordinal values are then translated into surrogate (cardinal) weights that are consistent with the supplied rankings (Riabacke *et al*. 2012). Several proposals on how to convert such rankings to numerical weights exist; the most prominent being the conversion of ranks to ratios.

According to Riabacke *et al*. (2012), ranking-based methods are simple, generally less cognitively demanding and advantageous for group consensus (since groups are more likely to agree on ranks than on precise weights). Moreover, according to HUT SAL (2005), they are ideal for a preliminary screening of the alternatives. However, since only information on the ranking order of the attributes is used, there are likely to be several weightings implying the same order. In certain situations, the latter mentioned could cause this approach to be problematic.

In Table 12 (HUT SAL 2005), the possible ranking-based methods for calculating the weight w_j of the attribute $j \in (1, \ldots, n)$ with ranking R_j are presented. In addition, the formulae for normalised weights w'_j are presented.

Table 12: Ranking-based Methods

NAME	$\boldsymbol{w_j}$	$\boldsymbol{w'_j}$
Rank Sum	$(n+1-R_j)$	$\frac{2\,(n+1-R_j)}{n\,(n+1)}$
Rank Reciprocal	${}^{I}/_{R_j}$	$\frac{1}{R_j\ \sum_{i=1}^{n} {}^{1}/_{i}}$
SMARTER (Rank Centroid)	$\sum_{i=R_j}^{n} \frac{1}{i}$	$\frac{1}{n} \sum_{i=R_j}^{n} \frac{1}{i}$
Rank Exponent	$(n+1-R_j)^z, z > 0$	$\frac{(n+1-R_j)^z}{\sum_{i=1}^{n}(n+1-i)^z}$

In Riabacke *et al.* (2012), it is stated that the rank centroid method has gained the most recognition out of all the conversion methods listed in Table 12 (HUT SAL 2005).

SELECTING A WEIGHTING TECHNIQUE

In Pöyhönen and Hämäläinen (1997), the convergent validity of five multi-attribute weighting methods was studied in an Internet experiment. The methods considered were: one version of the AHP, direct point allocation, SMART, swing weighs and trade-off weighting.

Pöyhönen (1998) found that the different weighting methods (although they are based on the same theoretical assumptions) led to different weights. These differences originate from the way decision makers restrict their responses depending on the numbers that the methods explicitly or implicitly propose. Therefore, Pöyhönen (1998) suggests that different weighting techniques be combined and that decision makers be allowed to interactively evaluate the results during the weighting process.

DETERMINING AGGREGATE NUMERICAL WEIGHTS

Alfares and Duffuaa (2008) performed a set of experiments to develop and evaluate an empirical methodology to convert ordinal attribute rankings from several decision makers into aggregate attribute (overall group) weights.

The experiments conducted in Alfares and Duffuaa (2008) involved two groups of decision makers (i.e. students and faculty) and two sets of attributes applicable to two contexts (i.e. student learning and instructor evaluation). In part one of the experiment, the decision makers were asked to rank each set of attributes based on their importance. After ranking the attributes pertaining to each context, the decision makers were required to assign weights to each attribute (i.e. part two of the experiment). The weight assignment followed the Max100 approach, suggested by Bottomley and Doyle (2001), in which a weight of 100% is given to the most important (first ranked) attribute.

In order to develop aggregate attribute weights, Alfares and Duffuaa (2008) utilised an empirical linear rank-weight relationship. This linear relationship specifies the average weight for each rank for an individual decision maker, assuming a weight of 100% for the first-ranked (most important) attribute. For any set of n ranked attributes, the percentage weight $w_{r,n}$ of an attribute n ranked as r is given by Equation 16 (Alfares and Duffuaa 2008):

Equation 16: Empirical Linear Rank-weight Relationship

$$w_{r,n} = 100 - S_n(r-1)$$

Where:

$$S_n = 3.195 + \frac{37.758}{n}$$

$$1 \leq n \leq 21$$

$$1 \leq r \leq n$$

With r and n integers.

According to Alfares and Duffuaa (2008), the upper limit with regard to the number of permissible attributes ($n \leq 21$) is meant to prevent $w_{r,n}$ from assigning negative weights to attributes ranked greater than 21.

Alfares and Duffuaa (2008) have proposed three methods for determining aggregate (group) weights when all the decision makers rank the same set of criteria. A small numerical example was used to compare the three proposed aggregation methods based on how closely they estimated the relative actual sum of weights given by all the decision makers (in part two of the experiment). The results obtained in Alfares and Duffuaa (2008), showed that the first proposed method (referred to as method S1) consistently had the Minimum Absolute Percentage Errors (MAPE). As a result, Alfares and Duffuaa (2008) concluded that method one is the best for aggregation when all individuals rank the same set of attributes. Therefore, only this method is considered in more detail.

Method S1

In this method, the individual ranks are first converted into individual weights for each attribute, then the average weight for each attribute is calculated among all individuals and then the average weights are normalised to make their sum equal to 100%. A discussion of these three steps follows.

1. For each individual i use Equation 16 (Alfares and Duffuaa 2008) to convert ranks $r_{i,j}$ into individual weights $w_{i,j}$ for all n attributes:

Equation 17: Ranks converted into Individual Weights

$$w_{i,j} = 100 - S_n(r_{i,j} - 1)\ ;\ i = 1, \dots, m\ ;\ j = 1, \dots, n$$

2. Calculate the average weight of each attribute by averaging its weights obtained from all m individuals:

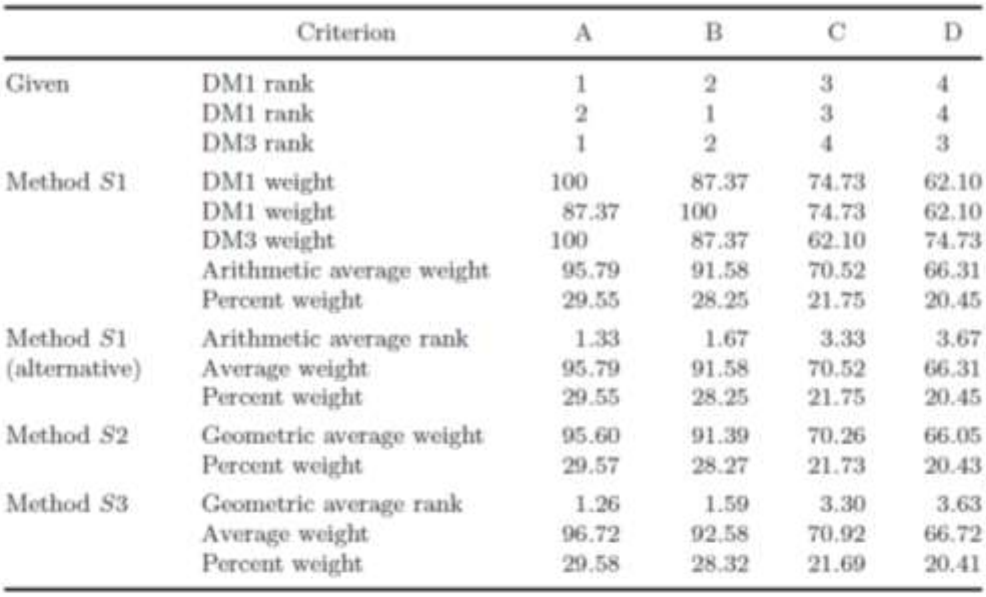
Equation 18: Arithmetic Average Weight

$$W_j = \frac{1}{m} \sum_{i=1}^{m} w_{i,j}\ ;\ j = 1, \dots, n$$

According to Alfares and Duffuaa (2008), the first two steps of this method can be reversed and the same values of relative aggregate weights would still be obtained. That is, one could average the ranks first and then convert average ranks into average (aggregate) weights.

3. Calculate the percent weight of each attribute by normalising the computed weights of all n attributes.

An example application of the three proposed aggregation methods, for the same set of ranked attributes, can be seen in Figure 26 (Alfares and Duffuaa 2008). This example involves three decision makers (i.e. DM1, DM2 and DM3) and four decision attributes (i.e. A, B, C and D).



	Criterion	A	B	C	D
Given	DM1 rank	1	2	3	4
	DM1 rank	2	1	3	4
	DM3 rank	1	2	4	3
Method $S1$	DM1 weight	100	87.37	74.73	62.10
	DM1 weight	87.37	100	74.73	62.10
	DM3 weight	100	87.37	62.10	74.73
	Arithmetic average weight	95.79	91.58	70.52	66.31
	Percent weight	29.55	28.25	21.75	20.45
Method $S1$ (alternative)	Arithmetic average rank	1.33	1.67	3.33	3.67
	Average weight	95.79	91.58	70.52	66.31
	Percent weight	29.55	28.25	21.75	20.45
Method $S2$	Geometric average weight	95.60	91.39	70.26	66.05
	Percent weight	29.57	28.27	21.73	20.43
Method $S3$	Geometric average rank	1.26	1.59	3.30	3.63
	Average weight	96.72	92.58	70.92	66.72
	Percent weight	29.58	28.32	21.69	20.41

Figure 26: Example Application of the Three Aggregation Methods

SYNTHESISING INFORMATION

AGGREGATION RULE

When preference elicitation is completed, the decision maker needs to aggregate the single attribute functions into an overall score that can be evaluated across all of the attributes. In order to accomplish the aforementioned, the decision maker needs to decide on an aggregation rule. According to Belton and Stewart (2002), the simplest and most widely used form of value function is the additive model. A discussion of this model follows.

ADDITIVE VALUE FUNCTION MODEL

The additive value function model can be represented by Equation 19 (Belton and Stewart 2002).

Equation 19: Additive Model

$$V(a) = \sum_{i=1}^{m} w_i v_i\,(a)$$

Where:

$V(a)$ = the overall value of alternative a

w_i = the weight assigned to reflect the importance of attribute i

$v_i\,(a)$ = the value score reflecting alternative a's performance on attribute i

m = the number of attributes

In Belton and Stewart (2002), the core requirements underlying the validity of an additive value function have been underlined. A discussion follows.

1. The attributes need to be selected and structured in such a way that they are complete (i.e. all of the important issues are addressed) and non-redundant (i.e. no double counting). If this is not properly executed, the results could be seriously biased.
2. The attributes need to be preferentially independent. That is, it should be possible for the decision maker to evaluate trade-offs between two or more attributes, on the assumption that all other attributes have fixed levels of performance, without the need to consider what these fixed levels are.
3. The partial values need to represent an interval preference scale. Suppose that alternative a is preferred to alternative b in terms of criterion i, while alternative b is preferred to alternative a in terms of criterion ℓ. If $w_i[v_i(a) - v_i(b)] = w_\ell[v_\ell(b) - v_\ell(a)]$, then the gain in terms of criterion i in selecting a is precisely compensated by the loss in terms of criterion ℓ. The principal implication of the model is that this trade-off is independent of the absolute performance levels. For example: the same compensation would apply whether $v_i\,(a) = 20$ and $v_i\,(b) = 10$ or whether $v_i\,(a) = 70$ and $v_i\,(b) = 60$.

In order for the resulting preference model to be valid, both the elicitation of the partial values $v_i\,(a)$ and the construction of the $V(a)$ needs to respect each of the aforementioned properties.

SENSITIVITY AND ROBUSTNESS

OVERVIEW

Analysis is needed to investigate whether the preliminary conclusions are sensitive to changes in aspects of the model and/or if they are robust. According to Belton and Stewart (2002), changes may be made to investigate the significance of missing information, to explore the effect of a decision maker's uncertainty about their values and priorities, or to offer a different perspective on the problem. However, if the exploration is driven simply by a wish to test the robustness of the results, there might be no practical- or psychological motivation for changing the values.

PERSPECTIVES ON SENSITIVITY ANALYSIS

Sensitivity analysis can be viewed from three perspectives. A discussion of these perspectives, as given in Belton and Stewart (2002), follows.

1. From a technical perspective, sensitivity analysis is the objective examination of the effect of changes in input parameters on the output of a model.
2. The function of sensitivity analysis from an individual's perspective is to provide the sounding board against which they can test their intuition and understanding of the problem.
3. The function of sensitivity analysis within the group context is to allow the exploration of alternative perspectives on the problem. This is often captured by different sets of attributes weights.

APPROACHES TO SENSITIVITY ANALYSIS

In Belton and Stewart (2002), three approaches to sensitivity analysis have been identified. A brief overview of these approaches follows.

1. Preference regions.

When working with three attributes, information about potentially optimal alternatives can simply and clearly be displayed in a 2-dimensional projection of weight space. This weight space (i.e. triangular region) can then be divided into preference regions. That is, areas of weight space in which a particular alternative would be the preferred option. The same display can be used to investigate the robustness of preferred alternatives to changes in any three attribute weights.

2. Potentially optimal alternatives.

For any selected alternative, it is possible to determine whether the specification of alternate weight values could make it the preferred alternative or not. It may also be useful to know how far it would be necessary to move from the current set of weights. For more detail, refer to Rios Insua (1990).

3. Monte Carlo methods.

The fundamental idea of these methods is to randomly generate values for model parameters (e.g. the importance weights) from assumed probability distributions. The frequency with which each alternative then turns out to be optimal, indicates which alternatives may require further attention as being "potentially optimal". For more detail, refer to Belton and Stewart (2002).

4.5.3 DECISION SUPPORT SYSTEMS

Three decision support systems have been identified for consideration. These are: 1) Web-HIPRE, 2) OnBalance and 3) DEFINITE 3.1.

WEB-HIPRE

SOFTWARE AVAILABILITY

The following information was obtained in Mustajoki and Marttunen (2013).

Developed by: Systems Analysis Laboratory, Aalto University, Finland.
Price: Free for academic use.
Website: http://www.hipre.hut.fi
Available since: February 1998.

SOFTWARE OVERVIEW

The architecture of Web-HIPRE takes advantage of the possibilities of the web to support the decision-making processes. According to Mustajoki *et al*. (2003), this entails the possibility to carry out interactive processes without any installations on local computers, the possibility to remotely use the software as well as platform-independency.

Mustajoki *et al*. (2003) state that Web-HIPRE can supports both MAVT-based methods and the AHP. A hierarchical model of the objectives related to the problem and the specific preferences can be easily developed. Weights can be elicited by different weighting procedures. Examples include, among others, point allocation, SMART, SWING and SMARTER. The model's output can then be visualised in a number of ways. For example: the overall values of the alternatives can be presented as bar graphs. These graphs can then, in different ways, be further broken down. For example: by dividing them into segments according to the contribution of the different attributes. Moreover, as stated in Mustajoki *et al*. (2003), one-way sensitivity analysis can be applied to study the effects of changes in either the attribute weights or the component values of the alternatives. If desired, graphical representations can also be used to reduce the biases related to the use of numbers.

ONBALANCE

SOFTWARE AVAILABILITY

The following information was obtained in Mustajoki and Marttunen (2013).

Developed by: Quartzstar Software Ltd.
Price: Charityware.
Website: http://www.quartzstar.com
Available since: no date available.

SOFTWARE OVERVIEW

OnBalance is a general-purpose software that implements MAVT to help separate what is measured from how it is valued. Since most of the difficult decisions are between good schemes, each supported by one or more managers, its interface is specifically designed for group decision-making (Mustajoki and Mattunen 2013). The home screen of OnBalance can be seen in Figure 27.

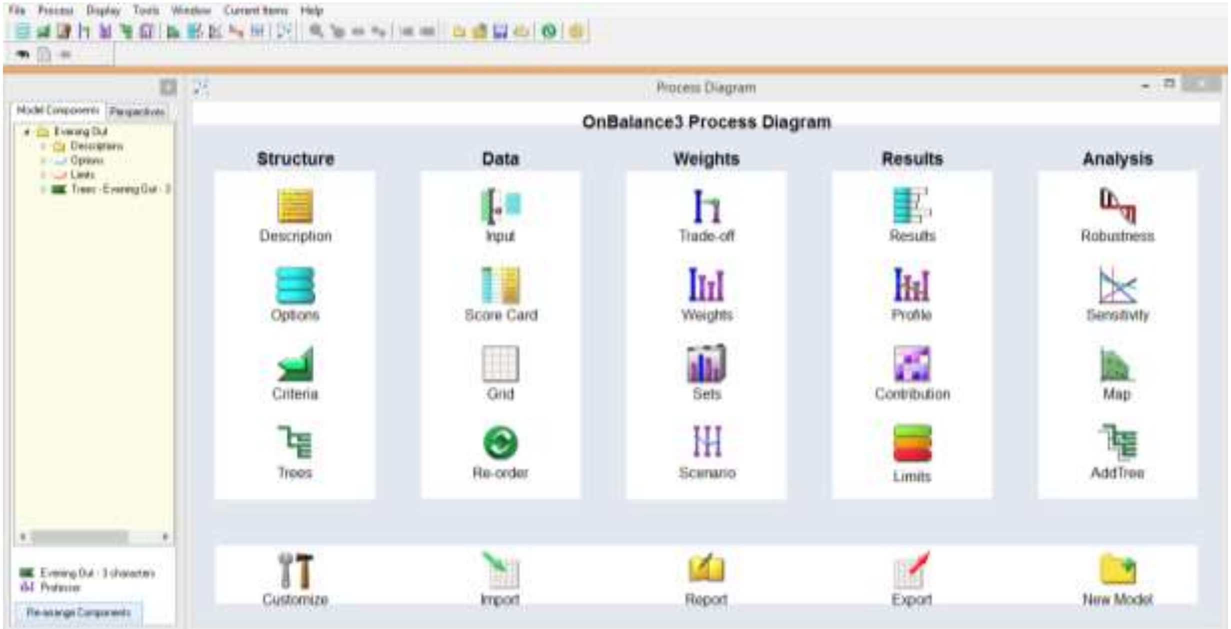


Figure 27: OnBalance Home Screen

OnBalance can be used to evaluate alternative solutions by taking into consideration the different decision attributes. As stated in Catrinu *et al*. (2008), OnBalance facilitates the comparison of attributes by ascertaining how much one would be willing to trade off one attribute against another. This is accomplished by selecting a reference attribute as the yardstick (e.g. the most preferred attribute) and then weighting all other attributes, in each alterative solution, accordingly.

DEFINITE 3.1

SOFTWARE AVAILABILITY

Developed by: Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Price: The single user academic version costs 750 euro.

Website: http://www.ivm.vu.nl/en/projects/Projects/spatial-analysis/DEFINITE/index.asp

Available since: First version released in 1994.

SOFTWARE OVERVIEW

DEFINITE (decisions on a finite set of alternatives - Dutch acronym BOSDA) is a decision support software package that has been developed to improve the quality of (environmental) decision-making. DEFINITE supports the whole decision process; from problem definition to report generation. According to Janssen and Herwijnen (2011), its structured approach ensures that the decisions arrived at are systematic and consistent.

The program contains a number of methods for supporting problem definition as well as graphical methods to support representation. Moreover, in order to be able to deal with all types of information, DEFINITE includes five different MCDM models as well as cost-benefit and cost-effectiveness analysis (Janssen and Herwijnen 2011). Other related procedures such as weight assessment, standardisation, discounting and a large variety of methods for sensitivity analysis are also available.

A unique feature of DEFINITE is a procedure that systematically leads an expert through a number of rounds of an interactive assessment session and then uses an optimisation approach to integrate all information provided by the experts to a full set of value functions. This feature has been used by Stewart and Janssen (2013).

5. RESEARCH METHODOLOGY

5.1 OVERVIEW OF RESEARCH METHODOLOGY

During the course of researching the field of managing performance measurement, the evident enormity and complexity of the proposition made herein became evident. It is against this background that it became apparent that the realisation of the proposition made herein demands a systematic approach. The various methodical steps associated with the warranted systematic approach resemble the objectives of this research project. These steps were established based on the insights gained from the work done in the preliminary part of this research project. The coherent organisation of these steps construed the rationale behind the methodology pursued. In essence, in order to develop an all-encompassing measurement framework that lays the groundwork for managing the performance of the ITS deployments, the methodology depicted in Figure 28 was embraced.

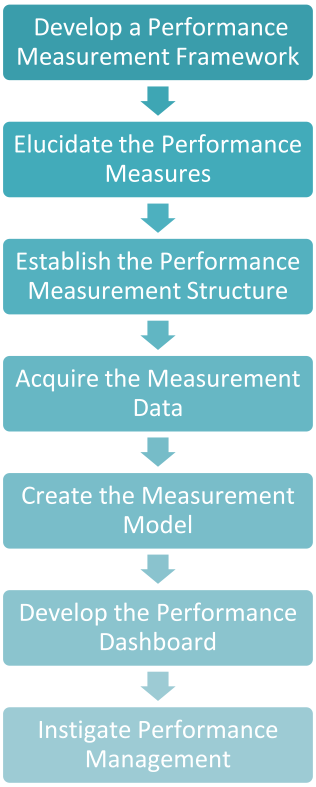


Figure 28: Overview of Research Methodology

This chapter includes a discussion on the practices, procedures and principles used in executing each of the methodical steps depicted in Figure 28.

5.2 PERFORMANCE MEASUREMENT FRAMEWORK

5.2.1 FRAMEWORK DEVELOPMENT

In order to capture all of the performance-related aspects in a generic and holistic manner, a SBSC as the reference model for the performance measurement framework has been adopted. During the development of this framework, there were many obstacles that rendered the ease of its construction. These obstacles demanded that a meticulous to and fro process be followed.

Due to the comprehensiveness of transport performance measurement, the larger performance measurement and -management field needed to be researched in-depth. This entailed studying the relating transport literature and the current transport trends and -movements, within the South African context, extensively. After acquiring an in-depth knowledge of the portraying consideration aspects and a practical understanding of the local ITS industry, it was possible to develop a baseline framework. This framework included all technological and non-technological performance-related aspects applicable to both the private- and the public transport environment.

However, since transport has immense economic-, social- and environmental effects, these three pillars of sustainability also needed to be integrated within the core management of the ITS projects. Therefore, it was required to expand the baseline framework to assess sustainable transport development. This was accomplished by identifying five sustainability perspectives. These are: 1) practices, 2) processes, 3) profit, 4) people and 5) planet. This resulted in the sustainability version of the initial baseline framework.

Moreover, since the framework needed to be representative of all the interested parties and be understandable for implementing agencies and decision makers in a participative context, the sustainability version of the baseline framework underwent many rigorous changes over the course of some intuitive tests and many introspection exercises. Numerous other versions were deducted from the aforementioned actions.

Ultimately, the final SBSC framework (i.e. the version sent out for validation by the personally selected practitioners) was developed. Based on this author’s opinion, this final version of the proposed framework included all of the portraying performance-related aspects applicable to both the private- and the public transport environment, embraced a structure for evaluating performance in the field of technology investments, catered for sustainable transport development, ascertained the preferences of all interested parties and facilitated consensus-orientated performance appraisal.

5.2.2 FRAMEWORK VERIFICATION AND VALIDATION

In order to ensure that the proposed framework has adequate flexibility and that it is suitable to assess the performance of ITS applications, the content of the framework has been verified and validated. This was accomplished by acquiring input from practitioners in the field of ITS, transport and performance measurement.

A website that portrays the SBSC framework and explains its reasoning was used as the communication medium for data capturing. This website was created with the aid of the free online website development platform supported by WIX[4]. Due to the sensitivity of the information given, the website was password protected. The password is: 15073580. The website was designed to be desktop-based. However, if desired, it can also be viewed on mobile phones. Screenshots of this website can be found in Appendix A and the website can be viewed at: http://cstruwig.wix.com/pm-framework.

5.2.3 FRAMEWORK ARRANGEMENT

Horizontally the framework has been subdivided into the five sustainability perspectives. These are:

1. PRACTICES: Governance, Planning and Decision Making,
2. PROCESSES: Operations, Services and Maintenance,
3. PROFIT: Money Matters,
4. PEOPLE: People Matters, and
5. PLANET: Environmental Matters.

Vertically the framework has been subdivided into performance measurement levels (i.e. L0 to L5). These levels comply with the following hierarchy: L0 - sustainability perspective, L1 - performance category, L2 - performance area, L3 - performance sub area, L4 - measurement field and L5 - performance measure.

Due to the vast size of the developed framework, all of the identified performance-related aspects and their performance measurement levels have been structured into five tables. That is, a table for each of the perspectives pertaining to the SBSC framework. Moreover, based on the requirements posed by the field of MCDM, each table (i.e. each sustainability perspective) was also represented as a value tree. These value trees were constructed with the aid of Microsoft Visio.

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[4] http://www.wix.com/

5.3 PERFORMANCE MEASURES

5.3.1 KPI FORMALISATION

In order to formalise the KPIs needed for performance evaluation, the specific consideration fields pertaining to each of the identified performance measures have been elucidated. The measurement considerations identified for consideration are the: 1) measurement system, 2) evaluation criterion, 3) interested party, 4) classification type, 5) measurement technique, 6) measurement time frame, 7) measurement scale and data type, and 8) measurement feasibility.

MEASUREMENT SYSTEM

The metric-based Système International (or SI units) has been used to facilitate the (standardised) evaluation of the quantifiable measures. In order to evaluate the non-quantifiable measures, three approaches have been identified. These are: 1) classifying them with the binary number system, 2) portraying them as relative indices and 3) assigning them with descriptive scores that are representative of their performance levels.

Binary assessment was used to, among others, signify whether the necessary documents are in place or whether the appropriate procedures are being followed. This was accomplished with the aid of checklists. **Index assessment** was used to evaluate composite measures. That is, measures that are influenced by separate empirical indicators. This was accomplished with the aid of weighted average formulas. These formulas encompass parameters that assess the performance and the overall importance of the identified index-related considerations. **Scorecard assessment** was used for qualitative, low granularity measures. This was accomplished by developing scorecards with multiple dimensions and then stipulating each dimension's corresponding performance level and -score.

EVALUATION CRITERIA

In order to establish the performance of the proposed measures, they need to be measured based on their specific evaluation criterion. Three evaluation criteria categories have been identified. These are: 1) evaluating the measure based on a comparison of one time period to another an indicating the rates of change as an increase or a decrease, 2) evaluating the measure based on KPI standards or desirable targets (e.g. industry thresholds and user requirements) and 3) evaluating the measure based on its conformity or nonconformity to the project- and/or legal prerequisites.

INTERESTED PARTY

For each measure, there is a party (or parties) that is particularly interested in or affected by its performance. For example: in the case of evaluating travel time, the transport user is the party who would have the most interest in and who would have the most benefit to gain from little travel time variability. Therefore, during standard and/or target development, the opinion of the associated interested party needs to be taken into consideration. Three interested parties have been identified. They are the: 1) transport user, 2) operator or contractor and 3) employer or client.

CLASSIFICATION TYPE

All of the proposed measures arise from the existence of various regulatory aspects, restricting guidelines, executable prerequisites and/or advising recommendations that are taken to be a given in transport projects. These givens have been generalised to include two classification types. These are: 1) project requirements and 2) planning principles.

Project requirements refer to the general set of documents that stipulate *what* a project is supposed to accomplish and specify *how* the project is supposed to be developed and implemented. These documents thus include the instructions describing: what functions the project is supposed to provide, what characteristics the project is supposed to have, what goals the project is supposed to meet as well as the specifications dictating: how the project is supposed to implement these instructions and in accordance to what external binding (legal and regulatory) documents.

Planning principles refer to the underlying principles of project management. These principles are usually captured in the project plan by outlining the actions or tasks required to achieve the desired objectives. They help to guide project managers in sensibly managing the time, the cost and the resources of the project. In a sense, they form the roadmap to, and foundation for, effective project management. Unlike project requirements, planning principles generally exist to guide projects in realising sustainable practices. Therefore, the implementation of their associated actions or tasks is not necessarily a mandatory action; rather an advisable action deemed essential by this author.

MEASUREMENT TECHNIQUE

In order to establish the project's performance with regard to adhering to the aforementioned givens, the data necessary to compute all of the proposed measures (whether they are a project requirement or a planning principle) needs to be obtained. Numerous measurement techniques can be used for data attainment. The decision of which measurement technique to use, is dictated by the specific restrictions posed by the measure under consideration. Five measurement techniques have been identified. A discussion of these techniques and example applications follows.

- Automatic measurement is applicable to any measure whose measurement operation is independent of human control since it is automatically evaluated by the supporting electronic software- or application management system. For example: traffic counts computed by the vehicle detection application.
- Automated measurement is applicable to any measure whose measurement operation involves using a measuring instrument or a technology-driven apparatus to reduce the amount of work done by the humans; thereby reducing the time taken to do the work. For example: operators viewing CCTV footage to detect incidents.
- Manual measurement is applicable to any measure whose measurement operation involves a human performing any manual operation, task or assessment. For example: spot checks made by field workers and observations made by ghost riders.
- Scorecard measurement is applicable to any qualitative, low granularity measure whose measurement operation involves using some guideline performance scorecard as the reference point for evaluation. For example: using a performance scorecard, in conjunction with a pilot project (i.e. a small-scale preliminary study), to determine a project's level of scalability.
- Survey measurement is applicable to any measure whose measurement operation involves using surveys to capture the necessary data needed for its computation. For example: an employee- and a customer satisfaction survey.

MEASUREMENT TIME FRAME

Depending on which measure's data is being obtained, the aforementioned measurement techniques need to be executed over different measurement time frames. Some of the measures may require continuous measurement, while for others ad-hoc measurement may suffice. The measures whose nature varies due to their temporal consciousness need to be evaluated on a continuous basis. For example: both traffic- and passenger density is directly influenced by the time of day. The measurement time frame relating to such time dependent measures could, for example, be: real-time, hourly, daily, weekly and monthly. Conversely, the measures whose nature are less variant and who are not dependent on time can be evaluated on an ad-hoc basis. This entails that they be measured only if and when needed or for a particular required purpose. For example: even though the evaluation of social inclusion may be premeditated, the (statistical) significance of the evaluation is not deterred by when (i.e. in what time period) it was executed.

MEASUREMENT SCALE AND DATA TYPE

In order to be able to sensibly interpret and analyse the data pertaining to each of the proposed measures, their applicable measurement scal**e** needs to be established. Measurement scales are used to categorise or rank descriptive data and to quantify numeric data. Moreover, the measurement scale establishes the type of statistical analysis required. Four measurement scales have been identified. A discussion of these scales and example applications follows.

1. Nominal scale is a scale in which the data is allocated to discrete categories and is hence neither measured nor ordered. These scales are used with data that has no numeric significance. For example: binary data classified into two categories: yes (1) and no (0).
2. Ordinal scale is a scale in which the data is ordered based on their magnitude (importance); with no standard of measurement of differences. These scales are typically used to measure and rank non-numeric concepts. For example: a person's level of satisfaction, happiness and discomfort with regard to service delivery.
3. Interval scale is a scale in which the differences between the values can be quantified in absolute (but not relative) terms; with only an arbitrary zero. Interval data thus caters for addition and subtraction, but not for multiplication or division. Examples of interval measures are temperature and year. For example: the difference between a temperature of 40 degrees and 30 degrees is the same difference as between 30 degrees and 20 degrees. However, 40 degrees is not twice as hot as 20 degrees and 0 degrees does not mean that there is "no heat".
4. Ratio scale is a scale in which the data permits the quantitative comparison of the differences between the values; with a fixed absolute zero. Examples of ratio data are: time, distance and monetary values (money). Ratio data can be meaningfully added, subtracted, multiplied and divided (to form averages, ratios, proportions, percentages and rates). Ratio data thus permits comparisons and trend evaluations.

While the first two measurement scales mentioned are founded on qualitative (i.e. descriptive) data, the last two measurement scales mentioned are founded on quantitative (i.e. numerical) data. If data is quantitative, an additional distinction with regard to whether the data is continuous or discrete can be made. In essence, the following data types exist: qualitative data and quantitative data that is either continuous or discrete. Continuous data can occupy any value over a continuous range (e.g. travel time) and discrete data can only take on certain values (e.g. traffic counts).

MEASUREMENT FEASIBILITY

The feasibility of each of the proposed measures has been evaluated. If any of the measures were deemed to be too difficult to execute or impractical to implement, viable alternatives and suitable proxies were identified. The former mentioned was proposed for the measures that are believed to be *not easily measureable* and the latter mentioned was recommended as a *cost efficient option* for those whose measurement is believed to be too costly.

5.4 PERFORMANCE MEASUREMENT

5.4.1 PERFORMANCE SCORE ASSESSMENT

In order to assess the performance scores of all the identified performance measures, the performance measurement structure relating to each of these measures has been established. Since the measurement structure is the same for all of the measures that have the same data type, an overview - per data type - of how the performance scores were assessed follows.

NON-QUANTIFIABLE MEASURES

The non-quantifiable measures were assessed with the aid of qualitative value scales that link descriptors to the (satisfaction) values. Two types of non-quantifiable measures have been identified. These represent the measures that have either nominal- or ordinal data.

NOMINAL DATA

All of the measures whose measurement system has been identified to be binary have nominal data. These measures were evaluated with the aid of **checklists**. The checklists were used to facilitate the binary assessment of the representative measures' conformity (i.e. yes = 1) or nonconformity (i.e. no = 0) to the specific project requirement or the planning principle.

ORDINAL DATA

All of the measures whose measurement system has been identified to be either an index or a score have ordinal data.

Indices were used to evaluate all of the composite measures. All of the identified composite measures were found to be effected by people's perceptions of the quality of the service provided. Therefore, since the quality management model SERVQUAL is, according to Parasuraman *et al*. (1985), the most widely utilised tool for measuring service quality, this model was taken into consideration during the identification of the specific index-related considerations. The considerations relating to each index were presented in tables (categorised by their associated dimensions, quality criteria and parameters) and captured in the proposed weighted average formulas.

Scorecards were used to evaluate all of the qualitative, low granularity measures. Each developed scorecard has multiple dimensions and each dimension corresponds to a certain level of performance. The different levels of performance were then represented by performance scores.

QUANTIFIABLE MEASURES

The quantifiable measures were assessed with the aid of quantitative value scales that link performance scores to the (satisfaction) values. Two types of quantifiable measures have been identified. These represent the measures that have either ratio- or interval data.

RATIO DATA

All of the measures whose data permits the quantitative comparison of the differences between the values and whose measurement scale has a fixed absolute zero have ratio data. These measures were evaluated with the aid of **value functions**. The four-step procedure for value function development, as presented in Alarcon *et al.* (2010), was followed. However, step four was replaced by using the value function form assessment technique. This entailed the direct assessment of the form of each representative measure's value function.

INTERVAL DATA

All of the measures whose data permits the differences between the values to be quantified in absolute - but not relative terms - and whose measurement scale only has an arbitrary zero have interval data. These measures were evaluated by considering their rates of change. That is, their associated degree of increase or decrease (as deducted from comparisons made to previous periods). Four types of **increase-decrease** measures have been identified. These are: 1) strictly decreasing measures, 2) strictly increasing measures, 3) index measures - which are a special case of strictly increasing measures, and 4) other special measures. As the name suggest, strictly decreasing measures refer to the measures whose improvement is associated with a steady decrease. Strictly increasing measures refer to the measures whose improvement is associated with a steady increase.

Index measures represent all of the composite measures. Special measures refer to measures for which neither a steady decrease or increase is desired.

5.4.2 SUPPORTING RESEARCH

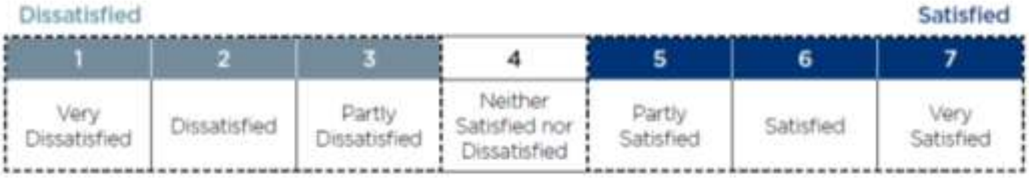
INDEX DEVELOPMENT

ILLUSTRATION

For explanation purposes, one example use and one example computation of the **Customer Satisfaction Index** (CSI) are discussed. A CSI is used to capture the transport user's opinion on the quality of the overall service delivery.

Example Use

With regard to public transport, Transport for NSW (2014) has identified nine criteria relating to service quality. These are: 1) timeliness, 2) safety and security, 3) ticketing, 4) convenience, 5) accessibility, 6) comfort, 7) cleanliness, 8) information and 9) customer service. The parameters (i.e. consideration fields) accompanying these criteria vary slightly based on which transit mode is assessed. The modes considered are: train, bus, ferry, light rail and urban taxis. Nevertheless, the overall question pertaining to each parameter is: "how satisfied are you with the service?" The scale used to rate the customer's satisfaction can be seen Figure 29 (Transport for NSW 2014).



Dissatisfied

Satisfied

1	2	3	4	5	6	7
Very Dissatisfied	Dissatisfied	Partly Dissatisfied	Neither Satisfied nor Dissatisfied	Partly Satisfied	Satisfied	Very Satisfied

Figure 29: CSI - Rating Scale

As an example, a list of the parameters - accompanying the nine quality criteria - used by Transport for NSW (2014) to evaluate the train service follows.

Timeliness

- The train turning up on time.
- Frequency of the train service.
- Journey time; considering the distance travelled.
- Time to connect to other transport services.

Safety and security

- Feeling safe at the train station.
- Feeling safe while on the train.

Ticketing

- Ease of purchasing your ticket.
- Choice of tickets that meet your travel needs.

Convenience

- Availability of car parking facilities near the train station.
- Ease of connection with other modes of transport.

Accessibility

- Ease of accessing the train station.
- Ease of getting on/off the train.
- Usefulness of signs to help you find your way.

Comfort

- Comfort at the train stop (i.e. shelter and seating).
- Seat availability on the train.
- Seat comfort on the train.
- Temperature on the train.
- Personal space on the train.

Cleanliness

- Cleanliness of the train station.
- Cleanliness of the train.

Information

- Availability of arrival information for the train.
- Availability of next stop information on the train.
- Availability of information about service delays.
- Ease of finding information (i.e. routes, stops and timetables).

Customer service

- Willingness of the train staff to help.
- Knowledge of the train staff.

- Presentation of the train staff.

EXAMPLE COMPUTATION

The analysis of the CSI entails the weighted average of the parameter weights (i.e. importance values) and the score of each response (i.e. satisfaction values). Refer to Equation 20.

Equation 20: CSI

$$CSI = \frac{1}{m}\sum_{j=1}^{m}\frac{1}{n}\sum_{i=1}^{n} s_{ij} \, . \, w_{ij}$$

Where:

n = the number of parameters (i.e. questions) relating to quality criteria j

s_i = satisfaction for parameter i relating to quality criteria j

w_i = average weight (i.e. importance) of parameter i relating to quality criteria j

m = the number of quality criteria considered

As an example, refer to Table 13. This table has been adopted from the work done in Poliaková (2010).

Table 13: CSI Computation Example

Quality Criteria	Parameter	Weight	Score	Average Weight	Ave. Weight * Score
Availability	Ticket procurement	10	10	1	10
	Links to other transport systems	10	5	1	5
	Average	10	7.5	N/A	**7.5**
Accessibility	Geographic accessibility	8	9	0.96	8.64
	Time accessibility	9	9	1.08	9.72
	Frequency of services	8	8	0.96	7.68
	Average	8.33	8.67	N/A	**8.68**
				CSI	**8.09**

BACKGROUND

SERVQUAL assesses customer (and employee) perceptions of service quality in service (and retailing) organisations. When first created in the mid-eighties, the SERVQUAL model consisted of ten dimensions of service quality (Parasuraman *et al*. 1985). These are: 1) tangibles, 2) reliability, 3) responsiveness, 4) communication, 5) credibility, 6) security, 7) competence, 8) courtesy, 9) understanding the customer and 10) access. Since some of these dimensions were overlapping (e.g.

communication, credibility, security, competence, courtesy, understanding customers and access), Parasuraman *et al*. (1988) reduced them to only five dimensions. The new dimensions are referred to as the RATER model. An overview of the RATER model follows.

1. **R**eliability: The ability to perform the promised service dependably and accurately.
2. **A**ssurance: The knowledge and courtesy of employees and their ability to inspire trust and confidence.
3. **T**angibles: The physical facilities, equipment and staff appearance.
4. **E**mpathy: The caring and individual attention the firm provides to its customers.
5. **R**esponsiveness: The willingness of the firm to help customers and to provide a prompt service

As stated in Parasuraman *et al*. (1988), two of these dimensions (i.e. assurance and empathy) contain items representing seven of the original dimensions (i.e. communication, credibility, security, competence, courtesy, understanding the customers and access). Therefore, while the RATER model only has five distinct dimensions, it still captures facts pertaining to all 10 originally conceptualised dimensions.

A synopsis of the service quality dimensions of the RATER model can be seen in Table 14.

Table 14: RATER Model

Dimension	Meaning	Quality Criteria
RELIABILITY	Delivering on promises.	Timeliness Consistency/regularity Accuracy
ASSURANCE	Inspiring trust and confidence.	Staff competence Respect for users Credibility Probity and confidentiality Safety and security
TANGIBLES	Representing the service physically.	Physical facilities Equipment Technology Employees Communication materials
EMPATHY	Treating customers as individuals.	Access (to staff, services and information) Communication (clear, appropriate and timely) Understanding the user Services appropriate for users' needs Individualised attention
RESPONSIVENESS	Being willing to help.	Willingness to help Provision of prompt services Problem resolution and complaint handling

	Flexibility

VALUE FUNCTION DEVELOPMENT

BACKGROUND

Alarcon *et al.* (2010) have outlined a four-step procedure for value function development. These are:

1. define the tendency (i.e. increase or decrease) of the value function,
2. define the points corresponding to the minimum ($Smin$, value 0) and maximum ($Smax$, value 1) satisfaction,
3. define the shape of the value function (i.e. linear, concave, convex or S-shaped), and
4. define the mathematical expression of the value function.

Since only the first three steps were applied herein, a discussion on only these steps follows.

TENDENCY OF THE VALUE FUNCTION

The value function can be either increasing or decreasing. According to Alarcon *et al.* (2010), the tendency of the value function is dependent on the nature of the indicator (or measurement variable). An increasing function is used when an increase in the measurement variable results in an increase in the decision maker's satisfaction. This type of measurement variable is referred to as a benefit measure. In contrast, a decreasing value function indicates that an increase in the measurement variable results in a decrease in the decision maker's satisfaction. This type of measurement variable is referred to as a cost measure. Refer to Figure 30 (Alarcon *et al.* 2010). In this figure the top part represents a value function for a cost measure and the bottom part represents the value function for a benefit measure.

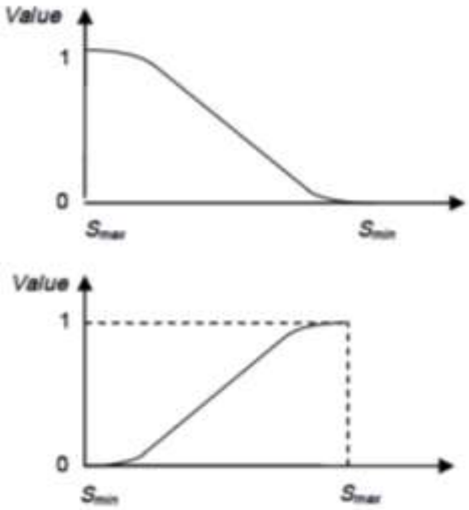


Figure 30: Tendencies of the Value Function

Some value functions can, however, also have a mixed tendency. That is, functions that increase at first but later decrease. As stated in Alarcon *et al.* (2010), this type of function is evident for indicators with two points of minimum satisfaction and one maximum between them or vice versa.

Minimum- and Maximum Points of Satisfaction

The points of minimum- and maximum satisfaction define the limits of the value function on the x-axis: $Smin$ = point of minimum satisfaction and $Smax$ = point of maximum satisfaction. The satisfaction values corresponding to these two points are 0 and 1 (or 100) respectively. However, according to Alarcon *et al.* (2010), these limits correspond to the satisfaction values and not necessarily to the minimum- and maximum values of the measurement variables; which may have (and will in general have) a wider range.

Shape of the Value Function

At this stage, two coordinates have been developed; namely $(Smin, 0)$ and $(Smax, 1)$. These coordinates need to be connected through some type of (continuous) function. As stated in Alarcon *et al.* (2010), there are four types of functions representing the most common relationships found in practice. These are: concave, convex, linear and S-shaped. A discussion of these function types follows (Alarcon *et al.* 2010).

- Concave function
    - This function is used when, starting from a minimum condition, satisfaction (at first) rapidly increases in relation to the indicator. Refer to Figure 31 (a). This type of relationship is chosen when it is more important to move away from the point of minimum satisfaction than to approach the point of maximum satisfaction.

- Convex function
    - This function is appropriate when there is hardly any increase in satisfaction for small changes around the point that generates minimum satisfaction. Refer to Figure 31 (b). This type of relationship is chosen when it is more important to approach the point of maximum satisfaction than to move away from the point of minimum satisfaction.
- Line function
    - This function is used when there is a steady increase in satisfaction. Refer to Figure 31 (c). This type of relationship is chosen when there is a proportional relationship throughout the range.
- S-shape function
    - This function is appropriate when a significant increase in satisfaction is detected at central values, while satisfaction changes little as the minimum- and maximum points are approached. Refer to Figure 31 (d). This type of relationship is chosen when the majority of alternatives are concentrated into a middle range between the points of minimum- and maximum satisfaction.

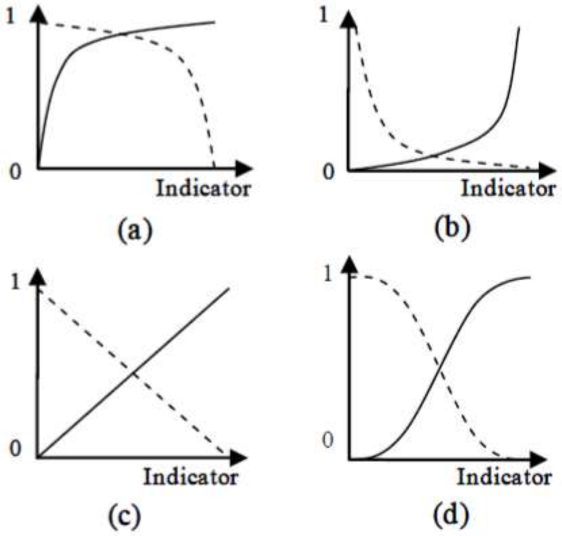


Figure 31: Different Types of Value Functions

According to Alarcon *et al.* (2010), the line function is the default option when no specific criteria can be defined. Therefore, this function type is considered in more detail.

Various methods to standardise measurement variables with a linear scale exist. The common linear scale transformation methods include maximum-, interval- and goal standardisation. A discussion of these methods, as given in RiskChanges (2014), follows:

- Maximum standardisation standardises the scores with a linear function between 0 and the highest absolute score. For a benefit measure[5], the absolute highest score is indicated with 1 (or 100) and for a cost measure[6] the lowest score becomes 1 (or 100).
- Interval standardisation standardises the scores with a linear function between the absolute lowest score and the -highest score. In a benefit measure, the absolute highest score is indicated with 1 (or 100) and the absolute lowest with a 0. For a cost measure, the reverse is true.
- Goal standardisation standardises the scores with a linear function between the user-specified end points (i.e. ideal- or goal value and minimum value) of the range. For a benefit measure, the maximum of the range is indicated with a 1 (or 100) and the minimum with a 0. For cost measure, the reverse is true.

RATE OF CHANGE DEVELOPMENT

BACKGROUND

According to Bartlett (1993), if a quantity changes (i.e. increases or decreases) by a fixed amount per unit time (e.g. ten units per year), the quantity is said to be changing linearly or arithmetically. If a quantity changes (i.e. increases or decreases) by a fixed fraction per unit time (e.g. 0.1 or 10 percent per year), the quantity is said to be changing exponentially or geometrically. If the quantity is increasing, growth is evident; if it is decreasing, decay is evident.

For the application required herein, exponential changes of either growth or decay will be considered in more detail. Refer to Equation 21 (Bartlett 1993).

Equation 21: Exponential Rate of Change

$$R = 100 * k$$

Where:

k = the fractional change per unit time

R = the percent change per unit time (i.e. rate of growth or decay)

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[5] The higher, the better.

[6] The lower, the better.

According to Bartlett (1993), if k is positive and constant, exponential growth is evident. If k is negative and constant, exponential decay is evident. For example: if $k = +0.03$ per year, then the growth rate R is 3 percent per year. Refer to Equation 22.

Equation 22: Fractional Growth or Decay

$$k_t = \frac{N_t - N_0}{N_0}$$

Where:

k_t = the fractional growth ($k > 0$) or decay ($k < 0$) at time t

N = the quantity being evaluated

t = time

N_0 = the value of N at time 0

N_t = the value of N at time t

5.5 MEASUREMENT DATA

5.5.1 DATA AVAILABILITY

In order to know what data needs to be acquired, it is necessary to first know what data is readily available in SA. By considering the current data availability within the advanced transport systems, factors such as whether data acquisition is real-time and whether data processing is automatic, automated or manual were elucidated.

ADVANCED PRIVATE TRANSPORT MANAGEMENT SYSTEMS

Refer to Table 15. This table has been composed with the assistance of one of SANRAL's contractors.

Table 15: Private Transport - Data Availability

MEASUREMENT FIELD	DATA INPUT	DATA OUTPUT	DATA AGE
FMS	Traffic classification with regard to traffic volumes per lane (e.g. loop detectors), vehicle speed (e.g. probe data) and vehicle type (e.g. radar systems and CCTV analytics).	Optimised and safe network flow conditions. Summarised report on traffic counts for freeway capacity management and expansion. Expected travel information dissemination to the public.	Real-time (data) and monthly to quarterly (report).

MEASUREMENT FIELD	DATA INPUT	DATA OUTPUT	DATA AGE
FMS	Traffic management with regard to law enforcement and security (e.g. ANPR system) and operating speed (e.g. average speed over distance cameras).	Report on capacity and longevity of infrastructure and general public safety.	Real-time (data) and monthly to quarterly (report).
	Operational performance management for optimal flow conditions (e.g. ramp metering and HOV lanes)	Report on average queue lengths and average travel speeds with regard to free flow conditions.	Real-time (data) and monthly to quarterly (report).
UTC and AMS	Management of traffic flow conditions and queues (e.g. SCOOT). Manual- or automated traffic counts regarding traffic volumes (e.g. on-site inspections and loop detectors).	Optimised and safe network flow conditions. Summarised report on traffic counts for urban planning and -development.	Real-time (data) and as and when needed.
IMS	Incident detection, -classification, -verification and -notification. Either incidents are detected by operators (e.g. CCTV footage) or operators are notified by external parties.	Performance scorecards and reports showing incident occurrence hotspots and recommendations for network capacity- and safety upgrades. Debriefings with the involved services regarding the incidents to aid the realisation of improved incident scene management in the future.	Real-time (monitoring) and monthly to quarterly (scorecards, reports and debriefings).
Asset Maintenance/ SLA Management	Faults are logged by operators/vehicle providers via e-mail/cell phone and dispatched by the service provider (linked to SLA). Each service provider has his/her own confidential sub-schema that is interrogated by the master schema.	Report on SLA adherence and compliance. Master schema is incorporated into the corporate SAP system to be used in high-level dashboard reporting.	Real-time (logged via email or cell phone).
Information Dissemination	ATMS software supported by the FMS operators/contractors and the TIC 24/7 call centre.	Website (e.g. i-Traffic), Facebook, Twitter, emails, SMS, VMS and HAR.	Real-time (maximum two minutes after incident verification).
Quality Assurance	Real-time CCTV footage alongside major roadways. Manual- and automated quality checks with regard to incident logs.	Audit report on quality and accuracy of incident logs.	Monthly.

MEASUREMENT FIELD	DATA INPUT	DATA OUTPUT	DATA AGE
Event Management	CoCT's official events plan process.	Operational deviation plan as identified for that specific category of event.	As and when needed.

ADVANCED PUBLIC TRANSPORT MANAGEMENT SYSTEMS

Refer to Table 16. This table has been composed with the assistance of the CoCT's IRT department.

Table 16: Public Transport - Data Availability

MEASUREMENT FIELD	DATA INPUT	DATA OUTPUT	DATA AGE
Base System Planning	Route survey data such as: schedules, routes, vehicles, transfers, duties and journey run times (for optimisation).	The base model that is used for operating-, marketing- and communication purposes. This model acts as input to the real-time monitoring system Lio and other real-time provisioning of data services, allows for publicity modules and enables communication with stakeholders and customers.	As and when needed (e.g. if new routes are added to the network, the base model needs to be re-optimised).
Vehicle Tracking	GIS location data from IBIS (Imager on Board the Integral Satellite) unit on vehicles.	Visual analysis of vehicle tracking that is linked to GIS map, strip map type platform and BI reporting platform.	Real-time (updates every 30 seconds).
Schedule Adherence	Route survey data (Trapezed-based).	Visual analysis of schedule adherence that is linked to GIS map, strip map type platform and BI reporting platform.	Real-time (updates every 30 seconds).
Operational Performance	Real-time data from monitoring system Lio and AFC data from bus downloads at depots.	BI reports, integrated into corporate SAP system, for high level dashboard reporting on: schedule adherence, mileage, speed of vehicles, revenue collected per route per stop, etc.	Daily (e.g. schedule adherence analysis), weekly (e.g. trend analysis) and monthly to quarterly (e.g. cost analysis).
Financial Performance	Tap-, load- and OD data from MyConnect cards in respect of EMV and transit products.	Microsoft Excel and Pdf reports on load data and card sales.	Daily (e.g. load and tap data) and monthly (e.g. OD data).
Driver Behaviour Risk Management	Equipment triggered by risky driver behaviour.	Web-based interface with full overview of drivers' behaviour used for post-analytic purposes.	Real-time (when triggered).

MEASUREMENT FIELD	DATA INPUT	DATA OUTPUT	DATA AGE
Asset Maintenance/ SLA Management	Faults are logged by operators/vehicle providers via e-mail/cell phone and dispatched by the service provider (linked to SLA). Each service provider has his/her own confidential sub-schema that is interrogated by the master schema.	Microsoft Excel report on SLA adherence and compliance. Master schema is incorporated into the corporate SAP system to be used in high-level dashboard reporting.	Real-time (logged via email or cell phone).
Public Relations	Output data from Diva and data provided by BI analysis.	Publicity modules, MyCiti service related information and various statistics in relation to the MyCiti service as a whole (e.g. reckless driving and failure to stop).	Weekly to monthly.
Customer Care	Website, Facebook, Twitter and TIC 24/7 call centre.	Email replies to queries. Pdf report on traffic and by-law complaints/offenses (e.g. urinate in public) as well as Microsoft Excel with breakdown of what complaints were about.	Hourly to daily (email replies) and weekly to monthly (list of complaints and their breakdown).
Quality Assurance	Real-time CCTV footage from inside stations, along trunk the route and on-board vehicles as well as spot checks from on-site inspections.	Microsoft Excel report on timetable-, fleet- and infrastructure monitoring. This report highlights which performance evaluation and quality assurance checks failed.	Real-time (e.g. CCTV footage), daily (e.g. monitoring) and monthly to quarterly (e.g. on-site inspections).
Event Management	CoCT's official events plan process.	Operational deviation plan as identified for that specific category of event.	As and when needed.

5.5.2 DATA ACQUISITION

SURVEY DEVELOPMENT

In order to obtain the required measurement data, 11 online questionnaire surveys have been developed. Six of these surveys were used obtain the data needed for KPI standard and/or target development (i.e. value elicitation) and the other five surveys were used to obtain the data needed to establish the importance of each of the performance-related aspects (i.e. weight elicitation). These surveys were created with the aid of the survey development platform supported by the University of Stellenbosch[7].

Based on the requirements posed by this research, the value elicitation of MCDM was segregated among the private- and the public transport environment. In essence, two surveys per interested party were developed. The resulting six surveys are thus: 1) private transport user, 2) public transport user, 3) operator or contractor: private transport, 4) operator or contractor: public transport, 5) employer or client: private transport and 6) employer or client: public transport. All six of these surveys are similar in nature and take on a similar line of questioning. Moreover, in some cases, the questions posed to the same interested party (e.g. transport user) are identical. However, since the transport environments have their own specific operating conditions and -standards, it was anticipated that the answers obtained for these identical questions could sometimes be different.

The five surveys regarding weight elicitation were individually developed for each of the perspectives pertaining to the SBSC. This segregation was deemed necessary such that each survey could specifically address each of the proposed value trees. Moreover, this segregation was also used in such a way that the survey responder would not be overwhelmed with one unnecessary long survey. Due to the in-depth knowledge of ITS systems required for weight elicitation, the chosen role player is the ITS expert. The five developed surveys are thus: 1) ITS expert: practices, 2) ITS expert: processes, 3) ITS expert: profit, 4) ITS expert: people and 5) ITS expert: planet.

The six value elicitation surveys and the five weight elicitation surveys can be viewed in Appendix B and Appendix C, respectively.

POPULATION AND SAMPLE

The population sizes associated with the surveys pertaining to the transport users are evidently vast. In order to render this vastness, it was decided to define their populations and corresponding samples as follows.

For the **private transport users**, the population was defined as all people who commute on freeways in SA. The sample chosen correlates to all people who commute on freeways that are members of the i-Traffic corporation. For the **public transport users**, the population was defined as all people who commute by train in SA. The sample chosen correlates to all people who commute by train that are members of the GoMetro corporation. Both of the aforementioned corporations have approximately

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[7] https://SUNsurveys.sun.ac.za

10 000 members nationally. These corporations have agreed to personally send out the surveys via their platforms such that no confidentially agreements were breached. The identity of the members participating in the surveys was anonymous, participation was voluntary and no incentivisation was provided.

GoMetro promoted the survey by both sending email invitations to their members and by posting the survey on their Facebook page. i-Traffic promoted the survey by both having a link to the survey on their website and by tweeting about the survey on their Twitter page. Moreover, i-Traffic also organised that this author be given the opportunity to promote the survey on the AM radio station Cape Talk (frequency 567). Cape Talk documented this talk as an article, with a link to the survey, on their website and on their Facebook page. This article can be viewed in Appendix D. The full conversation can also be listened to online by streaming it from their website[8].

Due to the relatively small population sizes associated with **the operator or the contractor**, **the employer or the client** and **the ITS experts**, the approach of convenience sampling was deemed viable. With this approach, the members participating in the data capturing were personally selected. Approximately 15 responders per role player group and, where applicable, per transport environment (i.e. private and public) were identified. For the operator or the contractor and the employer or the client, these represent people working in the respective fields nationally. For the ITS experts, these represent people working in the field of ITS internationally. Clearly, the identity of the members that were asked to participate in these survey were known. However, the identity of the members that did indeed participate were unknown. Moreover, participation was still voluntary and no incentivisation was provided.

HUMAN JUDGMENT AND UNCERTAINTY

In order to neutralise the issue of uncertainty described with human judgement, it would have been viable to conduct focus group sessions (prior to the commencement of the data capturing) with the various identified interested parties and role players. These focus group sessions are commonly used in the field of decision making. They not only aid in clearly conveying what is warranted from the survey respondents, but also in attaining a consensus on what is meant by the set of identified measures. If a general consensus is reached, the inevitable error associated with uncertainty can be reduced. However, due to the vast population sizes associated with the transport users, the time

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[8] http://www.capetalk.co.za/articles/5364/phd-student-hell-bent-on-easing-traffic-using-intelligent-transport-systems?utm_content=bufferbcd8e&utm_medium=social&utm_source=facebook.com&utm_campaign=buffer

consuming nature of the focus group sessions and the busy schedules of the operators or the contractors and the employers or the clients as well as the wide-spread locations of the ITS experts, focus group sessions could not be conducted.

In spite of the aforementioned, pilot studies on the transport user surveys were executed and, with regard to the ITS experts, the same group of people asked to participate in the verification and validation of the composition of the SBSC framework were also asked to participate in the ITS expert surveys. The former mentioned aided in ensuring that those surveys were easy to understand (based on the general public's framework of reference) and the latter mentioned aided in providing the experts with background information on how to approach (and what to expect of) those surveys.

MOTIVATION FOR NO INCENTIVISATION

Money has been said to change people's motivation (mainly for the better) and their behaviour towards others (mainly for the worse). The results of nine experiments conducted in Vohs *et al*. (2006) suggested that money brings about a self-sufficient orientation in which people prefer to be free of dependency and dependents. Vohs *et al*. (2006) state that reminders of money (relative to non-money reminders) led to reduced requests for help and reduced helpfulness towards others.

The standard model of labour is one in which individuals trade their time and energy in return for monetary rewards. Heyman and Ariely (2004) proposed that there are two types of markets that determine the relationship between effort and payment. These are: 1) monetary and 2) social. Heyman and Ariely (2004) hypothesised that monetary markets are highly sensitive to the magnitude of compensation, while social markets are not. This perspective can shed light on the well-established observation that people sometimes expend more effort in exchange for no payment (a social market) than they expend when they receive low payment (a monetary market). These ideas are supported by three experiments. The experimental evidence also demonstrated that mixed markets (i.e. markets that include aspects of both social- and monetary markets) more closely resemble monetary than social markets.

The aforementioned reasoning supports the decision of not providing the survey participants with any incentivisation.

DATA CAPTURING

The number of responses obtained and the data capturing period per developed survey can be seen in Table 17.

Table 17: Surveys - Data Capturing

NO.	SURVEY	NUMBER OF RESPONSES	DATA CAPTURING PERIOD
1	*Private Transport User*	39	3 weeks
2	*Public Transport User*	91	3 weeks
3	*Operator/Contractor: Private Transport*	4	3 weeks
4	*Operator/Contractor: Public Transport*	3	3 weeks
5	*Employer/Client: Private Transport*	3	3 weeks
6	*Employer/Client: Public Transport*	6	3 weeks
7	*ITS Expert: Practices*	9	4 weeks
8	*ITS Expert: Processes*	3	4 weeks
9	*ITS Expert: Profit*	4	4 weeks
10	*ITS Expert: People*	5	4 weeks
11	*ITS Expert: Planet*	4	4 weeks

The number of responses obtained for survey number three to survey number eleven comply with what was excepted and are thus deemed satisfactory. However, due to the vastness of the population sizes associated with survey number one and survey number two, it was initially desired (deemed sufficient) to obtain 200 responses. Unfortunately, these numbers could not be obtained. Therefore, it was required to execute statistical analysis on the data obtained from these surveys. This is discussed in Section 6.4.1. Moreover, as can be seen in Table 17, the data capturing period for the survey number seven to survey number eleven was one week longer than that used for the other surveys. This was deemed necessary due to the complexity and the time consuming nature of these specific surveys.

The raw data obtained from all of the aforementioned surveys can be viewed by referring to the attached CD. The content of this CD is listed in Appendix F.

5.5.3 DATA ANALYSIS

DATA PROCESSING

The processing of the data obtained from the surveys developed herein was done by this author.

The first step of the data processing was to wade through the data and to remove inapplicable answers. For example: answers that were incomplete, answers that were wrong due to misinterpretation, and so on. After sifting through the data, the remaining responses were used to calculate the representative performance-related aspect's median value and not its average value. It was decided to use the median values due to the relatively small number of responses obtained. Moreover, by using median values, there is a greater chance for any remaining obscure responses to be excluded from the processed values. In essence, median values are less sensitive to outlier data points.

5.6 MEASUREMENT MODEL

5.6.1 BACK-END DESIGN

By considering the data acquired from the surveys conducted herein, the most important perceptions of the various interested parties have been matched and integrated with the specific aspects of the transport service. This was accomplished by developing: standards and/or targets for all of the identified performance measures, importance weights for all of the performance-related aspects as well as ranks signifying the importance of the index-related considerations.

VALUE ELICITATION

Three value elicitation techniques have been used. These are: 1) direct rating, 2) category estimation and 3) assessing the form of the value function.

DIRECT RATING

The direct rating technique was used to assess the performance of all the measures that were evaluated with the aid of **checklists** and **scorecards**.

With regard to the checklists, the measure's conformity or nonconformity were captured as yes-no answers. The (satisfaction) value associated with the yes-descriptor was identified to be 100 and the (satisfaction) value associated with the no-descriptor was identified to be 0.

With regard to the scorecards, the measure's level of performance were captured by the performance scores. The (satisfaction) values associated with the performance scores were pre-determined without acquiring the input from the representative experts in the field of study. Based on the application required herein, this was deemed viable. The lowest performance level (i.e. a score of 0) was identified to have a (satisfaction) value of 0 and the highest performance level (i.e. a score of 3) was identified to have a (satisfaction) value of 100. Additional (satisfaction) values representing the performance levels in between these lowest- and highest performance levels were also developed. These (satisfaction) values are (mostly) fixed for all the identified qualitative, low granularity measures. That is, the in between performance levels (i.e. a score of 1 and 2) were identified to respectively have a (satisfaction) value of 50 and 75.

CATEGORY ESTIMATION

The category estimation technique was used to assess the performance of all the **increase-decrease** measures (including the identified **indices**). This entailed capturing viable rates of change in descriptive categories. These categories were indicated by score bands. The score bands signify different situations of performance. The (satisfaction) values associated with these score bands were also pre-determined without acquiring the input from the representative experts in the field of study. Based on the application required herein, this was deemed viable. The lowest (i.e. worst) score bands were identified to have a (satisfaction) value of 0 and the highest (i.e. best) score bands were identified to have a (satisfaction) value of 100. Additional (satisfaction) values representing the score bands in between these lowest- and highest score bands were also developed. These (satisfaction) values are (mostly) fixed for all of the increase-decrease measure types. That is, the in between score bands were identified to respectively have a (satisfaction) value of 25, 50 and 75.

Note: during score band development, it was assumed that only normalised data is considered. That is, it was assumed that any growth (or decay) that is evident from one measurement time period to another is taken into consideration when assessing the measures' rates of change. For example: when comparing the number of fatalities evident in two time periods with each another, the observed growth (or decay) in average daily traffic is also taken into consideration; thereby accurately representing the real situation.

ASSESSING THE FORM OF THE VALUE FUNCTION

The value function form assessment technique was used to assess the performance of all the measures that were evaluated with the aid of **value functions**. This entailed capturing the associated (satisfaction) values of (preferably) five distinct performance scores in such a way that the shape of each representative measure's value function could be established. According to Belton and Stewart (2002), this approach is deemed viable.

The (satisfaction) values corresponding to the performance scores were obtained from the value elicitation surveys conducted herein. In these surveys, the respective interested parties were presented with two questions for each of the representative measures. In the first question, the respective interested parties were asked to express their satisfaction with regard to certain data points (or ranges). These data points (or ranges) were pre-determined by carefully considering the application field and then establishing the measurement points (or ranges) that ought to be reasonable for each of the representative measures. These points do include the point perceived to be close to maximum satisfaction. However, they do not necessarily include the point of minimum satisfaction. They are rather representative of the performance scores located in between the points of minimum- and maximum satisfaction. In the second question, the respective interested parties were given carte blanche in expressing their minimum satisfaction thresholds. That is, the "worst" data point that they would tolerate or deem to be satisfactory; after which they would associate anything worse with zero satisfaction.

During value function development, the (pre-determined and user-specified) data points were taken as the x-coordinates. In the case where data ranges were employed, the median values of these respective ranges were used as the representative x-coordinates. The median (satisfaction) values of the responses obtained from the respective surveys were taken as the y-coordinates.

The developed value functions were then standardised by using the line function method. More specifically, it was decided to implement goal standardisation. That is, the plotted data points were standardised by using a linear function between the deducted end points of the range. Any performance score outside of these ranges were set to automatically take on a (satisfaction) value of either 0 or 100. The satisfaction values, corresponding to the performance scores within these ranges, were computed by using the standardised line function. The best (satisfaction) value obtainable was identified to be 100 and the worst (satisfaction) value obtainable was identified to be 0.

WEIGHT ELICITATION

The weight elicitation technique deemed appropriate and hence used was direct rating. Moreover, due to the exhaustiveness of the proposed measurement framework, bottom-up hierarchical weighting was executed. That is, in the weigh elicitation surveys, the ITS experts (as the identified role player) were asked to intuitively weigh the within- and cross family performance-related aspects from the bottom to the top of the hierarchy for each of the respective value trees. The resulting weights obtained were then depicted by weight levels. These weight levels correspond to the performance measurement levels that were defined previously.

Note: the importance values corresponding to the five sustainability perspectives were not obtained. In the final analysis, were these values are required, they were taken to each be equally important.

INDEX ELICITATION

The developed weighted average formulas require perception-related information and importance-related information; both of which can be obtained by conducting surveys among the representative target audiences. However, since the former mentioned was not deemed part of the scope of this research project, its data acquisition was not done herein. Nevertheless, for comprehensiveness reasons, an overview of viable techniques for processing the perception-related information is given. Following this, an overview of the technique (as used herein) for processing the importance-related information is given.

SATISFACTION SCORES

The users can portray their satisfaction with regard to each of the index-related considerations by using a scale similar to the one presented in Figure 29 (Transport for NSW 2014).

In order to make the raw responses (i.e. score points) more interpretable, Sauro (2011) has identified five techniques. These are: 1) percent satisfied, 2) top-box, 3) net top box, 4) Z-score to percentile rank and 5) coefficient of variation. An overview of the first three techniques mentioned follows.

1. **Percent satisfied**. This technique summarises the percentage of respondents that are satisfied with the item. In a seven-point scale (like the one shown in Figure 29 (Transport for NSW 2014), this refers to all of the respondents that checked boxes five (i.e. partly satisfied), six (i.e. satisfied) and seven (i.e. very satisfied).
2. **Top-box**. Here, only the top box is used in such a way that only the percentage of respondents that are very satisfied are summarised.
3. **Net top box**. This technique summarises the respondents' net satisfaction as a percentage. Net satisfaction is computed by subtracting the number of respondents that selected the bottom choice (e.g. very dissatisfied) from the number of respondents that selected the top choice (e.g. very satisfied). This answer is then expressed as the percentage of total responses. If desired, this technique can be altered to include the top- and bottom *two* choices or the top- and bottom *three* choices.

IMPORTANCE WEIGHTS

The data needed to compute the importance weights of the index-related considerations were obtained from the surveys conducted herein. In the developed surveys, the respective interested parties were asked to intuitively rank the different index-related considerations. The rank orders obtained were averaged and then re-ordered from smallest to largest. The smallest rank then became the highest rank (i.e. 1), the second smallest become the second-highest rank (i.e. 2), and so on. These new ranks were then used to calculate the percent weight of each index-related consideration. This was accomplished with the aid of Equation 16 (Alfares and Duffuaa 2008).

5.6.2 FRONT-END DESIGN

MODEL DEVELOPMENT

In order to establish the overall performance of the ITS applications, the information obtained from the aforementioned preference elicitations were synthesised by using the Additive Model inherent to Multi-Attribute Value Theory (MAVT). This model is represented by Equation 19 (Belton and Stewart 2002) and was applied to each of the five sustainability perspectives. As a result, five numerical measurement models have been developed. These models were coded in Microsoft Excel VBA (Visual Basic for Applications).

MODEL VERIFICATION AND VALIDATION

During the course of the preliminary research conducted herein, two prominent software packages that could possibly have been used to verify and validate the developed models were identified. These are: 1) OnBalance and 2) Definite 3.1. Unfortunately, due to the specific requirements posed by this research as well as its associated exhaustiveness, this could not be executed.

Various obstacles were identified. The main obstacle deterring the use of OnBalance was the fact that it only caters for non-hierarchical weighting. With regard to DEFINITE 3.1, the available standardisation options were deemed to be too limited and to have too little flexibility. It was found that DEFINITE 3.1 could not facilitate the construction of the desired standardised value functions required for each of the identified performance measure types (e.g. checklist, index and scorecard). It was especially difficult, possibly even impossible, to construct the standardised value functions applicable to the indices. The difficulty arose from the fact that score bands were used and that the satisfaction values associated with these score bands were not equally distributed. That is, the satisfaction values identified range from 0 to 50, then from 50 to 75 and then from 75 to 100.

Fortunately, based on the mathematical principles underlining the Additive Model, it was possible to ensure (as the VBA coding was compiled) that the correct procedure was being followed. For example: prerequisites such as the fact the within family (normalised) weights with the same parent node for each weight level need to adds up to one. Moreover, the effectiveness, validity and accuracy of the developed VBA models were ascertained by generating default values and using them as input to these models. Based on this author's opinion, the results obtained were not only deemed fitting and relevant, but also extremely valuable.

5.7 PERFORMANCE DASHBOARD

5.7.1 DASHBOARD DEVELOPMENT

In order to present the developed measurement models as a management tool, they have been represented as Graphic User Interface (GUI) dashboard. The developed performance dashboard documents the results from all five of the Microsoft Excel VBA models, on a per month basis, over an evaluation period of a year. This dashboard provides a graphical representation of an ITS project's performance in each sustainability perspective as well as its overall performance. This dashboard was coded in Microsoft Excel.

5.8 PERFORMANCE MANAGEMENT

5.8.1 PERFORMANCE-BASED CONTRACTING

At this stage, performance monitoring (i.e. collecting and analysing all of the relevant information needed for performance evaluation) and performance assessment (i.e. evaluating the project's performance based on the standards and/or targets stipulated) have been executed. The next step is to instigate performance management. This was accomplished by advocating performance-based contracting.

CIPS and NIGP (2012) define performance-based contracting as follows.

> *"It is a results-oriented contracting method that focuses on the outputs, quality or outcomes that may tie at least a portion of a contractor's (or an operator's) payment, contract extensions or contract renewals to the achievement of specific, measurable performance standards and -requirements."*

5.8.2 INCENTIVISATION

With the aid of performance-based contracting, performance can be incentivised based on the identified aspects' measurement- and payment structures. For the application required herein, the incentivisation has been based on a combination of activity-based payments and performance-related adjustments to the contractor's (or the operator's) nominal service payments. It is believed that this will aid to ensure that performance directly relates to the strategic objectives of the employer (or the client), the operational objectives of each of the business areas underlining the project and the (potentially high) service level expectations of the public.

5.8.3 PERFORMANCE MANAGEMENT INCENTIVE POLICY

The foundation for incentivisation is a performance management incentive policy. A discussion of the main elements relating to such a policy, as identified by this author, follows.

- Performance indicators.
    - The set of performance measures (i.e. KPIs) identified for evaluation.
- Performance appraisal period.
    - The entire period for which performance is managed and assessed. This period corresponds to the duration of the project. Transport-related projects typically have a life span of five to eight years.
- Performance review cycle.
    - The period for which performance-to-date is evaluated. Performance is typically reviewed either monthly or quarterly. The review cycle is dependent on the chosen payment period.
- Performance review process.
    - The formal process followed in reviewing the project's overall performance. This includes a discussion on the principles of performance assessment. That is, the chosen target service levels and score bands, their associated point allocation, the computation of the total performance score and then its standardisation.
- Payment structure.
    - The monetary incentives and -disincentives linked to the results of performance appraisal. This includes the chosen incentivisation thresholds.

- Payment period.
    - The period for which service payments are made. For operation- and maintenance activities, a monthly payment period is commonly used. For design- and build works activities, payments are made on acceptance of the works delivered.
- Below par performance.
    - The terms and conditions associated with severe underperformance and the late delivery of build-related activities.

5.8.4 IMPLEMENTATION PROCEDURE

PERFORMANCE INDICATORS

For simplification reasons and due to the exhaustiveness of the proposed performance measurement framework, only the measures pertaining to the SBSC perspective: processes were included in performance appraisal. Moreover, this decision is supported by the fact that the success of any project is greatly influenced by the management of its operation-, service- and maintenance activities.

PERFORMANCE APPRAISAL PERIOD AND PERFORMANCE REVIEW CYCLE

Both the performance appraisal period and the performance review cycle may vary based on the employer's (or the client's) needs and/or the specific project's desired outcomes. Moreover, the chosen review cycle is dependent on the chosen payment period. However, based on the application required herein, the performance appraisal periods has been set to five years and the performance review cycle has been set to one month.

PERFORMANCE REVIEW PROCESS

TARGET SERVICE LEVELS AND SCORE BANDS

Target service levels and score bands for the performance measures pertaining to the SBSC perspective: processes have been established. This was accomplished by using four performance thresholds. These are: 1) target service level, 2) top score band, 3) middle score band and 4) bottom score band. A discussion on the chosen performance thresholds, per identified data type, follows.

- For the ratio data, the target service level has been set to performance scores that result in a satisfaction of more than 95%. The top score band has been set to performance scores that result in a satisfaction of more than 80% and less than or equal to 95%. The middle score band has been set to performance scores that result in a satisfaction of more than 65% and less than or equal to 80%. The bottom score band has been set to performance scores that result in a satisfaction of 65% or less. If deemed necessary, each respective measure could have its own representative target service level and score bands. However, for simplification reasons, these were taken to be the same for all of the measures that have ratio data.

- For the interval data, the target service level has been set to decay rates of less than -0.075 and growth rates of more than 0.075. The top score band has been set to decay rates of more than or equal to -0.075 and less than -0.05 and growth rates of more than 0.05 and less than or equal to 0.075. The middle score has been set to decay rates of more than or equal to -0.05 and less than -0.025 and growth rates of more than 0.025 and less than or equal to 0.05. The bottom score band has been set to decay rates of -0.025 and more and growth rates of 0.025 and less. If deemed necessary, each respective measure could also have its own representative target service level and score bands. However, for simplification reasons, these were taken to be the same for all of the measures that have interval data (and all of the identified composite measures).
- For the ordinal data, specifically the scorecard measures, the target service level has been set to a score of three. The top score band has been set to a score of two. The middle score band has been set to a score of one. The bottom score band has been set to a score of zero. (Note: no indices are evident in the SBSC perspective: processes.)
- Since there are only two possible outcomes pertaining to the nominal data (i.e. yes or no), only one score band is needed. The target service level has been set to "yes" and the top-, middle- or bottom score band could be set to "no". The decision regarding which score band to use depends on the degree to which the employer (or the client) wishes to penalise the contractor (or the operator) for noncompliance. If deemed necessary, each respective measure could also have its own representative score band representing the "no" outcome. However, for simplification reasons, the middle score band was deemed feasible for all of the measures that have nominal data.

POINT ALLOCATION

Each of the aforementioned performance thresholds have been associated with performance points. If deemed necessary, each respective measure could have its own, unique points allocation. However, for simplification reasons, all of the identified measures were allocated with the same performance points as determined by the performance thresholds. A discussion on the chosen points, per stipulated performance threshold, follows.

If the target service level is met or exceeded, the contractor (or the operator) needs to be rewarded with ten points (i.e. +10). If performance falls within the top score band, the contractor (or the operator) needs to be penalised with ten points (i.e. -10). If performance falls within the middle score band, 50 points need to be deducted (i.e. -50). If performance falls within the bottom score band, 500 points need to be deducted (i.e. -500). In essence, the contractor (or the operator) is only rewarded if the target service level is met and is penalised for any suboptimal performance.

This point allocation procedure needs to be executed daily for each of the identified measures and the allocated points need to be accumulated over the performance review cycle. In essence, each measure's performance-related value for the given day is evaluated against the stipulated performance threshold. Then, based on its corresponding threshold, the measure gets rewarded (i.e. positive points) or penalised (i.e. negative points). Positive points need to be accrued for all of the days above the target service level and negative points need to be accrued for all of the days below the target service level. The aforementioned entails accumulating the points in each of the score bands above the representative score band. That is, if the measure's performance-related value for the given day falls within the bottom score band, the measure needs to be penalised by the sum of the points associated with the bottom-, middle- and top score bands. An example follows.

During a 30-day month, the following instances are logged for measure xyz:

18 days above the target service level = 18 x 10 points = 180 points
5 days in the top score band: 5 x (-10) points = -50 points
4 days in the middle score band: 4 x (-50) points plus 4 x (-10) points = -240 points
3 days in the bottom score band: 3 x (-500) points plus 3 x (-50) points plus 3 x (-10) points = -1680 points

TOTAL PERFORMANCE SCORE

The sum of the aforementioned points is representative of each measure's performance score. In this case, the performance score for measure xyz, for the specific 30-day month, is: -1790 (i.e. 180 - 50 - 240 - 1680). This score needs to be computed for each of the identified measures by accumulating their respective (daily) points over the performance review cycle. However, in order to obtain an idea of the project's overall performance, the performance scores of all of the identified measures also need to be added. The answer of this summation then represents the project's total performance score.

Note: it could be viable to also compute the total performance score per stipulated performance area. That is, adding the respective performance scores of all of the measures pertaining to the same performance area. With the aid of this computation, it would be possible to obtain an idea of the project's performance in each of the stipulated performance areas.

STANDARDISED PERFORMANCE SCORE

The total (project or performance area) performance score needs to be standardised. That is, the total performance score needs to be scaled such that it takes the absolute worst- and the absolute best performance situations into consideration. The former mentioned refers to the lowest score obtainable (i.e. absolute minimum score) and the latter mentioned to the highest score obtainable (i.e. absolute maximum score).

The standardised performance score was computed with the aid of Equation 23.

Equation 23: Standardised Performance Score

$$Standardised\ Performance\ Score = \frac{Total\ Performance\ Score - Absolute\ Minimum\ Score}{AbsoluteMaximum\ Score - Absolute\ Minimum\ Score}$$

Where:

Standardised performance score is a value between 0 and 1.

Absolute worst performance occurs when performance falls in score band three every day of the performance review cycle.

Absolute best performance occurs when the target service level is met or exceeded every day of the performance review cycle.

With the point allocation procedure utilised herein, a measure can receive a minimum score of -16800 [30 x (-10)] + [30 x (-50)] + [30 x (-500)] and a maximum score of 300 [30 x 10]. However, since each measure can respectively obtain either -16800 or +300, the total number of measures being evaluated also need to be taken into consideration. For example: if five measures are being evaluated, the absolute minimum score is -84000 (i.e. -16800 x 5) and the absolute maximum score is 1500 (i.e. 300 x 5).

The computed standardised performance score then acts as the yardstick for determining the contractor's (or the operator's) necessary compensation as deducted from the chosen payment structure.

PAYMENT STRUCTURE

For profitability and sustainability reasons, incentivisation thresholds have been used to establish the contractor's (or the operator's) necessary compensation. (Note: the incentivisation thresholds are not the same as the previously mentioned performance thresholds.) Incentivisation thresholds may vary based on the employer's (or the client's) needs, the specific project's desired outcomes and/or the associated service payment level of the contractor (or the operator). However, a compensation in the region of +5% to +10% and a penalisation in the region of -10% to -5% are commonly employed.

For the application required herein, the incentivisation thresholds have been represented by percentile regions. Five percentile regions were identified. Refer to Table 18.

Table 18: Percentile Regions

No.	Percentile Region	Incentivisation Threshold
1	< 0.5	-10%
2	0.5 - 0.75	-5%
3	0.75 - 0.85	0%
4	0.85 - 0.95	+5%
5	0.95 - 1	+10%

The contractor's (or the operator's) necessary compensation can be determined by mapping the project's standardised performance score to the percentile regions given in Table 18. Depending on which percentile region the standardised performance score belongs to, the contractor (or the operator) is either rewarded or penalised with the corresponding incentivisation percentages. In essence, based on the chosen incentivisation thresholds, a contractor (or an operator) can either earn a maximum 110% or a minimum of 90% of the nominal service payment.

PAYMENT PERIOD

The payment period may vary based on the employer's needs and/or the specific project's desired outcomes. However, since operation- and maintenance activities usually receive monthly service payments, their payment periods have been set to one month. No payment periods have been set for the design- and build works activities, since payments need to be made on acceptance of the works delivered.

BELOW PAR PERFORMANCE

In order to ensure the prosperity of the project under consideration, the terms and conditions associated with severe underperformance and late delivery of build-related activities have been established. These terms and conditions are set by the employer (or the client) and need to be thoroughly conveyed to the contractor (or the operator).

However, based on the application required herein, severe underperformance has been identified to occur if the project as a whole consecutively underperforms or if the contractor (or the operator) consecutively underperforms in a given performance area or for a given performance measure. A clear stipulation of what constitutes consecutively is needed. For example: how many months of underperforming would translate into below par performance? In this case, three months were deemed valid. With regard to build-related activities (i.e. systems and infrastructure) that are delivered late, a clear stipulates of what constitutes late delivery is also needed. For example: how many days or weeks after the delivery date would translate into below par performance? In this case, a week was deemed valid.

If any below par performance is detected, the contractor (or the operator) needs to be provided with a written notice. This notice then advises the contractor (or the operator) to make the necessary corrections within a specific timeframe. If the contractor (or the operator) does not adhere to the conditions stipulated in the written notice, contract termination needs to be considered.

6. RESEARCH APPLICATION

6.1 PERFORMANCE MEASUREMENT FRAMEWORK

6.1.1 FRAMEWORK VERIFICATION AND VALIDATION

OVERVIEW

Approximately 15 personally selected practitioners, worldwide, were asked to provide feedback on the composition of the proposed SBSC framework. Six practitioners consummated the request and provided invaluable insights and thoughts for consideration. These are:

- Anton Struwig (SA): professional ITS consultant at Techso.
- Schalk Smit (SA): MyCiTi Card Manager at TCT.
- Dr Meng Lu (The Netherlands): chair of the International Benefits, Evaluation and Costs (IBEC) working group.
- Pierre Pretorius (USA): principal at Kimley-Horn and Associates Inc. and ITS Specialist.
- Tom Kern (USA): interim president and Chief Executive Officer (CEO) of ITS America.
- Andrew Pickford (China): CEO of Transport Technology Consultants Ltd. and Performance Management/ ITS Specialist.

The identified practitioners' feedback were assessed and, where deemed relevant, the content of the SBSC framework was adjusted accordingly. The initial version of the proposed SBSC framework can be viewed by referring to the website developed by this author.

COMMENTS AND ALTERATIONS

Neutral comments included, among others, indicating that there are differences between the terminology and grammar in the USA and in SA. Moreover, there were mixed feelings regarding the comprehensiveness of the proposed SBSC framework. The framework's comprehensiveness was praised for following a thorough and consistent approach. Tom Kern said:

> *"This is a very impressive body of work, both in terms of the comprehensive framework you have created and the thoroughness and consistency with which you have defined the concept and elaborated on the key consideration of how to collect the data to substantiate and evaluate the effectiveness of the system." - Tom Kern*

However, concerns were also expressed since comprehensiveness adds complexity. For example: Pierre Pretorius stated that, due to the framework's broad- and comprehensive coverage, it will most likely only be applied in parts.

Minor alterations included, among others, the rectification of typographical errors as well as renaming, rephrasing and/or elaborating on certain performance-related aspects. Major alterations included, among others, introducing different/new performance-related aspects (as recommended) as well as introducing an extra consideration aspect in the field of future modifications.

A discussion on some of the major alterations that have been implemented follows.

- The performance sub area: information system governance procedures was augmented to include additional measurement fields. These included data accuracy, data quality and data accessibility.
- The performance sub area IMS was augmented to include an additional measurement field: staff safety.
- It was recommended that the performance sub area: operating efficiency include supply- and demand indicators. Therefore, its initial measurement field (i.e. volume) was replaced by the demand-supply relationship.
- Initially, the performance category: technology reliability only had one performance area: technology performance. However, it was recommended that technology reliability rather be assessed by evaluating both system health and system performance.
- The performance area: financial feasibility was augmented to include an additional performance sub area: social costs.
- The performance sub area: service promotion was modified to include the following measurement fields: raising awareness, developing understanding and securing acceptance.
- With regard to the performance areas: air pollution-, noise exposure- and energy use monitoring, it was recommended that their respective measurement fields: trend evaluation rather be assessed by taking emission-, sound- and energy intensity as their respective performance measures.

GENERAL CONSENSUS

In spite of the aforementioned comments and alterations, the practitioners were generally consent with the composition of the proposed SBSC framework. Their overall feelings were that the approach followed is systematic and that the framework could be useful for all ITS projects in any country (not just SA).

6.1.2 FRAMEWORK ARRANGEMENT

TABULAR REPRESENTATION

The five tabular representations of the developed framework can be seen in Table 20 to Table 24. For clarification purposes, an example of how to interpret these tables follows. Refer to Table 19.

Table 19: Framework Interpretation

L0	**Operations, Services and Maintenance**		
L1	Technology Reliability		
L2	System Health	System Performance	
L3	System Availability	Equipment Quality	Data Quality
L4	System Functionality	Value Evaluation	Data Verification and Validation
L5	System Uptime (Availability Targets)	Mean Time Between Failures	Error Rates (Performance Targets)

Table 19 can be interpreted by adopting the reasoning as explained below.

- Operations, Services and Maintenance represent one of the identified SBSC perspectives.
- Technology reliability is one of performance categories relating to operations, services and maintenance.
- System health and system performance form the performance areas of technology reliability.
- System availability forms the performance sub area of system health. Equipment quality and data quality form the performance sub areas of system performance.
- System functionality is the measurement field for system availability. Value evaluation is the measurement field for equipment quality. Data verification and validation is the measurement field for data quality.
- System functionality can be established by evaluating the system uptime (with regard to the availability targets). Value evaluation can be executed by determining the mean time between failures. Data verification and validation can be executed by determining the error rates (with regard to the performance targets).

Table 20: SBSC - Governance, Planning and Decision Making

0	**PRACTICES**																							
1	**Legal Compliance**					**Regulatory Enforcement**					**Research & Development**			**Institutional Liaison**				**Data Governance**						
2	Legal Sources					Regulators	Regulatory Documents				Research Support	Creativity Support		Institutional Coordination & Cooperation			Institutional Robustness	Data Management						
3	Legislations & Acts					Governing Bodies	Regulations & Policies				Research Development	Project Development		Operational Alignment		Strategy Alignment	Business Continuity	Information System Governance Procedures						
4	Transport	Environment	Labour	Safety & Security	Communications	Industry Role Players	Standards	Manuals	Guidelines & Instructions	Statements, Plans & Frameworks	Project-based Learning	Innovation Management	Continuous Improvement	Activity Integration	Technical Compatibility	Collaborative Relationships	Risk Management	Data Collection	Data Accuracy	Data Retention	Data Security	Data Quality	Data Fusion	Data Accessibility
5	National Road Traffic Act, National Land Transport Act, National Road Safety Act, SANRAL and National Roads Act & Road Traffic Management Corporation Act	National Environmental Management Act & Environment Conservation Act	Labour Relations Act, Basic Conditions of Employment Act, Employment Equity Act, Occupational Health and Safety Act & Skills Development Act	Disaster Management Act & South African Police Service Act	Promotion of Access to Information Act & Electronic Communications and Transactions Act	SA Institute of Civil Engineers, Committee of Urban Transport Authorities, Engineering Council of SA, ITSSA, Consulting Engineers SA, Committee of Land Transport Officials & SA Bureau of Standards	SA National Standards & SABS/ Technical Committee Standards	SA Road Traffic Signs Manual, Road Safety Audit Manual & Routine Road Maintenance Manual	Urban Transport Guidelines, Technical Methods for Highways, COLTO Incident Management Guidelines, Guidelines for Human Settlement, Planning and Design & EMV Card and AFC Data Structure Specifications	White Paper on National Transport Policy, Moving SA Action Agenda, National Development Plan 2030 & National Transport Master Plan 2050	Discharge & Share Information for Data Analysis	Ideation	Competitive Analysis	Agreements on Planning & Design Practices	Agreements on Operating Protocols & Technical Matters	Commitments to Sharing of Resources & Information	Disaster Recovery & Services	Data Source & Acquisition Protocols	Data Accuracy Protocols	Data Archival Protocols	Confidentiality, Integrity & Availability (CIA) Protocols	Quality Checking Protocols	Filtering, Cleaning & Presentation Protocols	Data Accessibility Protocols

Table 21: SBSC - Operations, Services and Maintenance

<table>
<tr><td>0</td><td colspan="33">PROCESSES</td></tr>
<tr><td>1</td><td colspan="23">Operational Performance</td><td colspan="3">Technology Reliability</td><td colspan="7">Asset Management & Maintenance</td></tr>
<tr><td>2</td><td colspan="6">Service Reliability</td><td colspan="6">Service Convenience</td><td colspan="7">Operational Seamlessness</td><td colspan="4">Operating Efficiency</td><td>System Health</td><td colspan="2">System Performance</td><td colspan="4">Asset Management</td><td colspan="3">Asset Maintenance</td></tr>
<tr><td>3</td><td colspan="2">Travel Time Variability</td><td colspan="2">Information Validity</td><td colspan="2">Public Travel & Personal Safety</td><td colspan="2">Accessibility</td><td colspan="2">Connectivity</td><td colspan="2">Regularity</td><td colspan="7">Incident Management Systems</td><td colspan="3">Service Quality</td><td>Service Utilisation</td><td>System Availability</td><td>Equipment Quality</td><td>Data Quality</td><td colspan="4">Operations Management</td><td>Preventative</td><td colspan="2">Corrective</td></tr>
<tr><td>4</td><td>Travel Time Duration</td><td>Schedule Adherence</td><td>Timeliness</td><td>Accurate & Available</td><td colspan="2">Incident Statistics</td><td>Access Point Proximity</td><td>Network Characteristics</td><td colspan="2">Access Options</td><td>Mode Preference</td><td>Periodicity</td><td>Occurrence & Detection</td><td>Verification & Classification</td><td>Authority Notification</td><td>Respondent Dispatch</td><td>Public Alert</td><td>Coordination</td><td>Staff Safety</td><td>Density & Congestion</td><td colspan="2">Mobility</td><td>Demand-Supply</td><td>System Functionality</td><td>Value Evaluation</td><td>Data Verification & Validation</td><td>Record</td><td>Monitor</td><td>Control</td><td>Evaluate</td><td>Scheduled Logs</td><td colspan="2">Defect Logs</td></tr>
<tr><td>5</td><td>Travel Time Factor</td><td>On-time Performance</td><td>Information Refresh Rate & Latency to Posting Updates</td><td>Supporting Electronic Management System & Manual Methods</td><td>Crash: no injuries, Crash: light to severe, Crash: fatalities & Break-downs</td><td>Property Crime Incidents</td><td>Access Time & Distance</td><td>Quality of Road & Transit Line</td><td>Commuting Time</td><td>Transfer Distance</td><td>Modal Split</td><td>Service Frequency</td><td>Detection Time</td><td>Verification Time</td><td>Notification Time</td><td>Response Time</td><td>Alert Time</td><td>Clearance Time</td><td>Adverse Health Conditions & Secondary Incidents</td><td>Level of Service & Degree of Crowding</td><td>Network Travel Speeds</td><td>Queue Length & Waiting Time</td><td>Degree of Saturation</td><td>System Uptime wrt Availability Targets</td><td>Mean Time Between Failures</td><td>Error Rates wrt Performance Targets</td><td>Asset Register</td><td>Network Surveillance System</td><td>Positioning System</td><td>Status Report & Supporting Electronic Management System</td><td>Number of Planned Tickets vs. Number of Tickets Fulfilled</td><td>Number of Tickets Logged</td><td>Mean Time To Repair</td></tr>
</table>

Table 22: SBSC - Money Matters

0	PROFIT																			
1	**Economic Performance**													**Financial Performance**						
2	Economic Sustainability				Economic Vitality		Socio-Economic Prosperity							Financial Feasibility (Benefit to Cost Analysis)						Investment Management
3	System Adaptability		System Preservation		Economic Development	Economic Growth	(Social) Benefits								Non-recurring Costs	Recurring Costs		Miscellaneous Costs	Social Costs	Investment Performance
4	Operational Resilience		Project Infrastructure Status Evaluation		Business Opportunities	Service Expansion	Energy & Environment		Safety	Efficiency	Customer Satisfaction		Mobility	Productivity	Capital Expenditure	Operating Expenditure		Unforeseen Expenditure	Negative Transport Externalities	Capital Gain
5	Scalability	Responsiveness	Traveller Experience Evaluation	Age Distribution & Remaining Useful Life of Transit Vehicles	Jobs Created	Capacity Building & Infrastructure Development	Traffic Flow Conditions	Public Transport Use	Primary & Secondary Incidents	Network Throughput	Confidence	Perception	Ease of Movement	System Effectiveness	Long-term Assets	Selling Expenses	General & Administrative Expenses	Fines, Law Suits & Environmental Damage Costs	Congestion, Accidents & Pollution	ROI

Table 23: SBSC - People Matters

0	PEOPLE																										
1	**Public Relations**							**Customer Service**								**Social Sustainability**						**Human Resource Management**					
2	Marketing			Networking				Traveller Information Provision				General Support Information				Sustainable Service Delivery				Sustainable Living		Employee Performance Management					
3	Service Promotion (Media)			Service Interaction (Social Media)				Assist	Confirm	Notify	Advise	Logging Attendance		Inter-personal Interaction	Self-service Systems	Social Justice		Social Equality		Social Development		Employee Satisfaction	Employee Commitment	Employee Engagement		Employee Development	
4	Raising Awareness	Developing Understanding	Securing Acceptance	Attractiveness	Exposure	Productive Relationships		Trip Planning	Transit & Traffic Information	Incident Notification	Route Guidance	Inquiries, Queries, Complaints & Compliments		Workforce	Service Inventory & Technology	Service Affordability		Social Inclusion		Public-Service Alignment		Job & Operating Environment	Adherence to Policy Agreements	Organisational Structure (Communication Channels)		Advancing Skillsets	Improvement Tracking
5	Campaigns	Publicity Modules	Public Information Modules	Size of Social Community/ Social Media Platform	Reposts or Shares	Type & Trend of Postings	Peer & Public Reviews	Routing Services	Modes, Fare & Schedule	Crashes, Adverse Weather Conditions, Schedule Delay & Strike	Alternative Route Options	Reaction Time	Helpfulness	Courtesy, Appearance & Knowledge	Simple & Easy to Use/ Understand	Running & Maintenance Cost	Subsidies (Discounted Fares)	Road Placement	Amenities for Disabled People	Usability Study	Community Development Programs	Employee Satisfaction Survey	Absenteeism Evaluation	Provision of Focus Groups	Availability of Trauma Counselling	Training Services	Progress Evaluation

Table 24: SBSC - Environmental Matters

0	PLANET													
1	**Air Quality Management**			**Climate Change Management**			**Noise Management**				**Energy Management**			
2	Air Pollution Monitoring			Weather Monitoring			Noise Exposure Monitoring				Energy Use Monitoring			
3	Mobile Source & Greenhouse Gas Emissions			Driving Behaviour			Noise Sources & Receivers				Energy Efficiency			
4	Governance	Mitigation	Trend Evaluation	Governance	Mitigation	Trend Evaluation	Governance	Mitigation		Trend Evaluation	Governance	Mitigation	Trend Evaluation	
5	Priority Pollutants	Emission Control Technologies & Reducing Activities	Emission & Air Quality Trends	Weather Conditions	Weather Control Technologies & Activities	Weather-related Incidents	Nosie Exposure	Noise Screening at Source	Noise Protection at Receiver	Noise Exposure Levels & Time Trends	Consumption Levels & Rates	Efficiency Programs	Energy Use Trends	Energy Efficiency Score

VALUE TREE REPRESENTATION

The five value tree representations of the developed framework can be seen in Figure 32 to Figure 36.

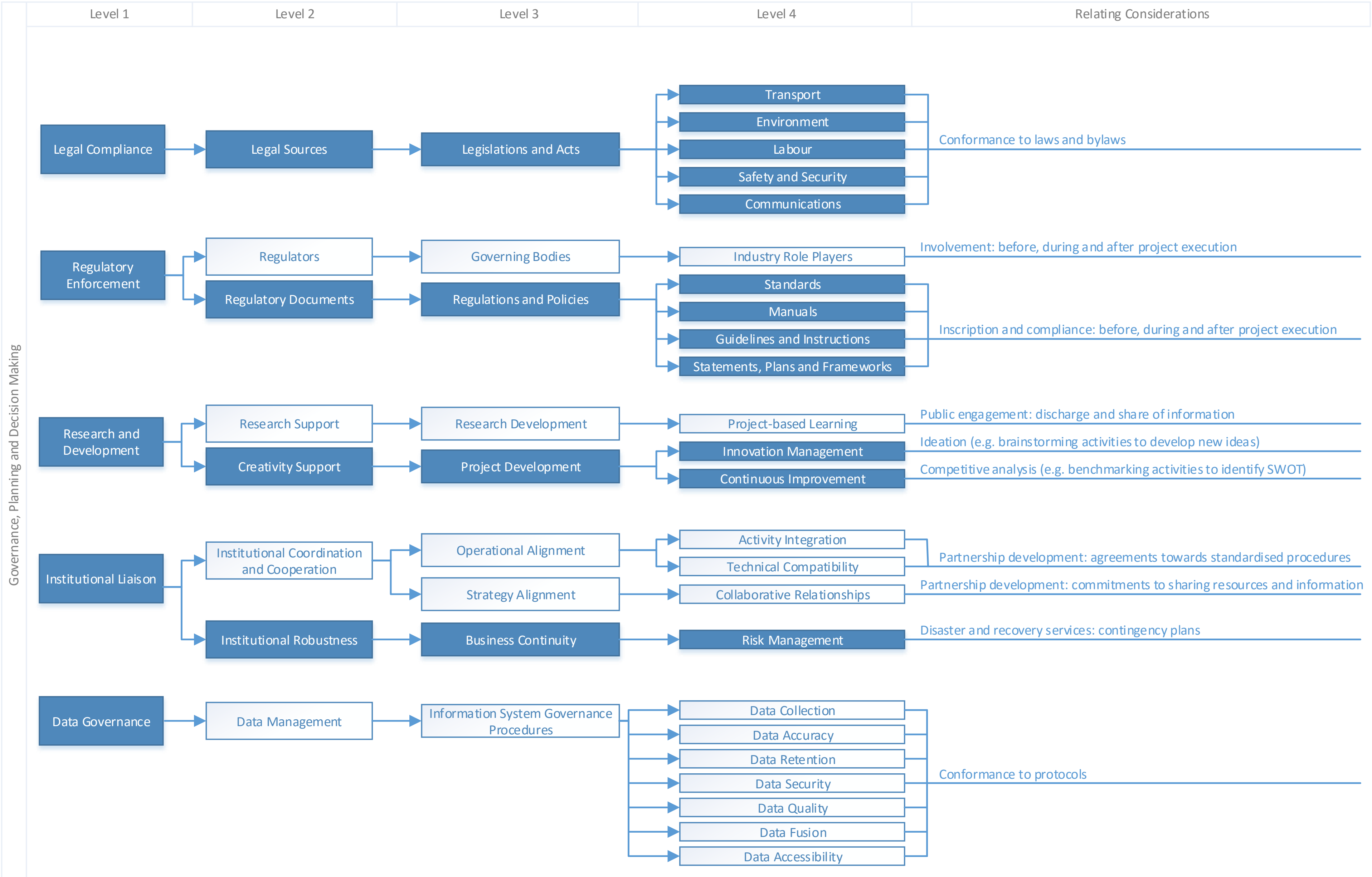
Figure 32: Value Tree - Governance, Planning and Decision Making

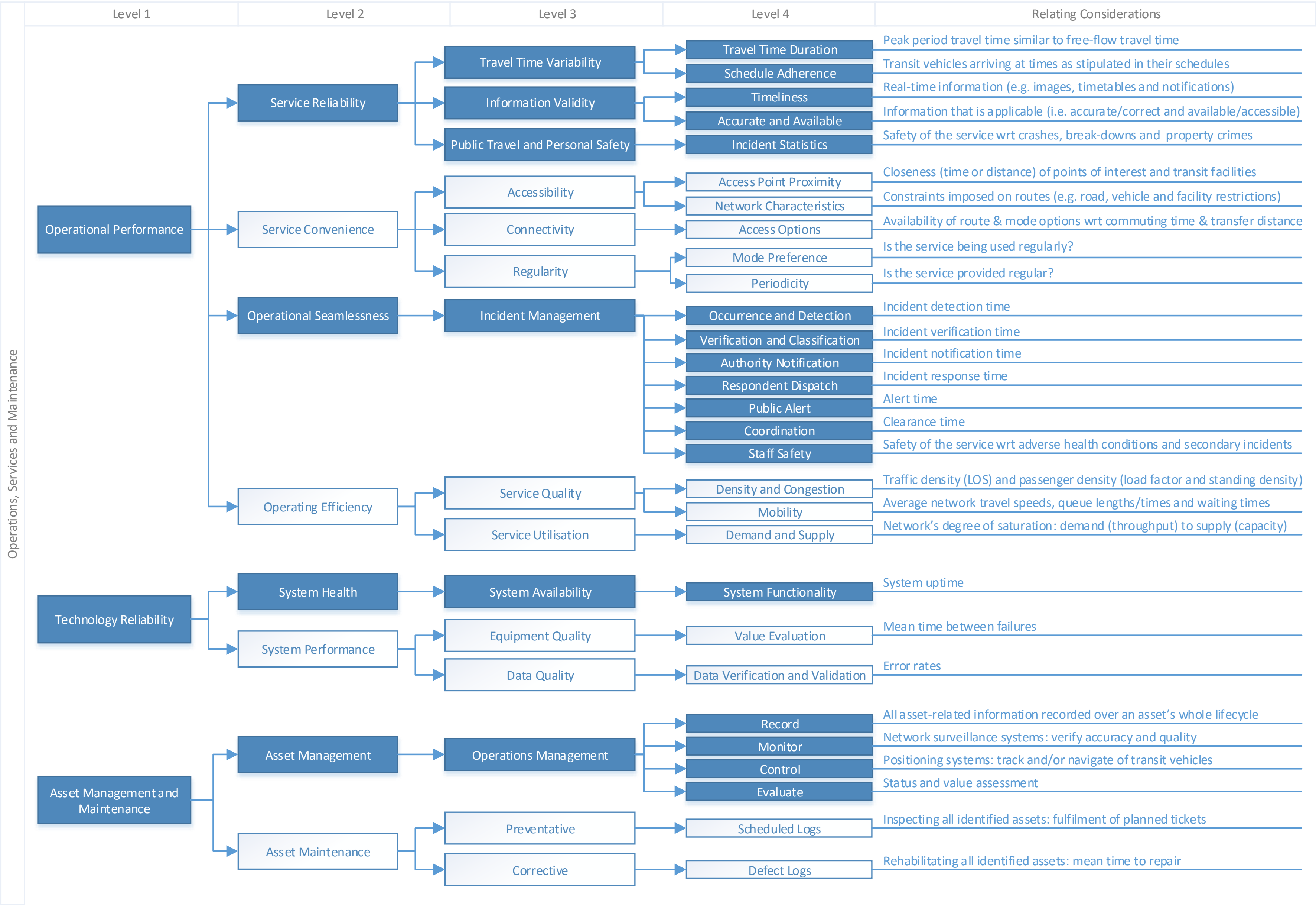
Figure 33: Value Tree - Operations, Services and Maintenance

Figure 34: Value Tree - Money Matters

Figure 35: Value Tree - People Matters

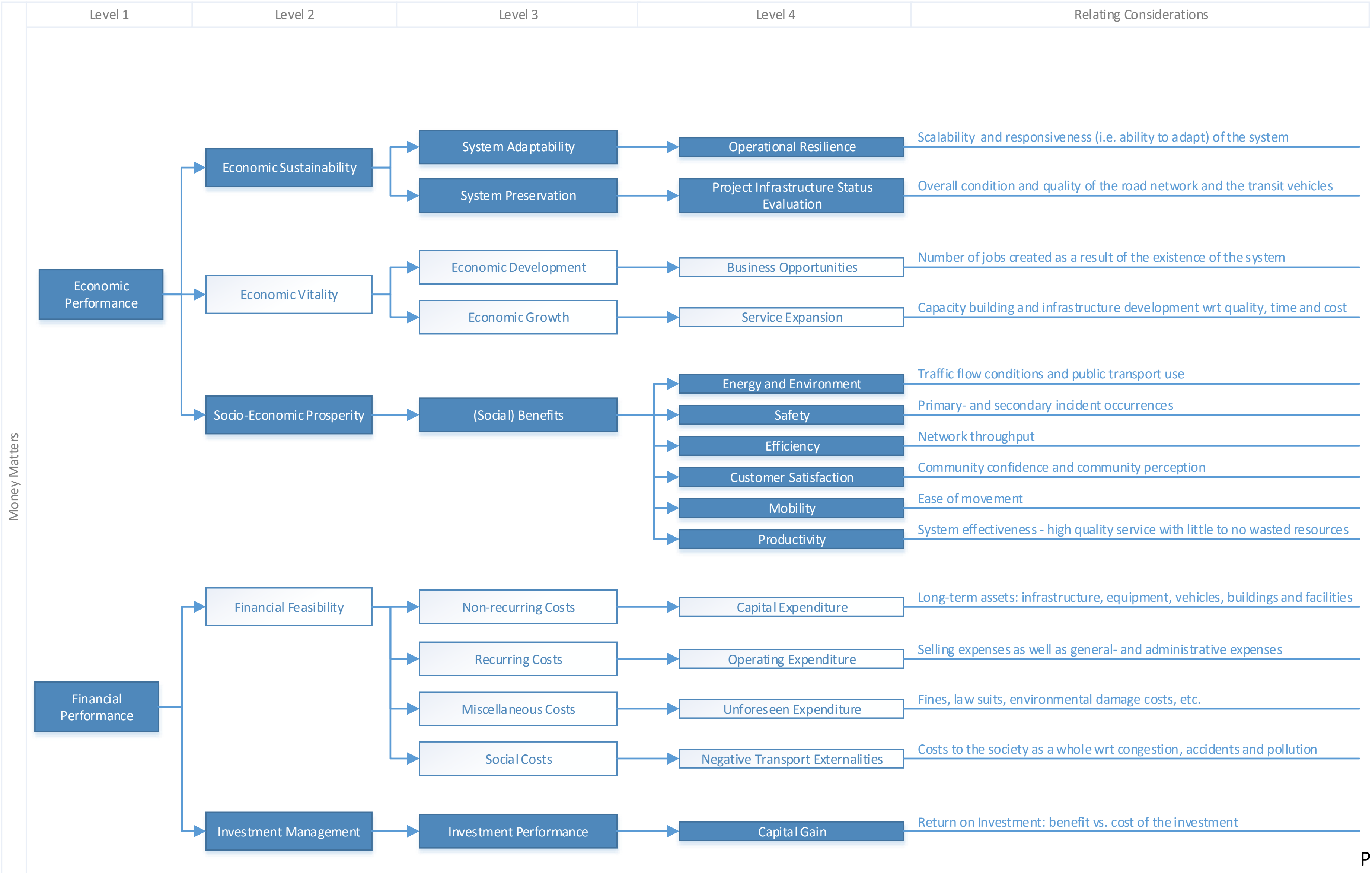
Figure 36: Value Tree - Environmental Matters

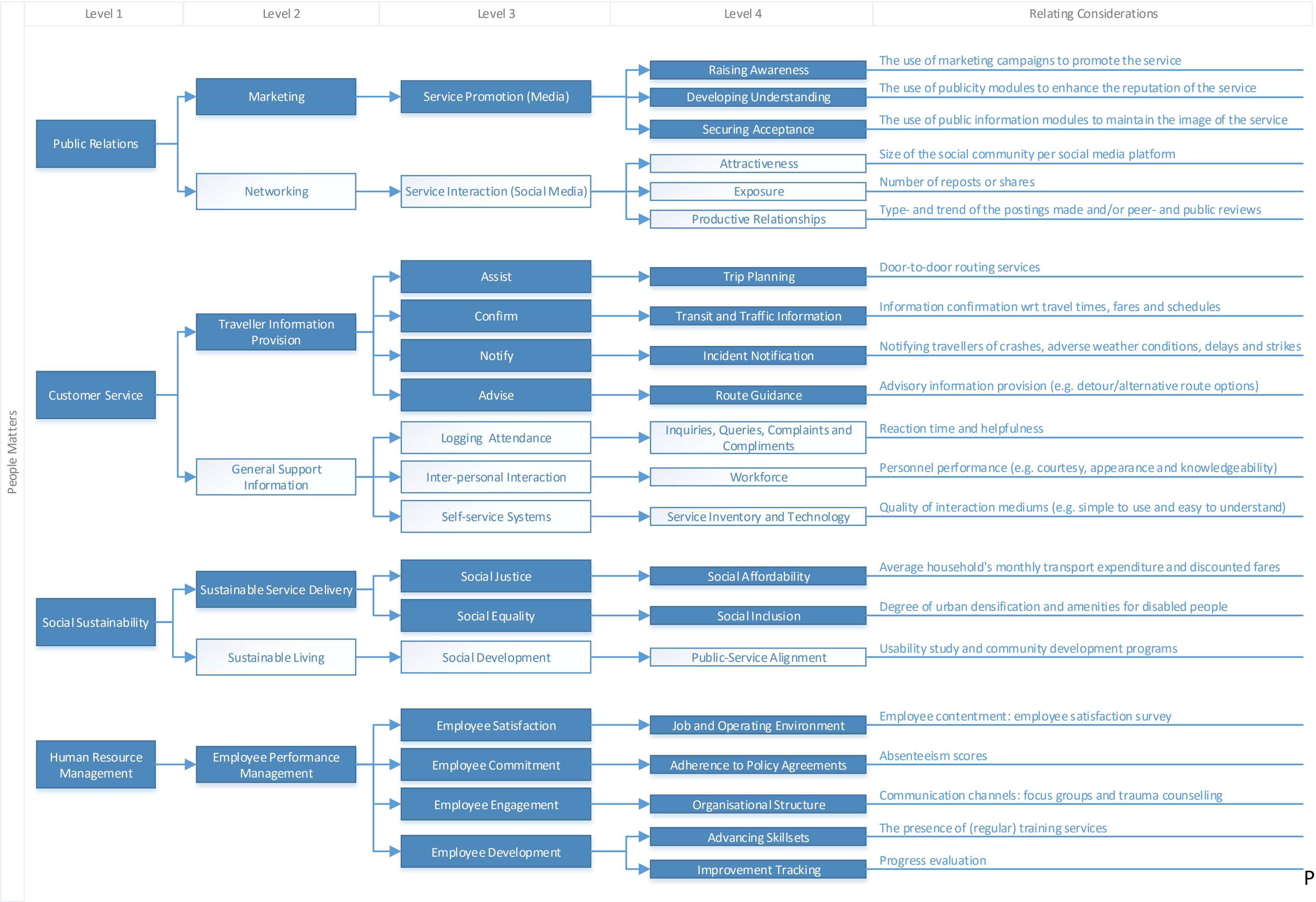

Level 1
Level 2
Level 3
Level 4
Relating Considerations
Governance, Planning and Decision Making
Legal Compliance
Legal Sources
Legislations and Acts
Transport
Environment
Labour
Safety and Security
Communications
Conformance to laws and bylaws
Regulatory Enforcement
Regulators
Governing Bodies
Industry Role Players
Involvement: before, during and after project execution
Regulatory Documents
Regulations and Policies
Standards
Manuals
Guidelines and Instructions
Statements, Plans and Frameworks
Inscription and compliance: before, during and after project execution
Research and Development
Research Support
Research Development
Project-based Learning
Public engagement: discharge and share of information
Creativity Support
Project Development
Innovation Management
Ideation (e.g. brainstorming activities to develop new ideas)
Continuous Improvement
Competitive analysis (e.g. benchmarking activities to identify SWOT)
Institutional Liaison
Institutional Coordination and Cooperation
Operational Alignment
Activity Integration
Technical Compatibility
Partnership development: agreements towards standardised procedures
Strategy Alignment
Collaborative Relationships
Partnership development: commitments to sharing resources and information
Institutional Robustness
Business Continuity
Risk Management
Disaster and recovery services: contingency plans
Data Governance
Data Management
Information System Governance Procedures
Data Collection
Data Accuracy
Data Retention
Data Security
Data Quality
Data Fusion
Data Accessibility
Conformance to protocols

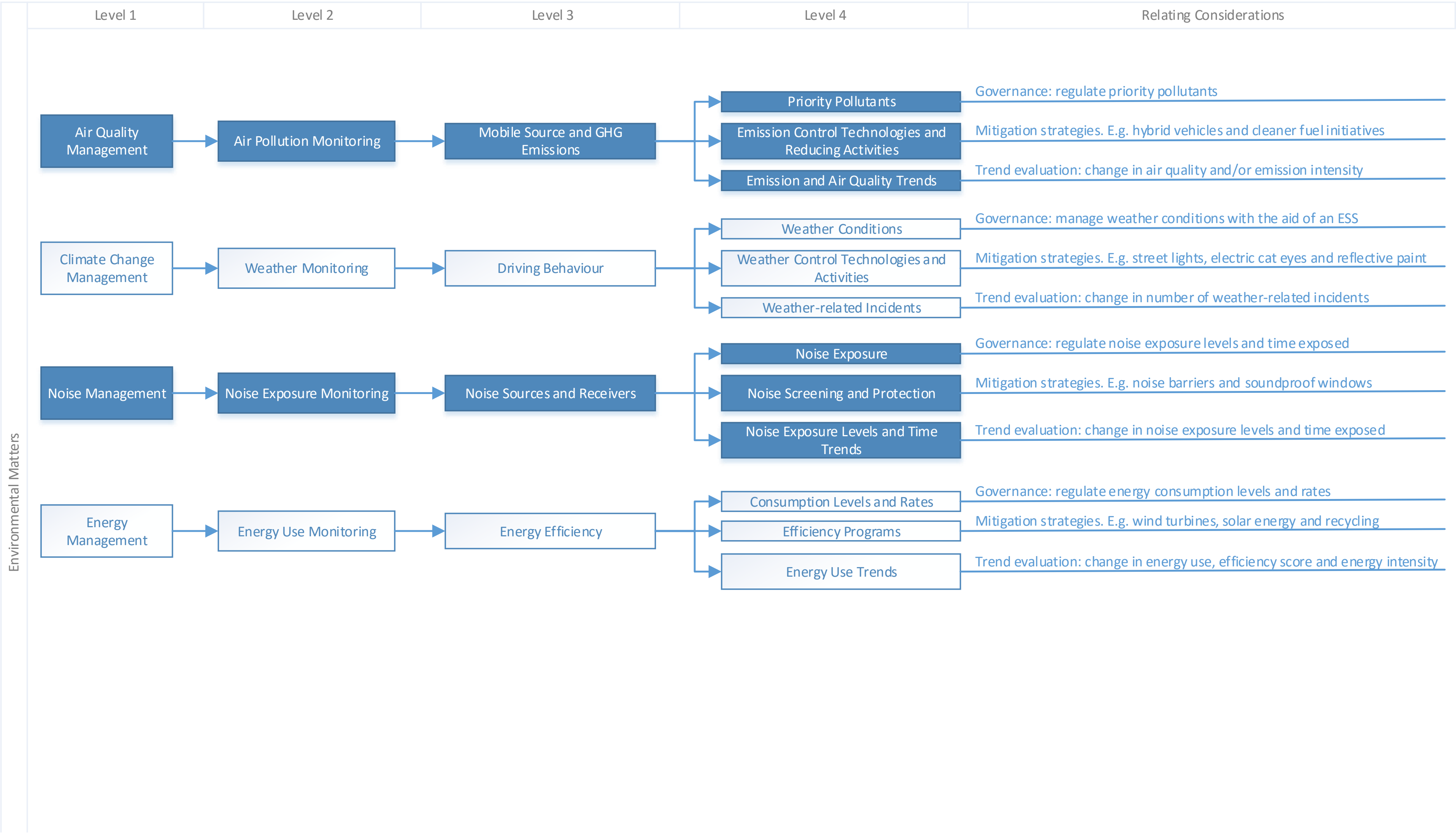


Operations, Services and Maintenance

Level 1	Level 2	Level 3	Level 4	Relating Considerations
Operational Performance	Service Reliability	Travel Time Variability	Travel Time Duration	Peak period travel time similar to free-flow travel time
			Schedule Adherence	Transit vehicles arriving at times as stipulated in their schedules
		Information Validity	Timeliness	Real-time information (e.g. images, timetables and notifications)
			Accurate and Available	Information that is applicable (i.e. accurate/correct and available/accessible)
		Public Travel and Personal Safety	Incident Statistics	Safety of the service wrt crashes, break-downs and property crimes
	Service Convenience	Accessibility	Access Point Proximity	Closeness (time or distance) of points of interest and transit facilities
			Network Characteristics	Constraints imposed on routes (e.g. road, vehicle and facility restrictions)
		Connectivity	Access Options	Availability of route & mode options wrt commuting time & transfer distance
		Regularity	Mode Preference	Is the service being used regularly?
			Periodicity	Is the service provided regular?
	Operational Seamlessness	Incident Management	Occurrence and Detection	Incident detection time
			Verification and Classification	Incident verification time
			Authority Notification	Incident notification time
			Respondent Dispatch	Incident response time
			Public Alert	Alert time
			Coordination	Clearance time
			Staff Safety	Safety of the service wrt adverse health conditions and secondary incidents
	Operating Efficiency	Service Quality	Density and Congestion	Traffic density (LOS) and passenger density (load factor and standing density)
			Mobility	Average network travel speeds, queue lengths/times and waiting times
		Service Utilisation	Demand and Supply	Network's degree of saturation: demand (throughput) to supply (capacity)
Technology Reliability	System Health	System Availability	System Functionality	System uptime
	System Performance	Equipment Quality	Value Evaluation	Mean time between failures
		Data Quality	Data Verification and Validation	Error rates
Asset Management and Maintenance	Asset Management	Operations Management	Record	All asset-related information recorded over an asset's whole lifecycle
			Monitor	Network surveillance systems: verify accuracy and quality
			Control	Positioning systems: track and/or navigate of transit vehicles
			Evaluate	Status and value assessment
	Asset Maintenance	Preventative	Scheduled Logs	Inspecting all identified assets: fulfilment of planned tickets
		Corrective	Defect Logs	Rehabilitating all identified assets: mean time to repair


Level 1
Level 2
Level 3
Level 4
Relating Considerations
Money Matters
Economic Performance
Economic Sustainability
System Adaptability
Operational Resilience
Scalability and responsiveness (i.e. ability to adapt) of the system
System Preservation
Project Infrastructure Status Evaluation
Overall condition and quality of the road network and the transit vehicles
Economic Vitality
Economic Development
Business Opportunities
Number of jobs created as a result of the existence of the system
Economic Growth
Service Expansion
Capacity building and infrastructure development wrt quality, time and cost
Socio-Economic Prosperity
(Social) Benefits
Energy and Environment
Traffic flow conditions and public transport use
Safety
Primary- and secondary incident occurrences
Efficiency
Network throughput
Customer Satisfaction
Community confidence and community perception
Mobility
Ease of movement
Productivity
System effectiveness - high quality service with little to no wasted resources
Financial Performance
Financial Feasibility
Non-recurring Costs
Capital Expenditure
Long-term assets: infrastructure, equipment, vehicles, buildings and facilities
Recurring Costs
Operating Expenditure
Selling expenses as well as general- and administrative expenses
Miscellaneous Costs
Unforeseen Expenditure
Fines, law suits, environmental damage costs, etc.
Social Costs
Negative Transport Externalities
Costs to the society as a whole wrt congestion, accidents and pollution
Investment Management
Investment Performance
Capital Gain
Return on Investment: benefit vs. cost of the investment


People Matters
Level 1
Level 2
Level 3
Level 4
Relating Considerations
Public Relations
Marketing
Service Promotion (Media)
Raising Awareness
The use of marketing campaigns to promote the service
Developing Understanding
The use of publicity modules to enhance the reputation of the service
Securing Acceptance
The use of public information modules to maintain the image of the service
Networking
Service Interaction (Social Media)
Attractiveness
Size of the social community per social media platform
Exposure
Number of reposts or shares
Productive Relationships
Type- and trend of the postings made and/or peer- and public reviews
Customer Service
Traveller Information Provision
Assist
Trip Planning
Door-to-door routing services
Confirm
Transit and Traffic Information
Information confirmation wrt travel times, fares and schedules
Notify
Incident Notification
Notifying travellers of crashes, adverse weather conditions, delays and strikes
Advise
Route Guidance
Advisory information provision (e.g. detour/alternative route options)
General Support Information
Logging Attendance
Inquiries, Queries, Complaints and Compliments
Reaction time and helpfulness
Inter-personal Interaction
Workforce
Personnel performance (e.g. courtesy, appearance and knowledgeability)
Self-service Systems
Service Inventory and Technology
Quality of interaction mediums (e.g. simple to use and easy to understand)
Social Sustainability
Sustainable Service Delivery
Social Justice
Social Affordability
Average household's monthly transport expenditure and discounted fares
Social Equality
Social Inclusion
Degree of urban densification and amenities for disabled people
Sustainable Living
Social Development
Public-Service Alignment
Usability study and community development programs
Human Resource Management
Employee Performance Management
Employee Satisfaction
Job and Operating Environment
Employee contentment: employee satisfaction survey
Employee Commitment
Adherence to Policy Agreements
Absenteeism scores
Employee Engagement
Organisational Structure
Communication channels: focus groups and trauma counselling
Employee Development
Advancing Skillsets
The presence of (regular) training services
Improvement Tracking
Progress evaluation


Level 1
Level 2
Level 3
Level 4
Relating Considerations
Environmental Matters
Air Quality Management
Air Pollution Monitoring
Mobile Source and GHG Emissions
Priority Pollutants
Emission Control Technologies and Reducing Activities
Emission and Air Quality Trends
Governance: regulate priority pollutants
Mitigation strategies. E.g. hybrid vehicles and cleaner fuel initiatives
Trend evaluation: change in air quality and/or emission intensity
Climate Change Management
Weather Monitoring
Driving Behaviour
Weather Conditions
Weather Control Technologies and Activities
Weather-related Incidents
Governance: manage weather conditions with the aid of an ESS
Mitigation strategies. E.g. street lights, electric cat eyes and reflective paint
Trend evaluation: change in number of weather-related incidents
Noise Management
Noise Exposure Monitoring
Noise Sources and Receivers
Noise Exposure
Noise Screening and Protection
Noise Exposure Levels and Time Trends
Governance: regulate noise exposure levels and time exposed
Mitigation strategies. E.g. noise barriers and soundproof windows
Trend evaluation: change in noise exposure levels and time exposed
Energy Management
Energy Use Monitoring
Energy Efficiency
Consumption Levels and Rates
Efficiency Programs
Energy Use Trends
Governance: regulate energy consumption levels and rates
Mitigation strategies. E.g. wind turbines, solar energy and recycling
Trend evaluation: change in energy use, efficiency score and energy intensity

6.1.3 FRAMEWORK COMPOSITION

This section encompasses a comprehensive explanation of the line of thought adopted in establishing the private- and the public transport environment's performance-related aspects. In order to present this section in a comprehensible manner, the explanation for the adopted framework is presented segmentally according the five sustainability perspectives. In each of these perspectives, specific reference is given to performance measurement level three (i.e. L3: performance sub area), performance measurement level four (i.e. L4: measurement field) and performance measurement level five (i.e. L5: performance measure). The work in this section constitutes this author's own thoughts and opinions (except when explicitly otherwise stated) and includes reworks from the applicable literature.

GOVERNANCE, PLANNING AND DECISION MAKING

LEGAL COMPLIANCE

LEGAL SOURCES

Legal sources were identified to be the sole performance sub area for the performance category: legal compliance.

Legal sources encompass legislations and acts. Legislation refers to the enactment of laws through legally binding acts. An act is a bill which has passed through the various required legislative steps and which has hence become law. The existing legislations, in the form of acts, were thus identified as the performance sub area for legal sources. Five legislative groups for evaluating the overall legal compliance of ITS projects were identified. These encompass laws relating to: 1) transport, 2) environment, 3) labour, 4) safety and security and 5) communications. The aforementioned groups form the measurement fields for the performance sub area identified.

The acts pertaining to **transport** include, among others, the National Road Traffic Act, the National Land Transport Act, the National Road Safety Act, the SANRAL and National Roads Act as well as the Road Traffic Management Corporation Act. Examples of acts relating to the **environment** are: the National Environmental Management Act and the Environment Conservation Act. The acts involving **labour** are, among others, the Labour Relations Act, the Basic Conditions of Employment Act, the Employment Equity Act, the Occupational Health and Safety Act as well as the Skills Development Act. Examples of acts concerning **safety and security** aspects are: the Disaster Management Act and the South African Police Service Act. Lastly, with regard to **communications**, the following acts exist: the

Promotion of Access to Information Act as well as the Electronic Communications and Transactions Act. For more detail regarding these acts, refer to Acts Online (2013). By law, a project is legally required to comply with all these relevant legislations. If this is the case, the legal compliance requirement is met.

REGULATORY ENFORCEMENT

REGULATORS

Regulators were identified to be a performance sub area for the performance category regulatory: enforcement.

Regulators refer to the governing bodies that regulate and supervise a particular industry or business activity. Governing bodies were thus identified as the performance sub area for regulators. The measurement field for governing bodies relates to all of the industry role players that are deemed relevant to the transport environment in general and, in particular, the ITS deployments.

Examples of applicable **role players** are: the South African Institution of Civil Engineering (SAICE), the Committee of Urban Transport Authorities (CUTA), the Engineering Council of South Africa (ECSA), Intelligent Transport Systems South Africa (ITSSA), the Consulting Engineers of South Africa (CESA), the Committee of Land Transport Officials (COLTO) and the South African Bureau of Standards (SABS). If these relevant role players act as supervisors before, during and after project execution, the regulatory enforcement requirement (with regard to regulators) is met.

REGULATORY DOCUMENTS

Regulatory documents were identified to be a performance sub area for the performance category: regulatory enforcement.

Regulatory documents relate to any governing document that regulates a project’s execution. The most prominent being regulations and policies. A regulation refers to any rule or directive made and maintained by an authority. A policy refers to a course or principle of action adopted or proposed by an organisation or individual. The existing regulations and policies were thus identified as the performance sub area for regulatory documents. Four regulative groups for directing the execution-related enforcement of ITS projects were identified. These are: 1) standards, 2) manuals, 3) guidelines and instructions as well as 4) statements, plans and frameworks. The aforementioned groups form the measurement fields for the performance sub area identified.

The enforcement of **standards** is regulated by, among others, the South African National Standards (SANS) as well as the SABS and its Technical Committees (TC) for standards development. An example of a local committee looking after ITS standards is the SABS/TC 204 (SABS n. d.). Examples of the most widely accepted and used **manuals** are: the South African Road Traffic Signs Manual, the Road Safety Audit Manual and the Routine Road Maintenance Manual. **Guidelines and instructions** include, for example, the Urban Transport Guidelines (UTG); the Technical Methods for Highways (TMH); COLTO's IM guidelines; the Guidelines for Human Settlement, Planning and Design (also known as the "red book"); the specifications relating to the Europay, MasterCard and Visa (EMV) card; and the data structures for AFC. Examples of **statements, plans and frameworks** are: the White Paper on National Transport Policy, the Moving SA Action Agenda, the National Development Plan 2030 and the National Transport Master Plan 2050. If these regulatory documents are taken into consideration (and included where necessary) before, during and after project execution, the regulatory enforcement requirement (with regard to regulatory documents) is met.

RESEARCH AND DEVELOPMENT

RESEARCH SUPPORT

Research support was identified to be a performance sub area for the performance category: research and development.

Research support refers to the support activities provided by the project for research purposes. Possible support activities include, among others, the provision of services and the sharing of resources. Such support activities facilitate research development by aiding the identification of new areas of research as part of project execution. Research development was thus identified as the performance sub area for research support. The realisation of research development is dependent on the degree to which project-based learning is pursued. Project-based learning facilitates the engagement of the public by allowing them to explore real-world problems and -challenges. This engagement then aids them in acquiring deeper knowledge and learning new skills. Project-based learning forms the measurement field for the performance sub area identified.

Project-based learning can be achieved by discharging- and sharing information with researchers when needed and if deemed viable. Researchers can then use this information for data analysis purposes and/or for the development of new applications. If the project fulfils such information dissemination, the research support requirement is met.

CREATIVITY SUPPORT

Creativity support was identified to be a performance sub area for the performance category: research and development.

Creativity support refers to the in-house support processes provided by the project for creativity stimulation. Such support processes help to ensure that project requirements do not hinder or prevent innovation. They aid in improving products, services and/or processes such that the performance of the project(s) can be enhanced. This is accomplished by facilitating the identification of and response to internal- and external opportunities. Project development was thus identified as the performance sub area for creativity support. Based on the aforementioned, the realisation of project development is dependent on both innovation management and continuous improvement practices. These form the measurement fields for the performance sub area identified.

The main practice of **innovation management** is ideation. Ideation is the process of generating, developing and communicating new ideas. An example of an ideation process is the activity of brainstorming. A popular practice of **continuous improvement** is competitive analysis. Competitive analysis in the form of, for example, benchmarking, provides for a critical assessment of the project's Strengths, Weaknesses, Opportunities and Threats (SWOT). If the project caters for such processes, the creativity support requirement is met.

INSTITUTIONAL LIAISON

INSTITUTIONAL COORDINATION AND -COOPERATION

Institutional coordination and -cooperation were identified to be a performance area for the performance category: institutional liaison.

The concept of institutional coordination and -cooperation is based on achieving mutually beneficial relationships through partnership development. Close coordination and cooperation can be attained if the institutions' strategies and operations are synchronised. In order to achieve such synchronisation, certain institutional agreements and commitments need to be in place. For example: agreements that cater for the dissemination of information, the formation of capabilities and the structuring of interactions. In essence, intra- and inter institutional alignment of both operational activities and strategic objectives are needed. Operational- and strategy alignment were thus identified as the performance sub areas. Operational alignment can be attained if standardised procedures, which cater for interoperable operations, are in place. The degree of interoperability achieved is dependent on both activity integration and technical compatibility. The attainment of strategy alignment enables higher performance by optimising the contributions of people, processes and inputs. Strategy alignment thus relates to collaborative relationships. The foundation for collaborative relationships is a common objective. Collaborative relationships are built on trust and sharing of knowledge. These aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Activity integration can be measured by considering the existence of agreements on planning- and design practices. **Technical compatibility** can be evaluated by considering the existence of agreements on operating protocols and technical matters. **Collaborative relationships** relate to the commitments made towards the sharing of resources and information. Therefore, collaborative relationships can be measured by determining whether the commitments made were successfully carried out. If such alignment initiatives are in place, the partnership development requirement is met.

INSTITUTIONAL ROBUSTNESS

Institutional robustness was identified to be a performance area for the performance category: institutional liaison.

Robustness within an institution relates to the institution’s ability to cope with changing conditions. Changing conditions refer to either internal- or external factors that could intervene or interfere with the normal state of operations. Business continuity was thus identified as the performance sub area for institutional robustness. Business continuity refers to the processes and procedures the institution puts in place to ensure that the essential functions can continue to operate (or can be recovered to an operational state within a reasonably time period) despite the occurrence of certain incidents. In essence, business continuity ensures for the proper management of risk. Risk management typically includes the following actions: identify the risk, determine the probability of its occurrence, assess the impact if it occurs and develop mitigation strategies. Risk management forms the measurement field for the performance sub area identified.

The main type of incident that need to be considered in **risk management** is the occurrence of disasters and their relating recovery services. Contingency plans for disaster recovery services thus need to be in place. This relates to a plan designed to take account of a possible future circumstances by managing their associated risk. If such plans exist, an institution can be classified as being robust.

DATA GOVERNANCE

DATA MANAGEMENT

Data management was identified to be the sole performance area for the performance category: data governance.

Data management refers to the overall management of the availability, usability, integrity and security of the data employed in the system. Effective data management is grounded on sound information system governance procedures. Information system governance procedures were thus identified as the performance sub area for data management. The procedural actions pertaining to information system governance are: 1) data collection, 2) data accuracy, 3) data retention, 4) data security, 5) data quality, 6) data fusion and 7) data accessibility.

Data collection refers to the action of recording all relevant data from all applicable data sources. Examples of data sources are: traffic counts, travel time data, accident data, incident logs, AVI (Automatic Vehicle Identification) data, ANPR data, passenger/ people counts, sales data, social media data, police records, systems data and journalistic data. Data accuracy refers to the action of evaluating whether the data values stored for an object are the correct values (i.e. the right value in right format). Data retention defines the policies of persistent data- and record management such that legal- and business data archival requirements can be met. Data security ensures the enforcement of protecting data from corruption and unauthorised access. Data quality refers to the action of assessing data's fitness to serve its purpose in a given context. Data fusion refers to the process of synthesising data from single- or multiple data sources to generate meaningful information. Data accessibility refers to software and activities related to retrieving or acting on data housed in a database or other repository. These aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Data collection can be measured by considering the information system's conformance to data source and -acquisition protocols. For example: adhering to the required data log frequency. **Data accuracy** can be measured by considering the information system's conformance to data accuracy protocols. **Data retention** can be measured by considering the information system's conformance to data archival protocols. For example: adhering to the required data backup period. **Data security** relates to whether the information system conforms to the CIA (Confidentiality, Integrity and Availability) protocols. **Data quality** can be measured by considering the information system's conformance to quality-checking protocols. For example: complying with the decided data standards and the data dictionaries of the databases. **Data fusion** relates to whether the information system conforms to the data filtering, -cleaning and -presentation protocols. **Data accessibility** can be measured by considering the information system's conformance to data accessibility protocols. For example: regulating how data is transmitted between computing devices and over networks. If such governing protocols exist, the data is deemed to be managed correctly.

OPERATIONS, SERVICES AND MAINTENANCE

OPERATIONAL PERFORMANCE

SERVICE RELIABILITY

Service reliability was identified to be a performance area for the performance category: operational performance.

A service, whether public- or private transport, is deemed to be reliable if three conditions are met. These are: 1) if travel time variability is managed to be as low as possible, 2) if the information given to the users is valid and 3) if using the service is safe. These three conditions were identified as the performance sub areas for service reliability.

Travel time variability can be managed by considering the degree of delay experienced by the transport user. For modes that do not run to a scheduled timetable, the degree of delay experienced can be expressed by evaluating the travel time duration. The degree of delay experienced, when travelling with modes that run to a scheduled timetable, can be expressed by evaluating the transit vehicles' adherence to their respective pre-set schedules (e.g. departing times). Information is deemed to be valid if it is given to the users in a timely manner (i.e. real-time), if it is accurate (i.e. correct) and if it is available (i.e. accessible). A service is deemed safe if the public experience both travel- and personal safety. These aforementioned criteria form the measurement fields for each of the performance sub areas identified.

As mentioned previously, the identified measure of **travel time duration** can be considered for modes that do not run to a pre-set schedule (i.e. private vehicle and taxi). However, since the bus mode of transport is also a road vehicle and hence also influenced by congested roads, it can be considered here as well. Travel time duration is identified to be measureable with the aid of a **travel time factor**. This factor is calculated as a ratio of the average peak period travel time as compared to a free flow travel time. The data needed to compute this factor can be obtained in four ways. These are: 1) probe vehicles that use Floating Car Data (FCD), 2) video detection that uses ANPR, 3) positioning systems (e.g. GPS) that use data fusion of cellular phone probes and FCD for data enrichment and 4) electronic sensors such as radar systems performing vehicle detection (e.g. Vehicle Detection Systems: VDS). Travel time factors need to be expressed per (major) road segment or OD pair, evaluated for a certain time period (e.g. day and month) and compared to a previous similar time period or a predefined standard.

As mentioned previously, the identified measure of **schedule adherence** can be considered for the modes that run to a scheduled timetable, with either a dedicated- or shared right of way (i.e. bus, rapid transit and train). Schedule adherence is identified to be measureable by evaluating **on-time performance**. This relates to the transit vehicles arriving at times as stipulated in their timetables. The data needed to compute on-time performance can be obtained in three ways. These are: 1) field data collection, 2) surveys among public transport service providers and -users and 3) real-time information (e.g. from AVL data and CCTV footage) on the arrival time of public transport vehicles to their stops or stations. The percentage of on-time performance needs to be expressed per mode of transport, evaluated for a certain time period (e.g. time of day, day, week and month) and compared to a previous similar time period or a predefined standard.

The **timeliness** of the information can be measured in two ways. Either the **information refresh** rate or the **latency to posting updates** can be measured. The former mentioned is only measured if and when applicable. Moreover, it relates to refreshing information such as updating images on, for example, websites. The latter mentioned is only measured in the event of change. Moreover, it applies to both timetable corrections and incident occurrence updates. In this sense, an incident is seen as anything that interferes with normal operating flow conditions. For example: road closures, protests and crashes. Both the information refresh rate and the latency to posting updates need to be expressed per communication medium (e.g. website, VMS and EMS at transit facilities), since the type of medium influences the degree of effort required. The information refresh rate thus needs to be expressed per type of communication medium, evaluated and averaged for a certain time period (e.g. day, week and month) and compared to a previous similar time period or a predefined standard. The latency to posting updates, measured from the occurrence of change, needs to be expressed per both type of communication medium and update type, evaluated and averaged for a certain time period (e.g. week, month and quarter) and compared to a previous similar time period or a predefined standard.

The **accuracy and availability** of the information can be measured in two ways. It could be that the supporting electronic management system executes measurement automatically. Otherwise, manual methods based on (statistical) sampling is needed. Examples of pragmatic approaches that can be followed are: evaluating maintenance reports for trouble tickets; executing field spot checks to observe any applicable discrepancies (e.g. failures not reported); evaluating footage from CCTV cameras for incorrect or delayed display of information; and cross-checking information on websites with the current state of affairs (e.g. verifying timetable accuracy). The results from the former mentioned approach will be in a format as determined by the supporting electronic management system. The data obtained from the latter mentioned approach, however, requires further manipulation. These findings need to be computed as an accuracy (i.e. correctness) and availability (i.e. accessibility) percentage, expressed per communication medium, evaluated for a certain time period (e.g. week, month and quarter) and compared to a previous similar time period or a predefined standard.

Since public travel- and personal safety are both indicative of the safety of the service, it is recommended that they be measured by considering incident statistics. **Public travel safety** can be evaluated by determining the total **number of occurrences per incident type** (e.g. crash: no injuries, crash: light to severe, crash: fatalities and break-downs). When these measures are evaluated for public transport vehicles, only those pertaining to be the drivers fault are deemed viable for consideration. This relates to any incident that occurred due to risky- or negligent driver behaviour (e.g. harsh braking, swirling, aggressive acceleration and sharp cornering). The incident statistics thus need to be computed separately for private- and public transport, expressed per incident type, evaluated for a certain time period (e.g. day, time of day, week and month) and compared to a previous similar time period or a predefined standard. **Personal safety** can be evaluated by determining the total **number of property crime incidents** that occur while travelling on major roads or at transit facilities. Examples of property crime incidents include, among others, theft- and vehicle hijacking occurrences. These numbers need to be expressed per both property crime type and per incident occurrence location, evaluated for a certain time period (e.g. day, time of day, week and month) and compared to a previous similar time period or a predefined standard.

SERVICE CONVENIENCE

Service convenience was identified to be a performance area for the performance category: operational performance.

The convenience of the service is dependent on three conditions. These are: 1) if the service is accessible, 2) if the service offers sufficient connectivity and 3) if the service provided is regular and being used regularly. These three conditions were identified as the performance sub areas for service convenience.

The accessibility of a service can be assessed by considering both the users' access point proximity and the characteristics of the network. The former mentioned considers whether the access points can be reached within a certain recommended time or distance margin. The latter mentioned considers whether the provided quality of the road or transit line can sufficiently serve and meet the needs of the transport user. Quality is taken into consideration, since some routes may be impassable or prohibited for some vehicles or users. The connectivity of the service is dependent on the availability of access options. Access options represent the variety of routes and modes with which a certain activity (i.e. access point) can be reached. For public transport journeys, this consideration also assesses the availability of the intra- and intermodal transfer options. The regularity of the private transport service relates to whether it is viewed by the users as a preferred mode of traveling. That is: is the private vehicle being used regularly? In public transport operations, the regularity of the service relates to its periodicity (i.e. frequency of operations). That is: is the transit service provided regular? These aforementioned criteria form the measurement fields for each of the performance sub areas identified.

The *first measure* identified for *accessibility* is the **proximity of the access points**. This refers to a typical user's average access time (or distance) to access points. In **private transport situations**, access points refer to the users' points of interest. These points of interest relate to both recreational- and work-related activities. Therefore, information regarding the **distribution of human activities** and the **road network** are needed. The former mentioned entails certain land use information. For example: the type and location of businesses, education facilities and public services. This type of information can be obtained by direct surveying or from the municipalities and/or the responsible authorities. Information regarding the latter mentioned entails the number- and width of lanes as well as the total roadway lane-kilometres. This type of information can commonly be obtained from planning authorities or commercial digital network providers. However, three other possible ways also exist. These are: 1) on-site survey inspections, 2) approximations from maps of the area integrated with the description of the road hierarchy and 3) GIS data platforms that contain information about lanes, lengths and hierarchy of the road network. By taking the aforementioned information into consideration, the access time (or distance) can be obtained in three ways. These are: 1) probe vehicles, 2) travel demand models that provide information on travel times for OD pairs and 3) GIS data platforms that contain information on average travel times on the road network segments. In

public transport situations, access points refer to the transit facilities (i.e. stops and stations). In order to determine the user's access time (or distance) to these facilities, information concerning their location is thus needed. The **location of transit facilities** can be obtained from either field data collection or from maps of public transport lines. By taking this information into consideration, the access time (or distance) can be obtained in three ways. These are: 1) a survey among transit users, 2) approximations from maps of the area and public transport lines and 3) a GIS database that uses data of the transit system (e.g. routes, facility locations and timetables). The access time (or distance) needs to be expressed per either individual, user group or OD pair, evaluated and averaged for a certain time period (e.g. time of day and day) and compared to a previous similar time period or a predefined standard. (Since the span of the service has a direct impact on access time or -distance, it could also be a viable measure for evaluating accessibility in public transport.)

The *second measure* identified for *accessibility* relates to the **characteristics of the network**. That is, the **quality of the road or the transit line**. This refers to the user's accessibility, when considering the constraints imposed on certain routes, to access points. General factors that have an influence on a user's accessibility include, among others, the presence of: HOV lanes, Non-Motorised Transport (NMT) facilities, amenities for people with disabilities, road restrictions with regard to vehicle load and height, park-and-ride facilities as well as transit vehicle- or facility restrictions (e.g. bicycles permitted or not). It is proposed that such factors be assessed by assigning major roads or transit lines with an **accessibility score**. This score is indicative of the service's efforts towards catering for and including all vehicles and users. Therefore, the score allocation needs to be done by a representative expert by taking some guideline scorecard as the reference point. The score needs to be computed by an expert as an impression index on efforts exhibited, expressed per major road or transit line, evaluated and averaged for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard.

In **private transport**, the more **access options** (in the form of route options) there are, the lower the commuting time (and often distance) will be. Therefore, the availability of **route options** can be evaluated by considering the average citizen's commuting time. The data needed for this computation can be obtained in three ways. These are: 1) surveys conducted in workplaces, 2) elaboration of the NHTS that describe the distance covered from home to work daily and 3) GIS data platforms that contain information about travel times on segments that connect houses (i.e. origins) with workplaces (i.e. destinations). The average citizen's commuting time needs to be expressed as a proportion of their (working) day, evaluated and averaged for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or perhaps a predefined standard.

In **public transport**, the more **access options** (in the form of mode options as well as intra- and intermodal transfer options) there are, the lower the commuting time as well as the transfer distance (and often time) will be. Therefore, the availability of **mode options** can be evaluated by determining the percentage of transfers between modes to be under “x” metres. The data needed for this computation can be obtained in three ways. These are: 1) a survey among public transport users, 2) a GIS data platform that contains information on the connection links among facilities and 3) real-time information about connections and transfers provided by the facility’s control centre. The transfer distance needs to be computed as a percentage of transfers adhering to the “x” metres margin, expressed for all facilities within a certain region, evaluated for a certain time period (e.g. semester and year) and compared to a predefined standard.

Mode preference can be measured by considering **modal split**. Modal split refers to the share of different modes of transport, including non-motorised modes and pedestrian trips, within overall transport demand. Modal split is commonly indicated as proportions. The data needed to compute these proportions can be obtained in two ways. These are: 1) stated preference surveys among travellers and 2) transport demand models providing realised information about the proportions of trips of different modes. The proportions need to be evaluated for a certain time period (e.g. month, quarter and year) and compared to a previous similar time period or a predefined standard.

Periodicity can be determined by considering the **service frequency**. This refer to the frequency of transit vehicle availability in both peak- and off-peak periods. (Service frequency is commonly measured by arrival rate.) The data needed for this computation can be obtained in two ways. These are: 1) timetables provided by public transport operators and 2) GIS data platforms that contain information about the frequency of public transport lines on the links of the network. In order to ensure proper service regularity, the service frequency (and operating hours) needs to comply with the users’ needs. That is, the service needs to be available to the public if and when needed. For example: even though the night period is deemed to be generally low in demand, the service needs to attempt to include the needs of the night-shift workers. The service frequency needs to be expressed per mode type and/or per route and per direction, evaluated for a certain time period (e.g. time of day and day) and compared to a predefined standard or users’ needs. Users’ needs can be determined by conducting a survey among both frequent- and occasional travellers.

OPERATIONAL SEAMLESSNESS

Operational seamlessness was identified to be a performance area for the performance category: operational performance.

Operational seamlessness is dependent on only one condition. In order for a service to operate seamlessly, any incidents that could impede the operation of the service need to be managed in a timely manner. In this sense, incidents refer to any event which is not part of the standard operation of a service and which causes or may cause an interruption to, or a reduction in, the quality of that service. Examples include, among others, crashes, stationary vehicles blocking a lane of traffic, special events and adverse weather conditions. The management of such incidents is referred to as IMS. IMS was thus identified as the sole performance sub area for operational seamlessness. The goal of IMS is not only to detect (and verify), respond and clear incidents as quickly and safely as possible, but also to notify the travelling public of the impacts of the incidents. These aforementioned criteria form the measurement fields for the one performance sub area identified.

If an incident occurs, it first needs to be detected. This is referred to as incident detection time. After detecting the incident, the incident needs to be verified and classified according to the incident type. This is referred to as incident verification time. After verifying and classifying the incident, the partner authorities/services need to be notified of the incident. This is referred to as incident notification time. After incident notification, the partner authorities need to dispatch respondents to the scene of the incident. This is referred to as incident response time. The travelling public also needs to be notified of incident occurrence. This is referred to as incident alert time. When the authorities have reached the incident scene, they need to coordinate the scene in such a way that the network can resume its normal flow conditions as soon as possible. This is referred to as incident clearance time.

The first group of measures proposed for IMS is all time conscious. The first measure in this group is the **detection time**. Detection time can be evaluated by considering the time it takes to detect an incident after its occurrence. If it is not be possible to determine the occurrence time, the detection time will be flagged as “not available”. The second measure proposed is the **verification time**. Verification time can be evaluated by considering the time it takes to verify and classify the incident according to the incident type. This time is measured from incident detection time. The third measure proposed is the **notification time**. Notification time is the time it takes to notify the partner authorities of the incident. This time is measured from incident verification time to the time the partner authorities are notified to dispatch respondents. The fourth measure proposed is the **response time**.

Response time is the time it takes for the authorities to reach the scene of the incident. This time is measured from incident verification time to the time the first emergency vehicle reaches the scene of the incident. The fifth measure proposed is the **alert time**. Alert time is the time it takes to notify the travelling public of the incident (i.e. information dissemination time). This time is measured from incident verification time to the time the update is posted on the representative communication medium. The last measure proposed is the **clearance time**. Clearance time is the time it takes the authorities to clear the incident scene. This time is measured from incident verification time (as one does not always exactly know when the incident occurred) to the time the last responder vehicle has left the scene of the incident. The data needed for these computations can be obtained from the facility's control centre, the representative operators and -authorities. All these measures need to be evaluated and averaged for a certain time period (e.g. month and quarter) and compared to a previous similar time period or a predefined standard.

Note: if it is desired to also evaluate how good the management system and operators are, the following can be considered: the percentage of incidents detected by the operators in the control centre as opposed to the percentage of incidents that the operators where informed about by another party. This can aid in indicating whether there are, for example, sufficient detection devices and/or whether the operators are underperforming or not.

The second group of measures proposed for IMS addresses the safety of the services and/or the authorities. This encompass the safety of the staff both at, and while travelling to, the scene of the incident. The proposed safety measures are the number of **adverse health conditions** and the number of **secondary incident occurrences** resulting from attending to the scene of the incident. The data needed for these computations can be obtained from the facility's control centre, the representative operators and -authorities. Both these measures need to be evaluated and averaged for a certain time period (e.g. month and quarter) and compared to a previous similar time period or a predefined standard.

OPERATING EFFICIENCY

Operating efficiency was identified to be a performance area for the performance category: operational performance.

A service that operates efficiently can achieve maximum productivity with minimum wasted effort (or expense). The operating efficiency of a service is thus determined by two conditions. These are: 1) the quality of the service provided and 2) the utilisation of the service. These two conditions were thus identified as the performance sub areas for operating efficiency.

In private transport, a high quality of service is provided if the service suffices in upholding high operating flow rate conditions. The flow rate of a service is determined and influenced by the network's design- and operating conditions. That is, the planned- and realised traffic density (i.e. number of vehicles per kilometre) and the planned- and realised travel speed of the road segment. If the service operates at or below optimum density, congestion and hence also delay will most likely be low and mobility (i.e. ease of movement) high. Similar logic is applicable to public transport situations. However, here passenger density and travel speed of the transit line or the route are considered. Passenger density considers the number of passengers on-board vehicles or at transit facilities. Therefore, it acts as a measure of congestion. Service utilisation can be determined by evaluating the transport demand-supply relationship. Demand can be expressed in terms of number of people, vehicles or volume per unit of time and space. Supply is considered to be a measure of capacity and can be expressed as the number of passengers, vehicles or volume that can be transported per unit of time and space. These aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Traffic density can be measured by considering the **LOS** of each major road segment. LOS is a well-known qualitative measure that considers congestion levels when categorising the quality of a service. In order to compute the LOS, data concerning the network's density is needed. Examples include, among others, speed, number of lanes, terrain type, hourly traffic volume and vehicle equivalents (i.e. the presence of trucks and buses) (Garber and Hoel 2010). This data can be obtained from the municipalities and/or the responsible authorities, real-time traffic information provided by the control centre and traffic counts from detectors. By taking the aforementioned information into consideration, road segments can be assigned, based on the HCM guidelines, with letters "A" through "F". LOS A relates to the best situation (i.e. free flow conditions) and LOS F to the worst situation (i.e. fully congested). The density of the road network can be expressed as either a percentage of road segments assigned with a LOS above a certain threshold (LOS C or better is usually deemed appropriate) or as the percentages of road segments assigned with LOS A trough F respectively. These percentages need to be evaluated for a certain time period (e.g. time of day and day) and compared to a similar time period or a predefined standard.

Passenger density can be measured by evaluating the **degree of crowding** on-board vehicles or at the transit facilities. The former mentioned can be calculated by determining the *load factor* (i.e. the average load to the total vehicle capacity) and the latter mentioned by determining the *passenger standing density* (i.e. the number of passengers per square metre). Therefore, data concerning the capacity of transit vehicles (e.g. bus sizes) and the facilities (e.g. turnstiles and platforms) are needed. This type of information can be obtained from ghost riders and public transport service providers. By taking the aforementioned information into consideration, the degree of crowding on-board vehicles or at the transit facilities can be obtained in four ways. These are: 1) manual passenger counts, 2) APC data, 3) survey among the travellers and 4) transport operators evaluating the footage from the CCTV cameras. The load factor and the passenger standing capacity need to be expressed per transit vehicle and -facility respectively, evaluated for a certain time period (e.g. time of day and day) and compared to a similar time period or a predefined standard.

The first measure proposed for **mobility** is the average **network travel speed**. This measure can be used to evaluate users' mobility when traveling with either private- or public transport. However, in situations where the mode of transport is a road vehicle with shared right of way (i.e. **private vehicle, taxi and bus**), the travel speeds need to be determined for both peak- and off-peak periods. The data needed for such computations can be obtained in three ways. These are: 1) probe vehicles that use FCD, 2) video detection that uses ANPR and 3) positioning systems (e.g. GPS) that use data fusion of cellular phone probes and FCD for data enrichment. In order to determine the travel speeds of modes that run to a scheduled timetable, with either a dedicated- or shared right of way (i.e. **bus, rapid transit and train**), general information on transit vehicle routes, -running times and headway regularity are needed. The data needed for such computations can be obtained in four ways. These are: 1) timetables and maps (with route classification) of public transport lines, 2) spot check observations made by field workers, 3) positioning systems (e.g. GPS) that track vehicle movement to determine travel time of transit vehicles between stops or stations and 4) transport operators that evaluate the footage from the CCTV cameras. It needs to be emphasised that the travel speeds should not be compared between modes. Moreover, the travel speeds need to be determined not only per mode type, but also within mode type. This distinction is necessary due to the fact that the vehicles operating solely in urban environments (e.g. feeder buses) are likely to be more subjected to, and influenced by, delays than vehicles operating in both urban- and rural environments (e.g. long distance buses). Travel speeds thus need to be computed per mode of transport, distinguished by the feeding areas (i.e. urban, rural and both), expressed per either individual, user group or OD pair, evaluated and averaged for a certain time period (e.g. time of day and day) and compared to a similar time period or a predefined standard. Possible standards could be, for example, the set speed of the road segment and the designated transit vehicle travel times as computed from the timetables.

For modes that do not run to a scheduled timetable (i.e. **private vehicle and taxi**), the user's **mobility** can also be represented by determining the **queue lengths** (or queuing times) during peak periods at major road segments or at intersections. For modes that run to a scheduled timetable (i.e. **bus, rapid transit and train**), the user's mobility can also be represented by determining the **waiting times** during peak periods at major transit stops or stations. Large values in both queue length and waiting time would deter the user's ease of movement. The data needed to compute the aforementioned can be obtained in three ways. These are: 1) traffic detectors, 2) vehicle tracking systems and 3) real-time traffic- and transit information provided by the control centre. The queue length (computed in kilometres or number of vehicles) and waiting time need to be expressed per either road segment/intersection or per stop/station, evaluated and averaged for a certain time period (i.e. morning- and afternoon peak) and compared to a previous similar time period or a predefined standard.

The **demand-supply relationship** can be determined by considering the network's **degree of saturation**. The degree of saturation is based on the proportion of demand (i.e. volume) to supply (i.e. capacity). Volume refers to the number of vehicles or persons entering or exiting the network during the analysis period (expressed per hour). Capacity is defined as the maximum hourly rate at which vehicles or persons can be reasonably expected to traverse a point during a given time period (usually 15 minutes) under prevailing roadway, traffic and control conditions. The data needed to compute the aforementioned can be obtained in four ways. These are: 1) manual passenger counts, 2) APC data, 3) traffic counts from detectors and 4) real-time traffic- and transit information provided by the control centre. The degree of saturation needs to be expressed per (major) road segment, OD pair or transit line, evaluated for a certain time period (e.g. time of day, day and week) and compared to a previous similar time period or a predefined standard. A value of one is indicative of the fact that demand and supply are equal and hence no further vehicles or persons are able to be processed by the network.

TECHNOLOGY RELIABILITY

System Health

System health was identified to be a performance area for the performance category: technology reliability.

A healthy system is a system that can provide what it should, when it should, 24/7. This refers to system availability. System availability was thus identified as the performance sub area for system health. If a system is available, it inherently then also means that the system is functioning. That is, the ITS equipment supporting the system is functional. Examples of ITS equipment are: the workstations and the video wall used in the TMC; field devices such as CCTV cameras, VMS and traffic detectors as well as turnstiles, smart card readers and gantries used in Electronic Payment Systems (EPS). Equipment functionality goes hand in hand with system readiness; if the equipment is functional, the system is ready to perform its intended service. System functionality forms the measurement field for the performance sub area identified.

System functionality is commonly assessed by measuring **system uptime**. System uptime refers to the percentage of time the system is operable (i.e. in working condition). The data needed for this computation can be obtained from the facility's control centre. System uptime needs to be computed as an operational percentage, expressed per equipment group (e.g. VMS and CCTV) or as an overall percentage, evaluated for a certain time period (e.g. month and quarter) and compared to a previous similar time period or predefined (availability) targets. These targets vary based on which ITS equipment is being evaluated. However, regardless of the equipment type, system uptime needs to be as close as possible to 100% operational.

SYSTEM PERFORMANCE

System performance was identified to be a performance area for the performance category: technology reliability.

In order for a system to perform satisfactory, both the quality of the ITS equipment and the quality of the data provided by the equipment need to comply with the set performance targets. Equipment quality and data quality were thus identified as the performance sub areas for system performance. The quality of the equipment can be established by evaluating its value. That is, does the equipment measure up to what was expected from it? The quality of the data provided by the equipment can be established with the aid of data verification and -validation procedures. These procedures facilitate determining, for example, whether the equipment used is outdated and/or not the most efficient or effective technology for the specific purpose. The aforementioned criteria form the measurement fields for the performance sub areas identified.

Equipment quality can be assessed by determining the **Mean Time Between Failures** (MTBF). The lower this mean time, the greater the exerted value of the equipment. The MTBF needs to be expressed per equipment group (e.g. VMS and CCTV), evaluated for a certain time period (e.g. semester and year) and compared to a similar time period or a predefined standard. **Data quality** can be measured by assessing the system's **error rates**. These error rates can be determined by executing data quality checks on an ad-hoc basis. For example: the results obtained from APC can be compared with manual passenger counts; or the results obtained from traffic detectors can be compared with manual vehicle counts. The error rates need to be computed as a (failure) percentage, expressed per equipment group (e.g. traffic detectors and APC), evaluated for a certain time period (e.g. month, quarter and semester) and compared to a similar time period or a predefined standard (e.g. less than 1%). The data needed for the aforementioned computations can be obtained from the municipalities, planning authorities and transport operators.

ASSET MANAGEMENT AND -MAINTENANCE

ASSET MANAGEMENT

Asset management was identified to be a performance area for the performance category: asset management and -maintenance.

Asset management refers to the coordinated activity of an organisation to realise value from their assets. The aim of asset management is thus to manage the functioning nature and adequacy of the assets. This refers to maintaining assets that are fit for their purpose and it may or may not require procurement, lifecycle management or rehabilitation. Operations management was thus identified as the performance sub area for asset management. Operations management can be accomplished with the aid of four actions. These are: 1) record, 2) monitor, 3) control and 4) evaluate. The aforementioned actions form the measurement fields for the performance sub area identified.

All assets (existing and future procurements) need to be **recorded** in the asset register. The asset register collectively organises all asset-related information over an asset's whole lifecycle. This entails, among others, information on its location, cost profile and date of purchase. This type of information is necessary for asset lifecycle management and financial bookkeeping (e.g. depreciation- and insurance purposes). In order to ensure that the assets operate as they should, they need to be monitored and, in some cases, controlled. The **monitoring** of the assets is accomplished with the aid of network surveillance systems. For example: using CCTV cameras to verify the accuracy and the quality of the messages on VMSs. **Control** actions are needed to manage the public transport fleet. This includes the tracking- and/or navigating of the transit vehicles with the aid of positioning systems. The functioning nature of the aforementioned four functions can be assessed with the aid of a scorecard.

In order to determine the status (and the value) of the assets, they need to be **evaluated** on a regular basis. This evaluation includes conducting spot checks on an ad-hoc basis during the asset's useful life. The findings from these checks need to be documented in either a status report or a supporting electronic management system. This type of information is necessary in determining whether assets require rehabilitation and facilitates the calculation of an asset's (book) value. The latter mentioned refers to the asset's replacement cost considerations that are needed for insurance purposes. In order to establish the adequacy of the assets, the presence of status reports or a supporting electronic management system needs to be assessed.

ASSET MAINTENANCE

Asset maintenance was identified to be a performance area for the performance category: asset management and -maintenance.

Asset maintenance is about preserving the asset's condition or operable state during its useful life. Asset maintenance is executed with the aid of two actions. These are: 1) preventative maintenance and 2) corrective maintenance. These two actions were identified as the performance sub areas for asset maintenance.

Preventative maintenance refers to the systematic inspection, detection, correction and prevention of incipient failures; before they become actual- or major failures. Corrective maintenance, on the other hand, refers to the activities undertaken to detect, isolate and rectify a fault such that the failed equipment, machine or system can be restored to its normal operable state. All maintenance activities need to be tracked and documented in the asset maintenance report or in the supporting electronic management system in the form of logs. Preventative maintenance is usually executed by planning ahead and determining which assets may require maintenance attention. The identified assets are then logged as scheduled logs. Corrective maintenance is usually executed by rectifying assets that have already failed. The assets that have failed are logged as defect logs. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

The effectiveness of **preventative maintenance** activities, in the form of **scheduled logs**, can be determined by comparing the number of tickets planned (i.e. how many assets were identified to be inspected) and the number of tickets fulfilled (i.e. how many assets underwent inspection). This ratio is expressed as a percentage. If the computed percentage is in the vicinity of 100, preventative maintenance activities are deemed to be effective. This percentage needs to be evaluated for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or a predefined standard (e.g. a percentage just over 100). The effectiveness of **corrective maintenance** activities, in the form of **defect logs**, can be determined by considering both the number of tickets logged (i.e. how many assets required rectification) and the Mean Time To Repair: MTTR (measured from asset log time). The number of defect logs and the MTTR need to be evaluated for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or a predefined standard (e.g. rectification within 72 hours). The data needed for the aforementioned computations can be obtained from the asset maintenance report or from a supporting electronic management system.

MONEY MATTERS

ECONOMIC PERFORMANCE

ECONOMIC SUSTAINABILITY

Economic sustainability was identified to be a performance area for the performance category: economic performance.

Economic sustainability involves the identification of various strategies to promote using the available resources to their best advantage. That is, the use of resources in a way that is both efficient and responsible as well as likely to provide long-term benefits. In essence, economic sustainability calls for using resources in such a way that the system continues to function over a number of years, while consistently returning or generating a profit. A system is thus deemed to have economic sustainability if two conditions are met. These are: 1) if the system is able to adapt over time and 2) if the system is preserved over time. These two conditions were identified as the performance sub areas for economic sustainability.

System adaptability is dependent on the resiliency of the system's operations. Operational resilience refers to a system that is resilient to change. That is, the system is flexible to alter operations and thus able to respond to any major foreseeable changes that could occur as a result of changing conditions. System preservation relates to the status (i.e. condition and quality) of the project's relating infrastructure. The principal infrastructure components are: structures, fleet (i.e. vehicles), equipment, inventory and buildings. By preserving the system, specifically the fleet, environmental sustainability is inherently also stimulated. That is, since actions are taken to maintain and preserve the transit vehicles, their emission- and fuel consumption rates are regulated and controlled; thereby protecting the environment. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Operational resilience can be measured by considering the system's scalability and responsiveness to change. **Scalability** is the ability of a system to change its scale in order to meet changing volumes of demand; without compromising its performance. Common scalability dimensions, as given in P2A (2014), include: 1) structural scalability (i.e. the ability of a system to expand its operating units), 2) functional scalability (i.e. the ability of a system to take on new functions or tasks), 3) geographic scalability (i.e. the ability of a system to maintain performance in a wider geographic area), 4) resource scalability (i.e. the ability of the system to maintain performance in changing inputs) and 5 result scalability (i.e. the ability to deliver various forms of results/products). A system's scalability can be determined by conducting a pilot project on the re-scaled situation. With the aid of a pilot project, a comparison of system's performance between the initial situation and the re-scaled situation can be made. Performance needs to be evaluated by an expert in the representative field with the aid of a scorecard that considers feasibility factors such as: time, cost and effort. If the system has a good level of scalability, its performance in both of the situations will be comparable. If performance is significantly compromised in the re-scaled situation, then the system may likely be of poor scalability.

Responsiveness is the ability of the system to meet traveller needs and to respond to market changes, within a reasonable time period, such that competitive advantage can be established. The dimension of responsiveness identified for consideration is: **volume**. Volume responsiveness involves understanding the nature of demand, volatility of demand, customer expectation on customer service delivery and product diversification. This demand related information needs to be captured in the travel demand models as thoroughly as possible.

In **private transport**, a system can respond to changes in travel volume by using, for example, intelligent adaptive traffic control systems. Intelligent adaptive traffic control systems can either be used at (major) intersections or at freeway merge- and diverge points. The former mentioned is referred to as signalised intersection control and the latter mentioned is referred to as ramp metering. Both of these methods use information from vehicle detectors, located in each of the lanes immediately in advance of the stop line, to adjust signal timings in response to variations in traffic demand and system capacity. These methods thus aim to maximise the capacity of the roadway and to prevent traffic flow breakdown (and the onset of congestion). The planning for (or the presence of) the aforementioned technologies is thus indicative of a private transport system's level of responsiveness. On the contrary, the evaluation of a **public transport** system's responsiveness is not based on the use of technologies. If a temporary increase in travel volumes is forecasted (e.g. in the event of special events), certain informal- and provisional approaches can be employed. For example: the establishment of temporary transfer points, the adjustment of ad-hoc transit routes (e.g. spinner buses) and the employment of group passenger pick-up services. As a short-term solution, the planning for (or the presence of) such approaches is thus indicative of a public transport system's level of responsiveness. It needs to be noted, however, that volume (demand) responsiveness is innately greater for road-based public transport modes than for rail-based public transport modes. The reason for this is due to the fact that it is easier to add, for example, buses than additional train services or rail carriages. Therefore, increments are larger for rail- than for road-based public transport modes. These differences between modes thus need to be taken into consideration when determining the public transport system's level of responsiveness. A project's efforts towards being responsive can be evaluated with the aid of a scorecard that considers the dimensions referred to here.

The evaluation of the **status of project infrastructure** needs to be executed separately for the private- and the public transport network. The status of the **private transport** network can be determined by evaluating the travellers' experience when travelling on major roadways. A **traveller experience evaluation** captures the users' opinion on, among others, the overall condition and the quality of the road network. This includes, among others, their satisfaction with regard to the transport-related equipment (e.g. VMS and traffic lights) and the roadway quality. The results from the evaluation survey need to be computed as a satisfactory percentage (e.g. equipment or roadways rated good or better), expressed per either (major) road segment or per OD route, evaluated for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or a predefined standard. If an increase in the satisfactory percentage is observed, it can be deducted that the private transport system is being preserved acceptably.

Note: if it is desired to also use this traveller experience evaluation in public transport, separation between policies relating to the provision of roads, road surface quality and the quality of the transit line needs to be made. This will facilitate that the service provider only be deemed liable for the aspects that are within their control. For example: assuming that a bus is appropriately specified for the road surface, the bus company cannot be blamed for operating on a poor road surface.

The **status** of the **public transport** network can be evaluated by considering the **age distribution** of the fleet. However, due to varying expected lifespan of transit vehicles, each transit vehicle type (i.e. bus, rapid transport and train) needs to have its own distribution graph. The respective age distribution graph can then be used to determine the **average remaining useful life** for each representative transit vehicle type. The data needed for this computation can be obtained from public transport service providers. The remaining useful life of the fleet needs to be expressed per transit vehicle type, evaluated and averaged for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or a predefined standard. An increase in the average remaining useful life of the fleet is indicative of two facts. Firstly, it can be deducted that the public transport system is being preserved acceptably. Secondly, since there is a relationship between fleet age and its environmental sustainability, it can also be deducted that environmental stewardship is fostered.

ECONOMIC VITALITY

Economic vitality was identified to be a performance area for the performance category: economic performance.

Economic vitality refers to a fully employed and diversified economy with stable, well-paying jobs in targeted industries. Economic vitality is achieved by a positive business climate followed by successful growing of the primary services provided. A system is thus deemed to have economic vitality if two conditions are met. These are: 1) if the system fosters economic development and 2) if the system stimulates economic growth. These two conditions were identified as the performance sub areas for economic vitality.

Economic development is about promoting the standard of living. That is, the quantitative- and qualitative changes the system fosters in the economy. This relates to whether the system sustains the creation of business opportunities. Economic growth is defined as an increase in the capacity of an economy to produce services (or goods); compared from one period of time to another. Therefore, economic growth relates to whether the system stimulates service expansion. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Business opportunities can be measured by considering the number of **jobs created** as a result of the existence of the system. For example: jobs created for project construction and -operation. The data needed for this computation can be obtained from the municipalities and/or the responsible authorities. The number of jobs created needs to be evaluated for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard (e.g. job creation to increase by “x” percent per year). If an increase in business opportunities is observed, the system is deemed to foster economic development.

In order to ensure that the transport system's capacity growths as planned, **service expansion** needs to be managed. Service expansion can be evaluated by considering the project's success with regard to adequately using its allocated funds for **capacity building and infrastructure development**. This relates to determining whether the project delivered acceptable infrastructure expansion, on time and as per the allocated budget. The three relating project management measures are thus: quality, time and cost. These measures need to be considered collectively, weighed equally, computed as a performance score, expressed per project, evaluated for the budget period (e.g. year) and compared to a previous similar time period or a predefined standard. If the project has adequately used its allocated funds, it then inherently means that sufficient economic growth was stimulated. This would be reflected through a satisfactory performance score.

SOCIO-ECONOMIC PROSPERITY

Socio-economic prosperity was identified to be a performance area for the performance category: economic performance.

Socio-economic prosperity is achieved when the project caters for an environment in which both the society and economy can flourish. Prosperous circumstances relate to thriving conditions (especially in, but not limited to, financial respects) that enhance the socio-economic standard of the country. The socio-economic standard of the country directly correlates to the benefits reaped from the project(s) deployed. Therefore, the well-known ITS project goals were taken to be the performance sub areas for socio-economic prosperity. These goals can be beneficial in the following areas of interest: 1) energy and environment, 2) safety, 3) efficiency, 4) customer satisfaction and 5) mobility and 6) productivity. For more information regarding ITS project benefits, refer to RITA US DoT (n. d.). The aforementioned interest areas form the measurement fields for the performance sub area identified.

The project benefits reaped from the ITS goal **energy and environment** need to be evaluated separately for private- and public transport. The attainment of the energy and environmental benefits in the **private transport** environment is based on the project's ability to manage **traffic flow conditions** in such a way that high operating flow rates can be maintained. ITS applications such as *ATMS and ATIS* aid in improving operating flow conditions. The attainment of the energy and environment benefits in the **public transport** environment is based on the project's ability to promote the **use of public transport** in such a way that it is seen as a preferred mode of travelling. ITS applications such *APTS and PIDS* aid in promoting public transport use. If any such applications are implemented, the project is in a favourable position to realise the associated energy and environmental benefits. An increase in either operating flow rate (i.e. vehicles per hour) or public transport ridership numbers result in a reduction in overall fuel consumption. A reduction in fuel consumption leads to fuel cost savings and emission benefits. Moreover, the less congested the private transport network is and the more people use public transport, the more energy can be conserved. The more energy is conserved, the more environmental- and health benefits can be reaped.

The project benefits reaped from the ITS goal **safety** can be measured by evaluating the number of **primary- and secondary incident occurrences**. ITS applications such as *speed over distance cameras and -calculators, adverse weather identification and -notification systems as well as collision avoidance systems* aid in improving the safety of the transport network. If any such applications are implemented, the project is in a favourable position to realise the associated safety benefits. If the safety of the transport network is improved, the total number of incidents are likely to decrease. A decrease in the number of incidents results in incident cost savings and less fatalities.

The project benefits reaped from the ITS goal **efficiency** can be measured by evaluating the transport **network's throughput**. Throughput relates to the number of vehicles or persons able to enter or exit the network during the analysis period (expressed per hour). The more efficient the transport network is, the higher its throughput will be. ITS applications such *AVL-based bus priority systems at traffic signals, EPS (e.g. Electronic Toll Collection: ETC and EFC*) *as well as route guidance and- navigation systems* aid in improving the efficiency and thus also the throughput of the transport network. If any such applications are implemented, the project is in a favourable position to realise the associated efficiency benefits. An increase in throughput results in travel time savings and also possibly peak spreading. The realisation of peak spreading leads to a reduction in peak demand.

The project benefits reaped from the ITS goal **customer satisfaction** can be measured by considering both the community's confidence in, and perception of, the service. **Community confidence** is indicative of the public's confidence in the agency's ability to (transparently) operate an efficient and effective transport system. If the project is rolled out on-time, within budget, and if the related ITS applications meet their desired- and expected functions, the community will (re)gain trust in the project. If the community trusts the service, it is more likely for them to then also favour the service. The **community's perception** is indicative of how the public experience the service provided. ITS applications such as *bus arrival notification systems, incident notification systems and Automated Parking Information Systems (APIS)* aid in stimulating a favourable customer perception. However, in order to maintain such a favourable perception, additional customer support services such as *feedback- and self-service systems* are needed. These systems facilitate the project in aligning their service with the needs of all users (including non-frequent travellers, elderly people and people with disabilities). As a result, service utilisation can be realised. That is, since the service is aligned to meet the needs of all people, more people are able to (or prefer to) use the service. This then also encourages the sustainability of the service. While an improvement in the utilisation of the private transport service possibly results in an increase in toll-road users; an improvement in the utilisation of the public transport service results in an increase in ridership numbers. An increase in either of these fields leads to the reaping of greater revenues. These revenues can then be used to maintain and expand the service as deemed just.

The project benefits reaped from the ITS goal **mobility** can be measured by evaluating people's **ease of movement**. ITS applications such as *variable speed limit systems, intelligent adaptive traffic control systems (i.e. signalised intersection control and ramp metering) and queue length monitoring* aid in increasing people's ability to move; thereby increasing their ease of movement. If any such applications are implemented, the project is in a favourable position to realise the associated mobility benefits. An increase in ease of movement results in travel time savings. Travel time savings lead to more effective and efficient use of time. The more (wasted) time is saved, the better the quality of citizens' lives.

The project benefits reaped from the ITS goal **productivity** can be measured by evaluating the effectiveness of the system. **System effectiveness** refers to the system's capability to uphold a high quality of service with little to no wasted resources. Therefore, a system is effective if it meets the needs and requirements imposed by the environment in which it operates and if it is sustainable in its nature. ITS applications such *crew rostering- and scheduling systems, vehicle tracking- and re-routing systems as well as emergency- and incident response systems* aid in promoting a high quality of service. If a high quality of service is maintained, more users will favour the service and hence resources can be used optimally. In essence, the associated productivity benefits that could be reaped from system effectiveness not only include the realisation of an optimum demand-supply relationship and hence also optimum resource use, but also the provision of a service that is effective in relation to its associated costs. The more users use the service, the more cost effective the service is. The more cost effective the service is, the better the return on investment is.

FINANCIAL PERFORMANCE

FINANCIAL FEASIBILITY

Financial feasibility was identified to be a performance area for the performance category: financial performance.

In order to determine the financial feasibility of the ITS project(s) deployed, a benefit-cost analysis needs to be conducted. Benefit-cost analysis is a systematic approach to estimating the strengths and weaknesses of a project by evaluating its representative benefit to cost ratio. As the name suggests, the analysis involves adding up the benefits gained from project employment and then comparing them with the costs associated with it. The (social) benefits gained from ITS projects are discussed in the performance area socio-economic prosperity under the performance category economic performance. The associated costs of ITS projects are considered here. The costs associated with ITS projects can be categorised into four groups. These are: 1) non-recurring costs, 2) recurring costs, 3) miscellaneous costs and 4) social costs. These four groups were thus identified as the performance sub areas for financial feasibility.

Non-recurring costs refer to any once-off cost incurred that is unlikely to occur again in the normal course of a project. Such costs mainly encompass capital expenditure (i.e. capex). Recurring costs refer to any regular cost incurred repeatedly over the normal course of a project. Such costs mainly encompass operating expenditure (i.e. opex). Miscellaneous costs refer to any unforeseen cost incurred during the course of a project. Such costs can vary over time. For more information regarding these ITS project costs, refer to RITA US DoT (n. d.). Social cost is the total cost to society. This can be represented by considering the negative transport externalities. Negative transport externalities refer to the costs caused by an activity (i.e. the project) that affect an otherwise uninvolved party (i.e. the traveller) who did not choose to incur that cost. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Capex is the money used to purchase, upgrade, improve or extend the life of long-term assets. **Long-term assets** are typically infrastructure, equipment (with a useful life of more than one year), vehicles, buildings and facilities. **Opex** is the money used to run the system and thus perform the service (or provide the product). Opex is usually divided into: 1) selling expenses and 2) general- and administrative expenses. **Selling expenses** are the costs pertaining to activities related to marketing the service (e.g. advertising- and promotional material cost). **General- and administrative expenses** are the costs pertaining to activities related to the day-to-day operations needed to provide the service (e.g. cost of workers, facility expenses and cost of maintenance and repairs). The main expenditures pertaining to **miscellaneous costs** include: fines, law suits and environmental damage costs. The estimated environmental damage cost can be determined by conducting an environmental impact assessment on the deployed project. The data needed for this financial computation can be obtained from the relevant implementing authorities.

In order to conduct a **benefit cost analysis**, the project alternative and base case need to be identified. Then the level of detail (e.g. spatial, temporal and user segmentation) needs to be decided. After the level of detail is established, the basic user cost factors (e.g. values of time, vehicle unit operating costs, accident rate and cost parameters, vehicle emission rate and cost parameters) and the economic factors (e.g. discount rate, analysis period, evaluation date and inflation rates) need to be determined. After the development of these factors, the associated performance data (with regard to the project alternative and the base case) for explicitly modelled periods needs to be obtained. Then the user costs and the user benefits (with regard to the project alternative and the base case) need to be measured and calculated. With this established, the benefits to all project years can be extrapolated/interpolated; unless all time periods are explicitly modelled. Lastly, the present value of the benefits and costs can be calculated such that a benefit cost ratio can be computed (PSRC 2009). The financial feasibility of the investment is then determined by the size of this ratio computed. A ratio bigger than one signifies that the associated project benefits is greater than its costs.

If **social costs** are also to be taken into consideration, a **social benefit cost analysis** needs to be conducted. A social benefit cost analysis (also referred to as economic analysis) is a feasibility study of a project from the viewpoint of a society to evaluate whether the project adds benefit or cost to the society as a whole. In order to reflect the social value, all social benefits and -costs of a project are quantified at shadow price and not market price (as is the case in the general benefit cost analysis).

The three main **negative transport externalities** include: 1) congestion, 2) accidents and 3) pollution. The social costs related to congestion are based on the valuation of the *societal loss* (with regard to time lost by the travellers) as a result of congested circumstances. This societal loss can be represented by considering both the value of time and the associated cost to travel. The social costs related to accidents are based on the valuation of the *economic loss* as a result of accident occurrences. This economic loss can be represented by considering two factors. Firstly, the cost to the injured person and secondly, the accident cost. The former mentioned include, among others, the costs of treatment and cure, hospitalisation, insurance, administration and judgment. The latter mentioned include, among others, damage to the vehicle and other property, time loss, congestion cost, administrative costs and damage to the environment. The social costs related to pollution are based on the evaluation of the *environmental loss* as a result of air- and noise pollution. The former mentioned can be represented by the cost of health effects and the latter mentioned by the cost of noise. Establishing and quantifying these transport externalities are a complex undertaking. However, it is possible if some simplifications and generalisations are assumed. For more information, refer to Shiftan *et al.* (2002).

INVESTMENT MANAGEMENT

Investment management was identified to be a performance area for the performance category: financial performance.

Investment management relates to planning, organising, directing and controlling the financial performance of ITS project investments. Investment performance was thus identified as the performance sub area for financial investment management. In order to determine the performance of ITS project investments, numerous financial measures exist. Examples include, among others, the evaluation of the investment’s liquidity, profitability and leverage. However, for the purpose required herein, it is proposed to only evaluate the efficiency of an investment. The efficiency of an investment can be determined by considering the profits generated in relation to the capital invested. This is referred to as capital gain evaluation. Capital gain forms the measurement field for the performance sub area identified.

Capital gain can be determined by considering the **Return on Investment** (ROI). In order to compute the ROI, the benefit (return) of an investment is divided by the cost of the investment. The ROI needs to be expressed as either a percentage or a ratio, evaluated on a regular basis (e.g. quarterly, semi-yearly or yearly) and compared to a previous similar time period or a predefined standard. A high ROI means that the investment gains compare favourably to the investment cost.

PEOPLE MATTERS

PUBLIC RELATIONS

MARKETING

Marketing was identified to be a performance area for the performance category: public relations.

Marketing is the action of promoting services (or selling products), including market research and advertising. Service promotion was thus identified as the performance sub area for marketing. A service can be promoted with the aid of marketing campaigns and -modules. The three main types of marketing strategies usually used for the adoption of an ITS-related product or service are: 1) raising awareness, 2) developing understanding and 3) securing acceptance. These marketing strategies need to be segmented among the representative markets and appropriate market targeting mechanisms need to be employed. Market segmentation is necessary since it is impossible (due to time-, cost- and effort restrictions) to target the entire market. The aforementioned criteria form the measurement fields for the performance sub area identified.

The **awareness of the service** can be raised with the aid of marketing campaigns. **Marketing campaigns** are used to promote a service through different mediums (e.g. television, radio, print and online) by using a variety of different types of advertisements (e.g. advertising, demonstrations, word of mouth and other interactive techniques). Examples of marketing campaigns include, among others, a traffic- and a road safety campaign. In order to develop an **understanding of the service**, publicity modules need to be used. **Publicity modules** are used to enhance the reputation of the service among the target audience, stakeholders, employees, partners, investors and any other people associated with it, through manipulation. In essence, publicity modules help to create a favourable image of the service in the minds of the potential customers through arguments and reasoning. **Acceptance of the service** can be secured with the aid of public information modules. **Public information modules** help to maintain the image of the service and to enhance the service provided by circulating relevant and meaningful information among the target audience (public). These modules are thus dependent on mass- and controlled media (e.g. press releases, newsletters and brochures) to circulate information for brand positioning.

In order to measure the success of the marketing strategies adopted, two approaches are recommended. Either a *transport customer satisfaction survey* or a *before and after analysis* can be conducted.

Transport customer satisfaction surveys are used to capture the private- and public transport users' opinion on overall service delivery. However, it needs to be noted that, segmentation among the factors considered is needed to distinguish between factors that are within or outside of the control of the service provider. The results from these surveys are represented as a **transport customer satisfaction index**. This index collectively combines the users' satisfaction levels with regard to the quality of the service delivered. For example: is the service on par which the users' needs and desires? The customer satisfaction index needs to be computed separately for either private- or public transport, expressed per either major road segment or per transit vehicle type (i.e. bus, rapid transport and train), evaluated and averaged for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard. If an increase in the satisfaction indices is observed, it can be deducted that the service adheres to the users' needs and thus stimulates a favourable public image.

Before and after analysis is used to establish whether the service provided results in any **enhancements**. For example: whether there is a reduction in the number of fatalities or an increase in the ridership numbers. The results from the before and after analysis need to be computed as an improvement percentage, expressed in the field of either private- or public transport, evaluated for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or a predefined standard. If any improvement is observed, the service succeeds in brand positioning and thus fosters an environment that caters for enhancements.

NETWORKING

Networking was identified to be a performance area for the performance category: public relations.

Networking is the action of interacting with individuals or groups by exchanging information on social media platforms. Service interaction was thus identified as the performance sub area for networking. Effective social media is neutral. However, service interaction needs to be regarded as a proactive method of cultivating favourable perceptions and rapidly addressing any negative sentiment that may arise. The success of service interaction can be measured by considering three factors. These are the: 1) attractiveness of the social media platform, 2) exposure gained from the social media platform and 3) cultivation of productive relationships through the social media platform.

The attractiveness of the social media platform relates to the number of (active) followers or likes and is directly representative of the reach and influence the service has or can have. The more users the social media platform has, the easier it is to get the right message across, to the right people, at the right time. The exposure gained from the social media platform relates to the possibility of luring potentially new users. The cultivation of productive relationships through the social media platform relates to the action of counteracting any negative perceptions. The aforementioned criteria form the measurement fields for the performance sub area identified.

The **attractiveness** of the social media platform can be measured by considering the **size of the social community** (expressed per social media platform). However, in order to obtain an accurate estimate of the attractiveness of the social media platform, a distinction between active- and non-active users also needs to be made. The **exposure** gained from the service media platform can be determined by evaluating the **number of reposts or shares**. The exact data needed for these computations, however, might be difficult to obtain. Therefore, it is recommended that the *rate of growth in social media attractiveness* rather be considered as a general measure encapsulating both the aforementioned measures. The rate of growth in social media attractiveness needs to be computed as the percentage increase in the number of users (e.g. followers or likes), expressed per social media platform (e.g. Twitter and Facebook), evaluated for a certain time period (e.g. quarter and semester) and compared to a previous similar time period or a predefined standard.

In order to determine whether service interaction cultivates **productive relationships**, the general **type and trend of the postings** made by the users can be evaluated. That is, do the users generally make positive- or negative comments on the social media platform(s)? Positive user recordings relate to, for example, implementable feedback, valuable recommendations and constructive criticism. Negative user recordings include, among others, expressions of distrust, dissatisfaction or disappointment. These recordings can be evaluated with the aid of a scorecard. Another method proposed is the use of **peer- and public reviews**. These reviews capture the transport users' opinion on overall service interaction in the form of a productive relationships index. This index assesses the users' experience when interacting with the service. For example: do they feel that they can easily convey their concerns and that their concerns are being addressed? These results need to be computed as either a score or a productivity index (e.g. favouring mostly positive- or useful implementable comments), expressed per social media platform (e.g. Twitter and Facebook), evaluated for a certain time period (e.g. month and quarter) and compared to a previous similar time period or a predefined standard.

CUSTOMER SERVICE

TRAVELLER INFORMATION PROVISION

Traveller information provision was identified to be a performance area for the performance category: customer service.

Traveller information provision is the act of delivering a high quality service by providing travel-related information in a professional and helpful manner. This information needs to be disseminated to different user types. For example: sophisticated smart-phone owning users, users without any mobile devices as well as internet-connected and non-internet connected users. The customer service delivery methods clearly differs among these different user types. Nevertheless, the customer service delivery methods generally aim to provide the users with: 1) assistive information, 2) confirmative information, 3) notification services and 4) advisory information. These four general aims of customer service delivery were thus identified as the performance sub areas for traveller information provision. In essence, the service provider needs to provide travellers with pre-trip and in-trip planning assistance, general transit- and traffic related information, incident notification information and route guidance. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Comprehensive **trip planning assistance** includes door-to-door routing services. The main dependent for door-to-door routing is that all mode options (i.e. NMT, private- and public transport) be considered when computing viable routes. Moreover, these routing services interact with the users in two manners. These are the: 1) user pull service and 2) service provider push service. While the transport environment is moving towards the push service (particularly during the trip), the pull service still needs to be retained for both the pre-trip and the in-trip phase of the journey. The presence of pull services allow travellers to experience a personalised service. Pull services facilitate, for example, the computation of the best route as determined by the traveller's specified criteria (e.g. departure/arrival time, travel cost, transfer distance and mode preference). Since some **transit- and traffic information** may change over time, they need to be regularly confirmed. For example: general mode related information, fare structure information and schedule information. The occurrence of certain incidents can impede the quality of the service, as experienced by the traveller. However, if the travellers are **notified about incident occurrence**, they feel more at ease. That is, by making them knowledgeable about the incident(s), they remain to feel that they have "control over their lives". Examples of incidents that require attention are: crashes, adverse weather conditions, schedule delay and strikes. Advisory information, such as **route guidance**, helps to avoid or dampen frustrating situations. For example: advising travellers of detour (alternative) route options when incident occurrence influences operating flow conditions. The provision of innovative world-class customer services that are proactive, effective and enabling in service delivery is dependent on the existence of the aforementioned customer service delivery methods. The project's success with regard to implementing these delivery methods can be evaluated with the aid of a scorecard.

GENERAL SUPPORT INFORMATION

General support information was identified to be a performance area for the performance category: customer service.

General support information refers to the range of services provided to help customers in using the service. These support services take on different forms for a variety of means. These are to provide: 1) logging attendance, 2) inter-personal interaction and 3) self-service systems. These three means of providing support were thus identified as the performance sub areas for general support information.

Attending to user logs such as inquiries, queries, complaints and compliments is vital to the success of the service. Such attendance can aid in improving customer morale and in reducing confusion with regard to expectations and current performance. Inter-personal interaction occurs when the customer interacts through the workforce with the service. This interaction has or can have a direct impact on the customer's experience of the service and thus influences their perception of the quality of the service. Examples of workforce personnel are: call centre personnel, roadside assist personnel, transit vehicle drivers, ticket agents and security guards. Self-service systems relate to the customer's interaction with the service by using service inventory and -technology. Examples of service inventory and -technology that act as interaction mediums are: ticket issuing- and validation machines as well as EPS such as EFC, ETC and Electronic Parking Payment (EPP). This interaction also has or can have a direct impact on the customer's experience of the service. If any of these devices is not functionally properly, an immediate connotation to poor or unsatisfactory service quality is made. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Logging attendance is dependent on the functioning nature of the communication mediums. The communication medium can be a call centre, a website or an application. These communication mediums facilitate user logs in the form of inquiries, queries, complaints and compliments. A satisfactory functioning nature occurs when the *reaction* to these logs are not only made as soon as possible, but also are of a *helpful* nature.

The data needed to compute the **reaction time** can be obtained from the facility's control centre and/or from the service providers. Reaction time needs to be measured from log time, expressed per log type and per communication medium, evaluated and averaged for a certain time period (e.g. month and quarter) and compared to a previous similar period or a predefined standards (e.g. web responses to be made within 24 hours).

The **helpfulness** of the reaction relates to whether or not the reaction is on par with what the customer requested. Since reaction helpfulness is a matter of customer perception, it is recommended to be evaluated by the ratio of the number of compliments and the number of complaints. The helpfulness ratio needs to be expressed per communication medium, evaluated for a certain time period (e.g. month and quarter) and compared to a previous similar period or a predefined standard. If this ratio is above one, it can be deducted that the responses made were generally deemed helpful.

The quality of the **inter-personal interaction** between the travellers and the workforce can be evaluated by considering **personnel performance**. For example: evaluating personnel courtesy and appearance as well as their knowledgeability in their field of expertise. The quality of the interaction between the travellers and the **self-service systems** can be evaluated by considering the **usefulness of the service inventory and the technology** in place. For example: are the inventory and technology simple to use and easy to understand? The quality of both of the aforementioned interaction mediums can be evaluated in three ways. These are: 1) periodic inspections by ghost riders or supervised in-field spot checks, 2) periodic evaluation of video recordings from cameras on-board transit vehicles, at transit facilities or next to major roadways and 3) periodic operational testing of service inventory and technology by a representative non-technical user. The provision of innovative world-class customer support services that are proactive, effective and enabling in service delivery is dependent on managing the quality of the aforementioned service interaction mediums. The project's success with regard to delivering high quality interaction mediums can be evaluated with the aid of a scorecard.

SOCIAL SUSTAINABILITY

SUSTAINABLE SERVICE DELIVERY

Sustainable service delivery was identified to be a performance area for the performance category: social sustainability.

Sustainable service delivery refers to the project's ability to provide services that not only meet the needs of the community's current members, but also support future generations in realising and maintaining a healthy community. In essence, the project needs to deliver services that has the capacity to respond to current- and emerging needs; can facilitate the achievement of desired social performance; and that can aid in maintaining the accepted social values. The project's proceedings in delivering a sustainable service can be represented by two conditions. These are: 1) social justice and 2) social equality. These two conditions were identified as a performance sub areas for sustainable service delivery.

Social justice refers to having justice in terms of the distribution of wealth, opportunities and privileges within a society. Therefore, the degree of social justice pursued can be represented through service affordability. If a service is affordable to all, all of the members in the society are given the same privileges and none of the members in the society is thus treated unfairly. Social equality refers to a state of affairs in which all people within a society have the same status in certain respects. This correlate to the fostering of social inclusion. Social inclusion is based on including all members of the society in such way that each is presented with the same opportunities. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

In the **private transport** environment, **service affordability** can be determined by evaluating how economical the running- and maintenance costs of owning a vehicle are. This evaluation can be conducted by determining the **percentage of a citizen's salary that goes towards his/her transport expenditures**. The data needed for this computation can be obtained from, for example, the South African National Income Dynamics Study (NIDS), the annual Kinsey report and the vehicle rates calculator provided by the Automobile Association (AA) of SA. NIDS commenced in 2008 and is conducted every two years. The study examines the livelihoods of individuals and households over time and provides information on, among others, labour market participation and economic activity. The annual Kinsey report on parts pricing provides information on, among others, some of the costs involved in servicing, repairing and fixing accident damage to vehicles. The vehicle rates calculator provided by the AA determines the average running cost per vehicle type or model. The percentage of a citizen's salary that goes towards his/her transport expenditures needs to be expressed per individual, user group or household, evaluated and averaged for a certain time period (e.g. year) and compared to a previous similar time period or a predefined standard (e.g. 33%).

The cost of the **public transport** service is directly related to the grants made by the government. Therefore, transit **service affordability** can be determined by considering the extent of the support provided by the government in the form of subsidies. If the subsidies are sufficient, discounted fare options (e.g. elderly people or frequent travellers) will be available. The availability of any discounted fare options is indicative of the support provided by the government and hence the affordability of the transit service. If there are too many interdependencies influencing the availability of discounted fare options (e.g. the efficiency of a service or cross-subsidisation), the cost per distance travelled can also be considered.

In the **private transport** environment, **social inclusion** can be determined by evaluating **road placement**. That is, are the roads build at strategic places where it can be optimally utilised by the majority of the population. This relates to land-use management. Specifically, urban transport modelling (travel trends) and -design (spatial planning). The data needed for this computation can be obtained from the representative municipalities, transport modellers, spatial planners and the NHTS. In order to determine whether the roads are accessible and useful to everyone, the degree of urban densification needs to be considered. Urban densification needs to be computed as the percentage of the population that can conveniently access major roads and freeways, evaluated for a certain time period (e.g. every two years) and compared to a previous similar time period or a predefined standard.

Social inclusion, in the **public transport** environment, can be measured by considering the **presence of amenities for people with disabilities**. For example: the availability of wheelchair ramps at transit facilities for mobility impaired people, audio signals at pedestrian crossings for sight impaired people and clear notice boards for hearing impaired people. The presence of any such amenities is indicative of the support provided to the people with disabilities and hence the social inclusion exhibited by the transit service.

SUSTAINABLE LIVING

Sustainable living was identified to be a performance area for the performance category: social sustainability.

Sustainable living refers to a state of flourishing, thriving, good fortune and successful social status. The latter mentioned is based on a person's standing in relation to other people within a society. Therefore, in order to pursue such a state of living and hence enhance the overall social status of the community, the project needs to foster social development. Social development was identified as the performance sub area for sustainable living. Social development is about putting people at the centre of development. This not only entails a commitment that development processes benefit people (particularly the poor), but also a recognition that people, and the way they interact in groups and society, and the norms that facilitates such interaction, shape development processes. In essence, public-service alignment needs to be stimulated. The aforementioned criterion forms the measurement field for the performance sub area identified.

In order to ensure that the services provided are beneficial to the public, a **usability study** needs to be conducted. A usability study facilitates the evaluation of a service (or product) by testing it on its users; thereby highlighting the users' needs and viewpoints. This will aid in determining whether the service adheres to providing the public with what they want. If this is the case, social development is stimulated. Another approach to fostering **social development** is to introduce **community programs** that shape human capital development**.** A prominent example of such development programs is transport education programs (e.g. road safety training for pupils). If the aforementioned approaches are used prior to project implementation as well as after project implementation, at an interval basis, it can be argued that the project adequately supports the enhancement of social development.

HUMAN RESOURCE MANAGEMENT

EMPLOYEE PERFORMANCE MANAGEMENT

Employee performance management was identified to be the sole performance area for the performance category: human resource management.

Employee performance management is about aligning the organisational objectives with the employees' agreed measures, skills, competency requirements, development plans and the delivery of results. In order to create a high performance workforce, the following conditions thus need to be evaluated. These are: 1) employee satisfaction, 2) employee commitment, 3) employee engagement and 4) employee development. These four conditions were identified as the performance sub areas for employee performance management.

Employee satisfaction encompasses how content or satisfied employees are with both their job descriptions and their operating environment conditions. Typical topics for the former mentioned include compensation, workload, leave, teamwork opportunities and available resources. The latter mentioned refers to the employees' thoughts on the quality of their operating environment with regard to the servicescape conditions. The concept servicescape, also called service setting, considers the totality of the ambience and the physical environment in which the service occurs. Therefore, typical topics addressed here are the ambient- and the general space function layout conditions. Employee commitment refers to the employees' faithfulness towards the company. That is, are they faithful in adhering to the company's policy agreements? Employee engagement is based on the existence of an organisational structure that clarifies employee roles, facilitates communication and establishes a chain of responsibility to help determine strengths and weaknesses. Employee development is not only about promoting and advancing skillsets, but also tracking the employees' improvement. The aforementioned criteria form the measurement fields for each of the performance sub areas identified.

Employee satisfaction can be evaluated by conducting an **employee satisfaction survey**. This survey evaluates the employees' opinion and overall contentedness with regard to their job- and operating environment. The results from this survey is captured as a satisfaction index. The Employee Satisfaction Index (ESI) needs to be computed per division or per department, expressed per employee, evaluated and averaged for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard. If an increase in the satisfaction indices is observed, it can be deducted that the service caters for an environment that meets the employees' needs.

The **employees' faithfulness** to adhering to policy agreements (e.g. contracts) can be determined by evaluating their **absenteeism scores**. The absenteeism scores need to be computed per division or per department, expressed per employee, evaluated and averaged for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard (e.g. allowable sick leave of 15 days a year). If a discrepancy between the policy agreement and the absenteeism scores exists, further investigation needs to be undertaken among the representative division, department or employee.

An organisational structure that **engages employees** is dependent on the existence of proper **communication channels**. These channels can be used to facilitate horizontal- and vertical communication as well as to ensure the general morale and well-being of the employees. An example of the former mentioned is focus group sessions. Focus groups can, for example, facilitate a favourable perception of management and management practices. An example of the latter mentioned is trauma counselling services. Trauma counselling services need to be provided to, for example, transport operators or emergency personnel who experienced a traumatic event such as a gruesome- or mortal accident. The type of communication channels provided needs to be documented per division or per department and, if appropriate, the frequency of the provided services needs to be evaluated.

In order to determine whether **advancing skillsets** are promoted, the presence of (regular) **training services** needs to be considered. Examples of in-service training and staff development programs are: introduction- or orientation training and career- or development training. The type of training services provided as well as which employee attended what program(s) need to be documented per division or per department and, if appropriate, the frequency of the provided services needs to be evaluated. In order to evaluate **employee performance** and thus determine their ability to assume greater responsibility in higher positions, their improvement needs to be tracked. This relates to **progress evaluation**. Progress evaluation needs to be done on a regular basis (e.g. quarter and semester) and documented per employee and per division or per department.

AIR QUALITY MANAGEMENT

AIR POLLUTION MONITORING

Air pollution monitoring was identified to be the sole performance area for the performance category: air quality management.

In order to monitor air pollution and hence the quality of the air we breathe, both the emissions from mobile sources and GHG need to be considered. While mobile source emissions refer to the emissions from vehicles, trucks and buses; GHG emissions refer to the emissions from burning fossil fuel to operate these transport modes. The fuel used for transport is mainly petroleum based, which includes petrol and diesel. The combination of mobile source- and GHG emissions was thus identified as the performance sub area for air pollution monitoring. The monitoring of air pollution with regard to mobile source- and GHG emissions encompasses three actions. These are: 1) govern, 2) mitigate and 3) evaluate. That is, the emissions need to be governed, they need to be regulated with the aid mitigation procedures and their status and trend need to be evaluated. This evaluation facilitates the determination of a project's performance with regard to implementing air quality management. The aforementioned actions form the measurement fields for the performance sub area identified.

Only the primary mobile source- and GHG emissions are identified for measurement. The **priority pollutants** from **vehicle emissions** that cause brown haze visibility and can affect human health are: Particulate Matter ($PM_{2.5}$ and PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone (O_3), Carbon Monoxide (CO) and Hydrogen Sulphide (H_2S) (CoCT 2005). These pollutants can be measured as, for example, parts per million (ppm) and grams per cubic meter of air (g/m^3). <u>These measurements can then be expressed, for example, per transit facility or per transport mode type (i.e. vehicles, trucks and buses).</u> The priority pollutants from **GHG emissions** that affect the temperature of the earth are: Carbon Dioxide (CO_2), Nitrous Oxide (N_2O) and Methane (CH_4) (CoCT 2005). These pollutants can be measured as, for example, grams per unit of travelled distance (e.g. g/km) or grams per unit of mechanical energy delivered by the engine (e.g. g/kWh). <u>These measurements can then be expressed, for example, per fuel type (i.e. diesel-driven and petrol-driven vehicles).</u>

The management of air quality relates to the control of emissions as regulated by the air quality standards. Numerous guidelines to air quality standards exists. Standards are given as, for example, national- and provincial ambient air quality standards; national-, provincial- and local emission standards for activities, including vehicle emissions (controlled emitters) and standards for planning, reporting and monitoring. Mitigation procedures that enable the compliance with these standards and counteract the impact of the pollution can either take on the form of emission control technologies and/or emission reducing activities. Examples of **emission control technologies** include technologies that facilitate vehicle-related weight reduction, emission reduction and energy recovery. Examples of **emission reducing activities** include the modernisation to hybrid vehicles, the promotion of public transport, the use of equipment that promotes seamless traffic flow, roadside testing of diesel-driven vehicles as well as the initiatives that support clean fuel. The degree to which a project is successfully mitigating the impact of its associated priority pollutants on air quality can be evaluated with the aid of a scorecard.

A project's performance with regard to implementing air quality management can be evaluated by measuring its **emission- and air quality trends**. These trends can be determined by considering the change in the emissions and/or the change in the air quality. A change in the form of an improvement indicates that a project has/had a favourable effect on air quality. The measured change needs to be exhibited by a percentage, computed as either a decrease in emissions or an increase in air quality, expressed per pollutant, evaluated for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard.

CLIMATE CHANGE MANAGEMENT

WEATHER MONITORING

Weather monitoring was identified to be the sole performance area for the performance category: climate change management.

Weather monitoring relates to the action of managing the effects of adverse weather conditions. Adverse weather conditions prevail when there is a severe presence of: wind, temperature, sunshine, rain, hail and fog. Such conditions can influence the road condition and can also impair human senses. For example: excessive rain can cause a slippery road surface and excessive sunshine can impair human sight. Both of the aforementioned situations influence driving behaviour. Therefore, driving behaviour was identified as the performance sub area for weather monitoring. The monitoring of the impact of adverse weather conditions on driving behaviour encompass three actions. These are: 1) govern, 2) mitigate and 3) evaluate. That is, the weather conditions need to be governed, the impact of adverse weather conditions on driving behaviour needs to be regulated with the aid mitigation procedures and a project's performance with regard to implementing weather control technologies and -activities need to be evaluated. The aforementioned actions form the measurement fields for the performance sub area identified.

Weather conditions can be governed with the aid of an **Environmental Sensor Station** (ESS). The ESS can either be installed stationary (i.e. within or along a roadway) or mobile (i.e. on a vehicle). The station consists of one (or more) environmental sensor(s) that measures atmospheric- (e.g. temperature, humidity, wetness and airflow), pavement-, soil- and water level conditions. The data from these sensors are send, in real-time, to the facility's control centre where it is analysed to identify variations and trends (or patterns) in the data. If any important variations are identified, warning messages are posted on the applicable message signs.

The impact of adverse weather conditions on driving behaviour can be regulated with the aid mitigation procedures. That is, **weather control technologies and -activities**. Examples of control technologies are: the presence of streetlights and electric cat eyes that automatically turn on when darkness is detected as well as the presence of reflective paint that glows under the glare of a vehicle's headlights. Examples of control activities are: the initiatives that support adverse weather notifications and that enforce information such as reduced speed limits on message signs. The degree to which a project is successfully mitigating the impact of adverse weather conditions on driving behaviour can be evaluated with the aid of a scorecard.

In essence, by mitigating the impact of adverse weather conditions on driving behaviour, a project is inherently executing safety precautions. A project's performance with regard to implementing weather control technologies and -activities can thus be determined by evaluating the change in the number of **weather-related incidents**. This relates to the number of incidents caused by adverse weather conditions. A change in the form of a reduction indicates that a project has/had a favourable effect on the safety of the travellers. The measured change needs to be exhibited by a percentage, expressed per type (i.e. severity) of incident, evaluated for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard.

NOISE MANAGEMENT

NOISE EXPOSURE MONITORING

Noise exposure monitoring was identified to be the sole performance area for the performance category: noise management.

Noise can be defined as an unwanted sound or an audible acoustic energy that adversely affects the physiological and/or psychological well-being of people or that disturbs or impairs the convenience or peace of any person. When monitoring noise exposure, both the noise source and the -receiver need to be considered. The noise source generates the noise. Examples of noise sources include vehicles and infrastructure. Vehicle noise sources include the engine, driveline, tyre contact patch, road surface, brakes and wind. An example of an infrastructure noise source (as a result of poor condition) is lose notice boards rattling in the wind. The generated noise is then transmitted or reflected via a variety of paths to the receiver. The receiver refers to the person (i.e. traveller - driver or passenger) that is exposed to the noise. Therefore, noise sources and -receivers were identified as the performance sub area for noise exposure monitoring. Noise exposure can be monitored by three actions. These are: 1) govern, 2) mitigate and 3) evaluate. That is, the noise exposure levels need to be governed, they need to be regulated with the aid of mitigation procedures and their status and trend need to be evaluated. This evaluation facilitates the determination of a project’s performance with regard to implementing noise management. The aforementioned actions form the measurement fields for the performance sub area identified.

The units of **noise exposure** are sound pressure level and loudness level. **Sound pressure levels** (expressed in Pascals: Pa) are used to assess the amplitude of the sound permissible to human hearing. These pressure levels are usually converted into decibels (dB). Decibels is a logarithmic scale that takes 20 µPa (i.e. threshold of hearing) as its reference level. **Loudness levels** (expressed in Hertz: Hz) are used to assess the frequencies of the sound audible to humans. Loudness is subjectively felt as the pitch of the sound (GreenFacts 2008). Noise exposure can be measured with aid of a sound-level meter. Sound-level meters store the measured sound pressure levels and integrate them over time in such a way that a cumulative noise-exposure reading for a given period of time (e.g. 8-hour workday) can be determined. Noise exposure needs to be computed separately for the noise source and the -receiver, expressed per vehicle, transit facility or infrastructure in both sound pressure- and loudness levels, evaluated and averaged for a certain time period (e.g. day and month) and compared to a previous similar time period or a predefined standard (i.e. permissible noise exposure levels and exposure time).

Mitigation procedures are needed to regulate noise emissions and thus ensure that the noise exposure levels comply with the recommended permissible standards and audible regulations. Noise emissions can be controlled with the aid of: 1) **noise screening** at the noise source and 2) **noise protection** at the noise receiver. The former mentioned encapsulates, for example, noise barriers and the latter mentioned insulation and soundproof windows. The degree to which a project is successfully mitigating its resulting noise exposure can be evaluated with the aid of a scorecard.

A project’s performance with regard to noise management can be evaluated by measuring its **noise exposure trends**. These trends can be determined by considering the change in noise exposure levels and/or the change in noise exposure time. A change in the form of a reduction indicates that a project has/had successfully implemented screening- and protection procedures. The measured change needs to be exhibited by a percentage, expressed per vehicle, transit facility or infrastructure, evaluated and averaged for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard.

ENERGY MANAGEMENT

Energy Use Monitoring

Energy use monitoring was identified to be the sole performance area for the performance category: energy management.

Energy use monitoring refers to the action of managing the efficient consumption of energy. Efficient energy use, also called energy efficiency, is about reducing the amount of energy that is required to provide the service (or product). Energy efficiency was thus identified as the performance sub area for energy use monitoring. Energy efficiency can be monitored by three actions. These are: 1) govern, 2) mitigate and 3) evaluate. That is, energy consumption levels and -rates need to be governed, they need to be regulated with the aid of mitigation procedures and the project’s performance with regard to consuming energy efficiently needs to be evaluated. The aforementioned actions form the measurement fields for the performance sub area identified.

Energy is measured in Joule. A project’s energy use is determined by its associated **consumption levels.** Consumption levels can be measured by considering, for example, the energy use by fuel type, sector, municipality and/or province. The efficiency of energy use can be evaluated by determining the energy **consumption rates**. Consumption rates can be measured by comparing, for example, the energy use to the energy emissions by fuel type.

Mitigation procedures in the form of **energy efficiency programs** can be used to monitor energy use. Energy efficiency programs include, among others, renewable energy programs (e.g. wind turbines and solar energy) and waste management programs (e.g. recycling). The degree to which a project is successfully implementing energy efficiency programs can be evaluated with the aid of a scorecard.

A project's performance with regard to using energy efficiently can be assessed by evaluating its energy trends. The **energy trends** can be evaluated by considering the change in consumption levels (or rates). A change in the form of a reduction indicates that a project has/had successfully implemented energy efficiency programs. The measured change needs to be exhibited by a percentage, expressed per vehicle or per transit facility, evaluated and averaged for a certain time period (e.g. semester and year) and compared to a previous similar time period or a predefined standard.

6.2 PERFORMANCE MEASURES

6.2.1 KPI FORMALISATION

In this section, the KPI formalisation is given per performance category and its relating performance area(s). Each performance area is shown as a table. Refer to Table 25 to Table 56.

GOVERNANCE, PLANNING AND DECISION MAKING

LEGAL COMPLIANCE

For the performance category: legal compliance, six KPIs have been identified. These relate to the performance area: legal sources.

Table 25: KPIs - Legal Sources

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Legislations and Acts	Transport	1	Laws and Bylaws	Binary	Conformity/ Nonconformity	Employer/ Client	Project Requirement	Manual	Ad-hoc	Nominal	Pro-active Non-compliance Management
	Environment	2									
	Labour	4									
	Safety and Security	5									
	Communications	6									

**Additional Notes*: **Additional Notes*

1 to 6: Pro-active non-compliance management needs to be implemented. That is, the employer/client or the operator/contractor needs to flag the potential fields of non-compliance or the possibility (in short-, medium- or long-term) of the occurrence of non-compliance. The performance can then be measured under a contract performance basis that includes the evaluation of pro-active alerts of actual- or potential non-compliance occurrences.

REGULATORY ENFORCEMENT

For the performance category: regulatory enforcement, five KPIs have been identified. These relate to the performance areas: regulators and regulatory documents.

Table 26: KPIs - Regulators

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Governing Bodies	Industry Role Players	1	Involvement	Binary	Conformity/ Nonconformity	Employer/ Client	Project Requirement	Manual	Ad-hoc	Nominal	Context Specific Legislative Examples

Table 27: KPIs - Regulatory Documents

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Regulations and Policies	Standards	2	Inscription	Binary	Conformity/ Nonconformity	Employer/ Client	Project Requirement	Manual	Ad-hoc	Nominal	Context Specific Legislative Examples
	Manuals	3									
	Guidelines and Instructions	4									
	Statements, Plans and Frameworks	5									

**Additional Notes*

1 to 5: Since the adopted performance management approach can never be exhaustive, this performance category needs to describe overall legislative context as examples only. Moreover, specific rules and regulations that matter to the project's or the operator's/contractor's performance need to be included. A project can then be governed by its own contract, annexes and supplementary documents.

RESEARCH AND DEVELOPMENT

For the performance category: research and development, three KPIs have been identified. These relate to the performance areas: research- and creativity support.

Table 28: KPIs - Research Support

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Research Development	Project-based Learning	1	Public Engagement	Binary	Conformity/ Nonconformity	Employer/ Client	Project Requirement	Manual	Ad-hoc	Nominal	Pure- and Applied Research?

**Additional Notes*

1: It could be challenging to measure the performance of 'discovery-based' research. Its success can never be guaranteed and thus the extent to which success is approached cannot be measured either. Nevertheless, for the purpose required herein, the presence of project-based learning initiatives is deemed sufficient.

Future Modifications

1: In order to ensure the viability of research development, a distinction between pure- and applied research would be needed.

Table 29: KPIs - Creativity Support

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Project Development	Innovation Management	2	Ideation	Binary	Conformity/ Nonconformity	Employer/ Client	Project Requirement	Manual	Ad-hoc	Nominal	Quantitative Targets?
	Continuous Improvement	3	Competitive Analysis								

Future Modifications

2 and 3: Ideally, project development could also include some quantitative targets. For example: using a scorecard based on multiple dimensions including an innovation utilisation rate (i.e. number of products or services that implement the innovation stimulation activities), an increase in quantity of independent innovations that improve the performance or reduce the cost of specific products or services, a demonstrated commitment to strategic leadership and use of related organisation-wide measures as well as value chain premiums.

INSTITUTIONAL LIAISON

For the performance category: institutional liaison, four KPIs have been identified. These relate to the performance areas: institutional coordination and -cooperation as well as institutional robustness.

Table 30: KPIs - Institutional Coordination and Cooperation

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Operational Alignment	Activity Integration	1	Partnership Development	Binary	Conformity/ Nonconformity	Employer/ Client	Planning Principle	Manual	Ad-hoc	Nominal	External Liaison and Internal Management?
	Technical Compatibility	2									
Strategy Alignment	Collaborative Relationships	3									

Table 31: KPIs - Institutional Robustness

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Business Continuity	Risk Management	4	Disaster and Recovery Services	Binary	Conformity/ Nonconformity	Employer/ Client	Planning Principle	Manual	Ad-hoc	Nominal	External Liaison and Internal Management?

Future Modifications

1 to 4: It could be challenging to confirm the ongoing compliance of this performance category. A viable option would be to split institutional liaison into two consideration fields. That is, external liaison (i.e. performance in managing relevant external relationships and social obligations, ideally implementing best practice social uplift, etc.) and internal management (i.e. performance in building and managing an organisation that has sufficient capacity to meet contractual requirements, impacts of environmental changes, etc.). Specific examples of the aforementioned include, among others, effective organisational relationships and the use of collaborative mechanisms to raise problems (and to solve them). Moreover, it could be viable to also include some quantitative targets. For example: implementing

DATA GOVERNANCE

For the performance category data governance, seven KPIs have been identified. These relate to the performance area: data management.

Table 32: KPIs - Data Management

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Information System Governance Procedures	Data Collection	1	Protocols	Binary	Conformity/ Nonconformity	Operator/ Contractor	Project Requirement	Automatic, Automated and Manual	Ad-hoc	Nominal	√
	Data Accuracy	2				Employer/ Client	Planning Principle	Manual			
	Data Retention	3				Operator/ Contractor	Project Requirement	Automatic, Automated and Manual			
	Data Security	4				Employer/ Client	Planning Principle	Manual			
	Data Quality	5									
	Data Fusion	6									
	Data Accessibility	7									

OPERATIONS, SERVICES AND MAINTENANCE

OPERATIONAL PERFORMANCE

For the performance category: operational performance, 30 KPIs have been identified. These relate to the performance areas: service reliability, service convenience, operational seamlessness and operating efficiency.

Table 33: KPIs - Service Reliability

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Travel Time Variability	Travel Time Duration	1	Travel Time Factor	Ratio	Standard/ Target	Transport User	Project Requirement	Automated	Continuous (Peak Period)	Ratio (Continuous)	√
	Schedule Adherence	2	On-time Performance	Percentage				Automated, Manual and Survey	Continuous (Peak Period)		
Information Validity	Timeliness	3	Information Refresh Rate	Rate				Automated and Manual	Continuous (Weekly) and Ad-hoc		
		4	Latency to Posting Updates	Time							
	Accurate (Correct) and Available (Accessible)	5	Accuracy	Percentage		Operator/ Contractor		Automatic, Automated and Manual	Ad-hoc		
		6	Availability						Continuous (Monthly)		
Public Travel and Personal Safety	Incident Statistics	7	Crash Incidents and Break-downs	Count	Increase/ Decrease	Employer/ Client		Automated and Manual	Continuous (Monthly)	Interval (Discrete)	
		8	Property Crime Incidents								

Computation of Quantitative Measures

1: The average peak period travel time to the free flow travel time; expressed as a ratio.

2: The number of transit vehicles arriving at times as stipulated in their timetables to the total number of transit vehicles in the representative fleet; expressed as a percentage.

3: The rate at which information is refreshed (e.g. updating images) to obtain or maintain real-time accuracy; expressed in seconds.

4: The time it takes to update and/or correct information (e.g. incident occurrence updates and timetable corrections) in the event of change; expressed in minutes.

5 and 6: The period of time for which the information portrayed to the public is accurate (i.e. correct) and available (i.e. accessible) to the total time period it was portrayed; expressed as a percentage.

7 and 8: The number of occurrences (i.e. crashes, break-downs and crime) in evaluation period$_{(x+1)}$ compared to the respective number of occurrences in evaluation period$_{(x)}$; evaluated as fractional decay.

Table 34: KPIs - Service Convenience

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Accessibility	Access Point Proximity	9	Access Time	Time	Standard/ Target	Transport User	Project Requirement	Automatic, Automated, Manual and Survey	Continuous (Peak Period) and Ad-hoc	Ratio (Continuous)	√
		10	Access Distance	Distance							Service Span?
	Network Characteristics	11	Quality of Road and Transit Line	Score				Scorecard	Ad-hoc	Ordinal	√
Connectivity	Access Options	12	Commuting Time	Proportion				Automated, Manual and Survey	Continuous (Peak Period) and Ad-hoc	Ratio (Continuous)	
		13	Transfer Distance	Percentage							
Regularity	Mode Preference	14	Modal Split	Proportion	Increase/ Decrease	Employer/ Client		Manual and Survey	Continuous (Monthly) and Ad-hoc		

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Regularity	Periodicity	15	Service Frequency	Rate	Standard/ Target	Transport User	Project Requirement	Automated, Manual and Survey	Continuous (Peak Period) and Ad-hoc	Ratio (Continuous)	√

**Additional Notes*

10: In the public transport environment, service span could also (instead of access distance) be used as a measure for access point proximity.

14: The modal shift measure does not discourage a net reduction in persons or goods travelling into or out of the target economic area, since this could indicate a loss in economic activity. The proposed modal split proportion merely favours the use of public transport.

Computation of Quantitative Measures

9 and 10: The average access time (expressed in minutes) and distance (expressed in kilometres) to access recreational points of interest. Access time is taken as a measure for private transport users and access distance as a measure for public transport users.

12: The average citizen’s total commuting time (expressed in minutes) as a proportion of their (working) day.

13: The number of transfers between modes to be under “x” metres to the total number of transfers; expressed as a percentage.

14: The proportion of public transport mode share within overall transport demand; evaluated as fractional growth.

15: The rate at which transit vehicles arrives at stops/stations; expressed in minutes for peak periods.

Table 35: KPIs - Operational Seamlessness

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Incident Management	Occurrence and Detection	16	Detection Time	Time	Standard/ Target	Operator/ Contractor	Project Requirement	Automated and Manual	Continuous (Monthly)	Ratio (Continuous)	√
	Verification and Classification	17	Verification Time								
	Authority Notification	18	Notification Time								

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Incident Management	Respondent Dispatch	19	Response Time	Time	Standard/ Target	Operator/ Contractor	Project Requirement	Automated and Manual	Continuous (Monthly)	Ratio (Continuous)	√
	Public Alert	20	Alert Time								
	Coordination	21	Clearance Time								
	Staff Safety	22	Adverse Health Conditions	Count	Increase/ Decrease					Interval (Discrete)	
		23	Secondary Incidents								

Computation of Quantitative Measures

16: The time it takes the operators to detect an incident; measured from incident occurrence time in seconds.

17: The time it takes the operators to verify and classify the incident according to incident type; measured from incident detection time in seconds.

18: The time it takes the operators to notify the partner authorities of the incident; measured from incident verification time in seconds.

19: The time it takes the authorities to reach the scene of the incident; measured from incident verification time in minutes.

20: The time it takes the operators to notify the travelling public of the incident; measured from incident verification time per representative communication medium in minutes.

21: The time it takes the authorities to clear the incident scene; measured from incident verification time per incident crash type in minutes.

22 and 23: The number of occurrences (i.e. adverse health conditions and secondary incidents) in evaluation period$_{(x+1)}$ compared to the respective number of occurrences in evaluation period$_{(x)}$; evaluated as fractional decay.

Table 36: KPIs - Operating Efficiency

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Service Quality	Density and Congestion	24	LOS	Percentage	Standard/ Target	Employer/ Client	Project Requirement	Automated and Manual	Continuous (Peak Period)	Ratio (Continuous)	√
		25	Load Factor	Proportion				Automated, Manual and Survey			
			Standing Density	Density							
Service Quality	Mobility	26	Network Travel Speed	Speed	Standard/ Target	Transport User		Automatic, Automated and Manual			
		27	Queue Length	Distance	Increase/ Decrease	Employer/ Client				Interval (Continuous)	
		28	Queue Time	Time	Standard/ Target	Transport User				Ratio (Continuous)	
		29	Waiting Time	Time							
Service Utilisation	Demand-Supply	30	Degree of Saturation	Proportion		Employer/ Client			Ad-hoc		

Computation of Quantitative Measures

24: The number of road segments (with regard to major roads and freeways) assigned with a LOS of C or better to the total of road segments under consideration; measured for peak periods and expressed as a percentage.

25-1: The proportion of the average transit vehicle load to the total transit vehicle capacity; measured for peak periods.

25-2: The average number of passengers per square meter of the facility's platform; measured for peak periods.

26: The average travel speed on freeways in peak periods; expressed in kilometres per hour.

27: The average length of queues in vehicles for major road segments or at major intersections; measured for peak periods and evaluated as fractional decay.

28: The average queueing times at major road segments or intersections; expressed in minutes.

29: The average time spend waiting for transit vehicles to arrive at stops/stations; expressed in minutes.

30: The proportion of the network's demand (i.e. volume: v) to its supply (i.e. capacity: c); measured for peak periods. In private transport, the v/c proportion is assed for major roads and freeways. In public transport, the v/c proportion is assed for the transit line.

Technology Reliability

For the performance category: technology reliability, three KPIs have been identified. These relate to the performance areas: system health and system performance.

Table 37: KPIs - System Health

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
System Availability	System Functionality	1	System Uptime	Percentage	Standard/ Target	Operator/ Contractor	Project Requirement	Automatic and Automated	Continuous (Monthly)	Ratio (Continuous)	√

Computation of Quantitative Measures

1: The period of time for which the system is operable (i.e. in working condition) to the time it was supposed to be operable; expressed as a percentage.

Table 38: KPIs - System Performance

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Equipment Quality	Value Evaluation	2	MTBF	Time	Standard/ Target	Operator/ Contractor	Project Requirement	Automated and Manual	Ad-hoc	Ratio (Continuous)	√
Data Quality	Data Verification and Validation	3	Error Rates	Percentage							

Computation of Quantitative Measures

2: The average elapsed time between inherent failures of a system; expressed in years.

3: The number of erroneous units of data (occurrences) to the total number of units of data transmitted; expressed as a percentage.

Asset Management and Maintenance

For the performance category: asset management and -maintenance, eight KPIs have been identified. These relate to the performance areas: asset management and asset maintenance.

Table 39: KPIs - Asset Management

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Operations Management	Record	1	Asset Register	Score	Standard/ Target	Operator/ Contractor	Project Requirement	Scorecard	Ad-hoc	Ordinal	√
	Monitor	2	Network Surveillance System								
	Control	3	Positioning System								
	Evaluate	4	Status Report	Binary	Conformity/ Nonconformity			Manual and Automated	Continuous (Monthly)	Nominal	
		5	Supporting Electronic Management System					Automatic			

Table 40: KPIs - Asset Maintenance

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Preventative	Scheduled Logs	6	Fulfilment	Percentage	Standard/ Target	Operator/ Contractor	Project Requirement	Automatic and Manual	Continuous (Monthly)	Ratio (Continuous)	Use as Management Tool
Corrective	Defect Logs	7	Tickets Logged	Count	Increase/ Decrease					Interval (Discrete)	
		8	MTTR	Time	Standard/ Target					Ratio (Continuous)	

**<u>Additional Notes</u>*

6 to 8: Since the resilience of the maintenance regime also depends on spares availability and available skills, the chosen measures for asset maintenance could also be used as a management tool to incentivise an adequate level of spares availability and available skills.

Computation of Quantitative Measures

6: The number of tickets fulfilled (i.e. scheduled logs) to the number of planned tickets; expressed as a percentage.

7: The number of tickets logged (i.e. the number of assets that required rectification) in evaluation period$_{(x+1)}$ compared to the number of tickets logged in evaluation period$_{(x)}$; evaluated as fractional decay.

8: The average time to repair a failed asset; measured from asset log time in hours.

MONEY MATTERS

Economic Performance

For the performance category: economic performance, 14 KPIs have been identified. These relate to the performance areas: economic sustainability, economic vitality and socio-economic prosperity.

Table 41: KPIs - Economic Sustainability

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
System Adaptability	Operational Resilience	1	Scalability	Score	Standard/ Target	Employer/ Client	Planning Principle	Scorecard	Ad-hoc	Ordinal	√
		2	Responsiveness								
System Preservation	Project Infrastructure Status Evaluation	3	Traveller Experience	Index	Increase/ Decrease			Survey			
		4	Remaining Useful Life of Fleet	Age				Automated and Manual		Interval (Continuous)	

**<u>Additional Notes</u>*

4: Age is taken to be continuous data, since the concept of a fraction of a year is plausible.

Computation of Quantitative Measures

4: The average remaining useful life of the fleet computed from its representative transit vehicle age distribution graph; evaluated as fractional growth.

Table 42: KPIs - Economic Vitality

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Economic Development	Business Opportunities	5	Jobs Created	Count	Increase/ Decrease	Employer/ Client	Planning Principle	Automated and Manual	Continuous (Yearly)	Ratio (Continuous)	√
Economic Growth	Service Expansion	6	Capacity Building and Infrastructure Development	Score	Standard/ Target			Scorecard	Ad-hoc	Ordinal	

Computation of Quantitative Measures

5: The number of jobs created in evaluation period$_{(x+1)}$ compared to the number of jobs created in evaluation period$_{(x)}$; evaluated as fractional growth.

Table 43: KPIs - Socio-Economic Prosperity

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
(Social) Benefits	Energy and Environment	7	Traffic Flow Conditions	(Social) Wealth	Increase/ Decrease	Employer/ Client	Planning Principle	Automatic, Automated and Manual	Continuous (Quarterly)	Ratio (Discrete and Continuous)	√
		8	Public Transport Use								
	Safety	9	Primary and Secondary Incidents								
	Efficiency	10	Network Throughput								
	Customer Satisfaction	11	Confidence								
		12	Perception								

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
(Social) Benefits	Mobility	13	Ease of Movement	(Social) Wealth	Increase/ Decrease	Employer/ Client	Planning Principle	Automatic, Automated and Manual	Continuous (Quarterly)	Ratio (Discrete and Continuous)	√
	Productivity	14	System Effectiveness								

**<u>Additional Notes</u>*

7 to 14: The (social) wealth measures are taken as the benefits when computing the (social) benefit to cost ratio.

Computation of Quantitative Measures

7 to 14: These measures are considered individually, from evaluation period$_{(x)}$ to evaluation period$_{(x+1)}$, and evaluated as fractional growth.

Financial Performance

For the performance category: financial performance, six KPIs have been identified. These relate to the performance areas: financial feasibility and investment management.

Table 44: KPIs - Financial Feasibility

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Non-recurring Costs	Capital Expenditure	1	Long-term Assets	Expenditure	Increase/ Decrease	Employer/ Client	Planning Principle	Automatic and Manual	Continuous (Quarterly)	Ratio (Discrete and Continuous)	Life Cycle Costing?
Recurring Costs	Operating Expenditure	2	Selling Expenses								
		3	General and Administrative Expenses								
Miscellaneous Costs	Unforeseen Expenditure	4	Fines, Law Suits and Environmental Damage Costs								

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Social Costs	Negative Transport Externalities	5	Congestion, Accidents and Pollution	Social Distress	Increase/ Decrease	Employer/ Client	Planning Principle	Automatic and Manual	Ad-hoc	Ratio (Discrete and Continuous)	Life Cycle Costing?

**Additional Notes*

1 to 4: The expenditure measures are taken as the costs when computing the benefit to cost ratio.

5: The social distress measure is only considered when computing the social benefit to cost ratio.

Computation of Quantitative Measures

1 to 5: These measures are considered individually, from evaluation period$_{(x)}$ to evaluation period$_{(x+1)}$, and evaluated as fractional decay.

Future Modifications

1 to 5: Since the total costs over the full life span of a project is sometimes warranted, it could be viable to also consider the total life cycle cost of a project when evaluating its financial feasibility. This includes, among others, the purchase costs, installation costs, operating costs, maintenance costs and upgrade costs.

Table 45: KPIs - Investment Management

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Investment Performance	Capital Gain	6	ROI	Percentage	Increase/ Decrease	Employer/ Client	Planning Principle	Automatic and Manual	Continuous (Quarterly)	Ratio (Continuous)	Exchange Rate?

Computation of Quantitative Measures

6: The benefit of an investment divided by its associated costs in evaluation period$_{(x+1)}$ compared to the respective numbers in evaluation period$_{(x)}$; expressed as a ratio and evaluated as fractional growth.

Future Modifications

6: Since the technology associated with ITS projects are often imported, it would be viable to also consider the exchange rate when evaluating the performance of transport investments.

PEOPLE MATTERS

PUBLIC RELATIONS

For the performance category: public relations, seven KPIs have been identified. These relate to the performance areas: marketing and networking.

Table 46: KPIs - Marketing

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Service Promotion (Media)	Raising Awareness	1	Customer Satisfaction	Index	Increase/ Decrease	Employer/ Client	Planning Principle	Survey	Ad-hoc	Ordinal	√
	Developing Understanding	2									
	Securing Acceptance	3	Service Enhancements	Ratio				Automated and Manual		Ratio (Continuous)	

Computation of Quantitative Measures

3: The number of fatalities (in the private transport environment) and the ridership numbers (in the public transport environment) evident in evaluation period$_{(x+1)}$ compared to the respective numbers in evaluation period$_{(x)}$; expressed as a ratio. The former mentioned is evaluated as fractional decay and the latter mentioned as fractional growth.

Table 47: KPIs - Networking

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Service Interaction (Social Media)	Attractiveness	4	Social Community Size	Ratio	Increase/ Decrease	Employer/ Client	Planning Principle	Automated and Manual	Ad-hoc	Ratio (Continuous)	Growth Rate
	Exposure	5	Reposts or Shares								
	Productive Relationships	6	Type and Trend of Postings	Score	Standard/ Target			Scorecard		Ordinal	√

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Service Interaction (Social Media)	Productive Relationships	7	Peer and Public Reviews	Index	Increase/ Decrease	Employer/ Client	Planning Principle	Survey	Ad-hoc	Ordinal	√

**Additional Notes*

4 and 5: As mentioned previously, the attractiveness of the social media platform and the exposure gained from the service media platform are collectively measured as the rate of growth in social media attractiveness.

6 and 7: Either one or both of these measures can be used to evaluate the success of service interaction with regard to cultivating productive relationships.

Computation of Quantitative Measures

4 and 5: Growth rate - the size of the social community in evaluation period$_{(x+1)}$ compared to the sizes in evaluation period$_{(x)}$; expressed as ratio per social media platform and evaluated as fractional growth.

CUSTOMER SERVICE

For the performance category: customer service, eight KPIs have been identified. These relate to the performance areas: traveller information provision and general support information.

Table 48: KPIs - Traveller Information Provision

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Assist	Trip Planning	1	Routing Services	Score	Standard/ Target	Employer/ Client	Planning Principle	Scorecard	Ad-hoc	Ordinal	√
Confirm	Transit and Traffic Information	2	Mode, Fare and Schedule								
Notify	Incident Notification	3	Crashes, Adverse Weather Conditions, Schedule Delays and Strikes								
Advise	Route Guidance	4	Alternative Route Options								

Table 49: KPIs - General Support Information

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Logging Attendance	Inquiries, Queries, Complaints and Compliments	5	Reaction Time	Time	Standard/ Target	Operator/ Contractor	Project Requirement	Automated and Manual	Continuous (Quarterly)	Ratio (Continuous)	√
		6	Helpfulness	Ratio		Employer/ Client	Planning Principle				
Inter-personal Interaction	Workforce	7	Personnel Performance	Score				Scorecard		Ordinal	
Self-service Systems	Service Inventory and Technology	8	Quality of Interaction Mediums								

Computation of Quantitative Measures

5: The average time taken to react to inquiries, queries, complaints and compliments; measured from log time and expressed per communication medium in hours.

6: The total number of compliments compared to the total number of complaints, expressed per service provider as a ratio.

SOCIAL SUSTAINABILITY

For the performance category: social sustainability, six KPIs have been identified. These relate to the performance areas: sustainable service delivery and -living.

Table 50: KPIs - Sustainable Service Delivery

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Social Justice	Service Affordability	1	Transport Expenditure	Percentage	Standard/ Target	Employer/ Client	Planning Principle	Automated and Manual	Ad-hoc	Ratio (Continuous)	√
		2	Discounted Fares	Binary	Conformity/ Nonconformity					Nominal	Travel Cost?
Social Equality	Social Inclusion	3	Degree of Urban Densification	Percentage	Standard/ Target					Ratio (Continuous)	√
		4	Amenities for Disabled People	Binary	Conformity/ Nonconformity			Manual		Nominal	

Computation of Quantitative Measures

1: The percentage of an average household's monthly income that goes towards their transport expenditure.

3: The percentage of the urban population that can conveniently access major roads and freeways.

Future Modifications

2: In order to counteract the many interdependencies influencing the availability of discounted fare options (e.g. the efficiency of a service and cross-subsidisation), it could be viable to also evaluate the cost per distance travelled.

Table 51: KPIs - Sustainable Living

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Social Development	Public-Service Alignment	5	Usability Study	Binary	Conformity/ Nonconformity	Employer/ Client	Planning Principle	Manual	Ad-hoc	Nominal	√
		6	Community Development Programs								

HUMAN RESOURCE MANAGEMENT

For the performance category: human resource management, six KPIs have been identified. These relate to the performance area: employee performance management.

Table 52: KPIs - Employee Performance Management

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Employee Satisfaction	Job and Operating Environment	1	Employee Contentment	Index	Increase/ Decrease	Employer/ Client	Planning Principle	Survey	Ad-hoc	Ordinal	√
Employee Commitment	Adherence to Policy Agreements	2	Absenteeism Scores	Count				Automated and Manual		Interval (Discrete)	
Employee Engagement	Organisational Structure (Communication Channels)	3	Focus Groups	Binary	Conformity/ Nonconformity					Nominal	Frequency?
		4	Trauma Counselling								
Employee Development	Advancing Skillsets	5	Training Services								
	Improvement Tracking	6	Progress Evaluation								

Computation of Quantitative Measures

2: An employee's average number of absent days in evaluation period$_{(x+1)}$ compared to his/her associated number of absent days in evaluation period$_{(x)}$; averaged for all employees within a certain division and evaluated as fractional decay.

Future Modifications

3 to 6: It could be viable to not only consider the presence of these services and actions, but also their frequency. That is, how often such services are provided and how often such actions are executed.

ENVIRONMENT MATTERS

AIR QUALITY MANAGEMENT

For the performance category: air quality management, five KPIs have been identified. These relate to the performance area: air pollution monitoring.

Table 53: KPIs - Air Pollution Monitoring

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Mobile Source and GHG Emissions	Priority Pollutants Governance	1	Vehicle Emissions	Ratio	Standard/ Target	Employer/ Client	Planning Principle	Automated	Ad-hoc	Ratio (Continuous)	Manufacturer Declarations
		2	GHG Emissions								Roadside Air Quality Tests
	Pollution Mitigation	3	Emission Control Technologies and Reducing Activities	Score				Scorecard		Ordinal	√
	Trend Evaluation	4	Change in Air Quality	Percentage	Increase/ Decrease			Manual		Ratio (Continuous)	Emission Intensity
		5	Change in Emissions								

**<u>Additional Notes</u>*

1: Since it is expensive to measure vehicle emissions, it is proposed that these emissions rather be regulated on the basis of manufacturer declarations.

2: Since it is difficult to measure GHG emissions, it is proposed that these emissions rather be regulated on the basis of roadside air quality tests. However, the relationships between emissions and air quality is complex and location-specific.

4 and 5: It is recommended that these measures collectively be evaluated by considering emission intensity. Emission intensity is the average emission rate of a given pollutant from a given source relative to the intensity of a specific activity. This type of measure is commonly used to derive estimates of air pollutant and/or GHG emissions based on the amount of fuel combusted.

Computation of Quantitative Measures

4 and 5: Emission intensity - the level of emissions per unit of regional GDP in evaluation period$_{(x+1)}$ compared to the ratio in evaluation period$_{(x)}$; evaluated as fractional decay.

CLIMATE CHANGE MANAGEMENT

For the performance category: climate change management, three KPIs have been identified. These relate to the performance area: weather monitoring.

Table 54: KPIs - Weather Monitoring

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Driving Behaviour	Weather Conditions Governance	1	ESS	Binary	Conformity/ Nonconformity	Employer/ Client	Planning Principle	Automatic	Ad-hoc	Nominal	√
	Impact Mitigation	2	Weather Control Technologies and Activities	Score	Standard/ Target			Scorecard		Ordinal	Network Resilience?
	Trend Evaluation	3	Change in the Number of Weather-related Incidents	Percentage	Increase/ Decrease			Manual		Ratio (Continuous)	√

Computation of Quantitative Measures

3: The number of (purely) weather-related incidents in evaluation period$_{(x+1)}$ compared to the number of incidents in evaluation period$_{(x)}$; evaluated as fractional decay.

Future Modifications

2: It could be viable to not only evaluate the impact of weather conditions on driving behaviour, but also to consider the resilience of the network. By considering this, the impact of climate change can also be evaluated. For example: adverse climate conditions often results in more expensive infrastructure.

NOISE MANAGEMENT

For the performance category: noise management, seven KPIs have been identified. These relate to the performance area: noise exposure monitoring.

Table 55: KPIs - Noise Exposure Monitoring

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Noise Sources and Receivers	Noise Exposure Governance	1	Levels	Sound Pressure	Standard/ Target	Employer/ Client	Planning Principle	Automated	Ad-hoc	Ratio (Continuous)	Manufacturer Declarations
		2		Loudness							
		3	Period	Time				Manual			In-field Tests
	Noise Exposure Mitigation	4	Noise Screening at Source	Score				Scorecard		Ordinal	√
		5	Noise Protection at Receiver								
	Trend Evaluation	6	Change in Noise Exposure Levels	Percentage	Increase/ Decrease			Manual		Ratio (Continuous)	Sound Intensity
		7	Change in Noise Exposure Time								

**<u>Additional Notes</u>*

1 and 2: Since it is difficult and expensive to measure noise exposure levels, it is proposed that these levels rather be regulated on the basis of manufacturer declarations.

3: Since the periods of time deemed acceptable for noise exposure may vary based on the considered location, it is proposed to rather conduct random in-field tests.

6 and 7: It is recommended that these measures collectively be evaluated by considering sound intensity. Sound intensity is defined as the sound power per unit of area. The SI unit of sound intensity is the watt per square metre. The usual context is the noise measurement of sound intensity in the air at a listener's location as a sound energy quantity.

Computation of Quantitative Measures

6 and 7: Sound intensity - the sound power per unit of area in evaluation period$_{(x+1)}$ compared to the ratio in evaluation period$_{(x)}$; evaluated as fractional decay.

ENERGY MANAGEMENT

For the performance category: energy management, four KPIs have been identified. These relate to the performance area: energy use monitoring.

Table 56: KPIs - Energy Use Monitoring

Performance Sub Area	Measurement Field	No.	Performance Measure	System	Evaluation Criteria	Interested Parties	Classification Type	Technique	Time Frame	Scale and Data Type	Feasibility
Energy Efficiency	Energy Consumption Governance	1	Levels	Ratio	Standard/ Target	Employer/ Client	Planning Principle	Automated	Ad-hoc	Ratio (Continuous)	Manufacturer Declarations
		2	Rates								
	Energy Use Mitigation	3	Efficiency Programs	Score				Scorecard		Ordinal	√
	Trend Evaluation	4	Change in Energy Consumption	Percentage	Increase/ Decrease			Manual		Ratio (Continuous)	Energy Intensity

***Additional Notes*

1 and 2: Since it is difficult and expensive to measure energy levels and -rates, it is proposed that energy consumption rather be regulated on the basis of manufacturer declarations.

4: It is recommended that this measures rather be evaluated by considering energy intensity. Energy intensity is measured by the quantity of energy required per unit output or activity such that using less energy to produce a product reduces the intensity. This measure is commonly used to measure the energy efficiency of a nation's economy.

Computation of Quantitative Measures

4: Energy intensity - the total energy used by the project per unit of production or unit of regional GDP in evaluation period$_{(x+1)}$ compared to the ratio in evaluation period$_{(x)}$; expressed as fractional decay.

6.3 PERFORMANCE MEASUREMENT

6.3.1 CHECKLISTS

For simplification reasons, all of the binary-related performance measures pertaining to the same performance area have been grouped together into one checklist. This resulted in the development of 11 checklists. However, each measure within each of these checklists still needs to be assessed individually. That is, if the specific measure under consideration conforms to the specific project requirement or the planning principle, the measure's representative checkbox gets ticked and the measure receives a satisfaction value of 100. Conversely, if the specific measure under consideration does not conform to the specific project requirement or the planning principle, the measure's representative checkbox gets crossed and the measure receives a satisfaction value of 0.

LEGAL SOURCES CHECKLIST

By law, a project is legally required to comply with the applicable legislations. The relevant laws and bylaws identified for inclusion can be seen in Figure 37.

Laws and Bylaws

☐ Transport
☐ Environment
☐ Labour
☐ Safety and Security
☐ Communications

Examples

- ✓ Transport: the National Road Traffic Act, the National Land Transport Act, the National Road Safety Act, the SANRAL and National Roads Act as well as the Road Traffic Management Corporation Act.
- ✓ Environment: the National Environmental Management Act and the Environment Conservation Act.
- ✓ Labour: the Labour Relations Act, the Basic Conditions of Employment Act, the Employment Equity Act, the Occupational Health and Safety Act as well as the Skills Development Act.
- ✓ Safety and security: the Disaster Management Act and the South African Police Service Act.
- ✓ Communications: the Promotion of Access to Information Act as well as the Electronic Communications and Transactions Act.

Figure 37: Legal Sources Checklist

REGULATORS AND REGULATORY DOCUMENTS CHECKLIST

The regulatory requirements imposed on projects can be classified into two broad groups. Firstly, the involvement (in the form of supervision) from industry role players and secondly, the inscription of (and the adherence to) the necessary regulatory documents. Refer to Figure 38.

Involvement

☐ Industry Role Players

Inscription

☐ Standards

☐ Manuals

☐ Guidelines and Instructions

☐ Statements, Plans and Frameworks

Examples

- ✓ Industry role players: SAICE, CUTA, ECSA, ITSSA, CESA, COLTO and SABS.
- ✓ Standards: SANS as well as SABS and its TC for standards development.
- ✓ Manuals: the South African Road Traffic Signs Manual, the Road Safety Audit Manual and the Routine Road Maintenance Manual.
- ✓ Guidelines and instructions: UTG; TMH; COLTO's IM guidelines; the Guidelines for Human Settlement, Planning and Design (also known as the "red book"); the specifications relating to the EMV card; and the data structures for AFC.
- ✓ Statements, plans and frameworks: the White Paper on National Transport Policy, the Moving SA Action Agenda, the National Development Plan 2030 and the National Transport Master Plan 2050.

Figure 38: Regulators and Regulatory Documents Checklist

RESEARCH- AND CREATIVITY SUPPORT CHECKLIST

As part of the research and development requirement imposed on projects, it is advisable and beneficial for the project to engage the public and to create an environment that fosters creativity. The former mentioned refers to the provision of services and the sharing of information (specifically for research purposes). This aids the interested public members to acquire insight and knowledge as well as to learn new skills. The latter mentioned refers to the practices that can be used to improve products, services and/or processes. The overall aim of these practices is to enhance the performance of the project. The measurement fields identified for consideration can be seen in Figure 39.

Public Engagement

☐ Project-based Learning

Innovation Management

☐ Ideation

Continuous Improvement

☐ Competitive Analysis

Examples

- ✓ Ideation: brainstorming.
- ✓ Competitive analysis: benchmarking.

Figure 39: Research- and Creativity Support Checklist

INSTITUTIONAL COORDINATION AND -COOPERATION CHECKLIST

The realisation of mutually beneficial relationships through partnership development is dependent on close coordination and cooperation. This can be achieved by synchronising the institutions' strategies and operations. That is, developing intra and inter-institutional agreements and commitments. The measurement fields identified for consideration can be seen in Figure 40.

Partnership Development

☐ Activity Integration
☐ Technical Compatibility
☐ Collaborative Relationships

Examples

✓ Activity integration: agreements on planning- and design practices.
✓ Technical compatibility: agreements on operating protocols and technical matters.
✓ Collaborative relationships: commitments towards sharing resources and information.

Figure 40: Institutional Coordination and Cooperation Checklist

INSTITUTIONAL ROBUSTNESS CHECKLIST

In order for an institution to be robust, it needs to be able to cope with internal- and external factors that could intervene or interfere with the normal state of operations. Despite changing conditions, the essential functions need to continue to operate or be recoverable to an operational state within a reasonably time period. Therefore, processes and procedures for managing risk need to be in place. Refer to Figure 41.

Disaster and Recovery Services

☐ Risk Management

Examples

✓ Risk management: contingency plans as well as a management- and reporting structure.

Figure 41: Institutional Robustness Checklist

Note: since the presence of contingency plans does not necessarily mean that the organisation is managed to mitigate high-impact (or high probability) risks, the plan also needs to be supported by a management- and reporting structure. This management- and reporting structure not only needs to promote high-levels of awareness throughout the organisation, but also facilitate the acting on flagged issues.

DATA MANAGEMENT CHECKLIST

Effective data management is grounded on sound information system governance procedures. The procedural actions pertaining to information system governance can be seen in Figure 42.

Protocols

- ☐ Data Collection
- ☐ Data Accuracy
- ☐ Data Retention
- ☐ Data Security
- ☐ Data Quality
- ☐ Data Fusion
- ☐ Data Accessibility

Examples

- ✓ Data collection: data source- and acquisition protocols. For example: adhering to the data log frequency.
- ✓ Data accuracy: data accuracy protocols.
- ✓ Data retention: data archival protocols. For example: adhering to the data backup period.
- ✓ Data security: CIA protocols.
- ✓ Data quality: quality-checking protocols. For example: adhering to the data standards and the data dictionaries of the databases.
- ✓ Data fusion: data filtering, -cleaning and -presentation protocols.
- ✓ Data accessibility: data accessibility protocols. For example: data transmission between computing devices and over networks.

Figure 42: Data Management Checklist

ASSET MANAGEMENT CHECKLIST

In order to determine the status (and the value) of the assets, they need to be evaluated on a regular basis. This evaluation includes conducting spot checks on an ad-hoc basis during the asset's useful life. The findings from these spot checks need to be documented in either of the two forms shown in Figure 43. Without such documentation, it is virtually impossible to make any deductions regarding the performance of the project's assets.

Operations Management: Evaluation

- ☐ Status Report or Supporting Electronic Management System

Examples

- ✓ Supporting electronic management system: electronic *software* management- or electronic *application* management system.

Figure 43: Asset Management Checklist

SUSTAINABLE SERVICE DELIVERY CHECKLIST

Sustainable service delivery is dependent on delivering services that are both socially just and -equal. The former mentioned correlates to service affordability. That is, providing services that are affordable to all. The latter mentioned correlates to social inclusion. That is, including all members of the society in such a way that each is presented with the same opportunities. Refer to Figure 44.

Service Affordability

☐ Discounted Fares (Governmental Subsidies)

Social Inclusion

☐ Amenities for Disabled People

Examples

✓ Discounted fares: weekly- and monthly passes or special rates (e.g. students and elderly people).

✓ Amenities for disabled people: wheelchair ramps at transit facilities for mobility impaired people; audio signals at pedestrian crossings for sight impaired people; and clear notice boards for hearing impaired people.

Figure 44: Sustainable Service Delivery Checklist

SUSTAINABLE LIVING CHECKLIST

Sustainable living is dependent on delivering services that promote social development. Social development means that people are put at the centre of development. This is accomplished by aligning the public's needs with those of the service. Refer to Figure 45.

Public Service Alignment

☐ Usability Study

☐ Community Development Programs

Examples

✓ Community development programs: transport education programs.

Figure 45: Sustainable Living Checklist

EMPLOYEE PERFORMANCE MANAGEMENT CHECKLIST

Employee performance management is about aligning the organisational objectives with the employees' agreed measures, skills, competency requirements, development plans and the delivery of results. This can be accomplished by both engaging and developing employees. Refer to Figure 46.

Employee Engagement

☐ Organisational Structure (Communication Channels)

Employee Development

☐ Advancing Skillsets

☐ Improvement Tracking

Examples

✓ Organisational structure (communication channels): focus groups and trauma counselling services.

✓ Advancing skillsets: in-service training and staff development programs. For example: introduction- or orientation training and career- or development training.

✓ Improvement tracking: progress evaluation.

Figure 46: Employee Performance Management Checklist

ENVIONMENTAL GOVERNANCE CHECKLIST

In order to control the impact of transport matters on the environment, four fields need to be managed. These are: air quality, climate change, noise and energy. Refer to Figure 47.

Air Quality Management
- ☐ Priority Pollutants

Climate Change Management
- ☐ Weather Conditions

Noise Management
- ☐ Noise Exposure

Energy Management
- ☐ Energy Consumption

Examples
- ✓ Priority pollutants: Manufacturer declarations and/or roadside air quality tests.
- ✓ Weather conditions: ESS.
- ✓ Noise exposure: Manufacturer declarations and/or in-field tests.
- ✓ Energy consumption: Manufacturer declarations.

Figure 47: Environmental Governance Checklist

6.3.2 INDICES

Four perception indices have been identified. These are the: 1) traveller experience index, 2) CSI, 3) productive relationships index and 4) ESI. The separate empirical indicators that influence these composite measures were identified by considering which of the RATER model's dimensions apply to each of the respective proposed indices. By taking the aforementioned as the reference point, the factors that are within the control of the service provider, per proposed index, were then established.

TRAVELLER EXPERIENCE INDEX

The status of project infrastructure can be evaluated with the aid of a traveller experience survey. This survey assesses how the private transport users experience travelling on major roadways and freeways. The results from this survey are then collectively combined and captured as a traveller experience index. The index-related considerations identified for inclusion can be seen in Table 57.

Table 57: Traveller Experience Index

Dimension	Quality Criteria	No.	Parameter
Tangibles	Equipment	1	Functional equipment
	Technology	2	Up to date technology
	Communication materials	3	Applicable messages that are easy to understand
	Physical facilities	4	Convenience (e.g. time accessibility)
Assurance	Safety and security	5	Freedom from danger, risk and/or doubt

The performance and the overall importance of the index-related considerations presented in Table 57 were captured in the weighted average formula shown in Equation 24.

Equation 24: Traveller Experience Index

$$I_{Traveller\ Experience} = W_E \, . S_E + W_T \, . S_T + W_C \, . S_C + W_F \, . S_F + W_{SS} \, . S_{SS}$$

Where:

S_E = Satisfaction score for equipment

W_E = Importance weight for equipment

S_T = Satisfaction score for technology

W_T = Importance weight for technology

S_C = Satisfaction score for communication materials

W_C = Importance weight for communication materials

S_F = Satisfaction score for physical facilities

W_F = Importance weight for physical facilities

S_{SS} = Satisfaction score for safety and security

W_{SS} = Importance weight for safety and security

CUSTOMER SATISFACTION INDEX

The success of the marketing strategies adopted can be evaluated with the aid of a transport user satisfaction survey. This survey needs to be conducted for both public- and private transport. This will facilitate the separate assessment of the transport users' opinion on overall service delivery in each of the respective transport environments. The results from these surveys are then collectively combined and captured as two distinct CSI. The respective index-related considerations identified for inclusion can be seen in Table 58 and Table 59.

Table 58: CSI for Private Transport

Dimension	Quality Criteria	No.	Parameter
Reliability	Timeliness	1	Travel time; considering the distance travelled
	Accuracy	2	Accuracy of information (e.g. traffic images and expected service delays)
Assurance	Respect for users	3	Availability of (personalised) information (e.g. shortest route options)
	Safety and security	4	Public travel- and personal safety: incident management
	Probity and confidentiality	5	Privacy of individual movement

Dimension	Quality Criteria	No.	Parameter
Tangibles	Physical facilities	6	Convenience (e.g. geographic accessibility)
Empathy	Understanding the user	7	Door-to-door navigation (e.g. trip assistance)
	Service appropriate for users’ needs	8	Amenities for people with disabilities
		9	Alternative route options where road restrictions exist (e.g. vehicle height and -weight)

The performance and the overall importance of the index-related considerations presented in Table 58 were captured in the weighted average formula shown in Equation 25.

Equation 25: CSI - Private Transport

$$I_{Customer\ Satisfaction-Private} = W_T\,.S_T + W_A\,.S_A + W_R\,.S_R + W_{SS}\,.S_{SS} + W_P\,.S_P + W_F\,.S_F + W_U\,.S_U + W_{ND}\,.S_{ND} + W_{NR}\,.S_{NR}$$

Where:

S_T = Satisfaction score for timeliness

W_T = Importance weight for timeliness

S_A = Satisfaction score for accuracy

W_A = Importance weight for accuracy

S_R = Satisfaction score for respect for users

W_R = Importance weight for respect for users

S_{SS} = Satisfaction score for safety and security

W_{SS} = Importance weight for safety and security

S_P = Satisfaction score for probity and confidentiality

W_P = Importance weight for probity and confidentiality

S_F = Satisfaction score for physical facilities

W_F = Importance weight for physical facilities

S_U = Satisfaction score for understanding the user

W_U = Importance weight for understanding the user

S_{ND} = Satisfaction score for service appropriate for users’ needs: amenities for people with disabilities

W_{ND} = Importance weight for service appropriate for users’ needs: amenities for people with disabilities

S_{NR} = Satisfaction score for service appropriate for users’ needs: alternative route options where road restrictions exist

W_{NR} = Importance weight for service appropriate for users' needs: amenities for people with disabilities: alternative route options where road restrictions exist

Table 59: CSI for Public Transport

Dimension	Quality Criteria	No.	Parameter
Reliability	Timeliness	1	Frequency of services (e.g. departures)
	Consistency/ regularity	2	Availability of services (e.g. operational hours)
	Accuracy	3	Accuracy of services (e.g. on-time departures)
		4	Accuracy of information (e.g. expected service delays)
Assurance	Staff competence	5	Personnel access (e.g. appearance and knowledgeability)
	Respect for users	6	Availability of information (i.e. routes, stops/stations and timetables)
		7	Ease of purchasing tickets
	Safety and security	8	Public travel- and personal safety: driver behaviour
	Probity and confidentiality	9	Privacy of individual movement
Tangibles	Physical facilities	10	Convenience (e.g. geographic- and transfer link accessibility)
		11	Comfort (e.g. shelter and seating)
		12	Cleanliness (e.g. stops/stations and transit vehicles)
Empathy	Understanding the user	13	Door-to-door navigation (e.g. trip assistance)
	Service appropriate for users' needs	14	Amenities for people with disabilities
		15	Alternative route options where facility restrictions exist

The performance and the overall importance of the index-related considerations presented in Table 59 were captured in the weighted average formula shown in Equation 26.

Equation 26: CSI - Public Transport

$$I_{Customer\ Satisfaction-Public} = W_T\,.S_T + W_{CR}\,.S_{CR} + W_{AS}\,.S_{AS} + W_{AI}\,.S_{AI} + W_{SC}\,.S_{SC} + W_{RI}\,.S_{RI} + W_{RT}\,.S_{RT} + W_{SS}\,.S_{SS} + W_P\,.S_P + W_{FCON}\,.S_{FCON} + W_{FCOM}\,.S_{FCOM} + W_{FCLE}\,.S_{FCLE} + W_U\,.S_U + W_{ND}\,.S_{ND} + W_{NR}\,.S_{NR}$$

Where:

S_T = Satisfaction score for timeliness

W_T = Importance weight for timeliness

S_{CR} = Satisfaction score for consistency/regularity

W_{CR} = Importance weight for consistency/regularity

S_{AS} = Satisfaction score for accuracy of services

W_{AS} = Importance weight for accuracy of services

S_{AI} = Satisfaction score for accuracy of information

W_{AI} = Importance weight for accuracy of information

S_{SC} = Satisfaction score for staff competence

W_{SC} = Importance weight for staff competence

S_{RI} = Satisfaction score for respect for users: availability of information

W_{RI} = Importance weight for respect for users: availability of information

S_{RT} = Satisfaction score for respect for users: ease of purchasing tickets

W_{RT} = Importance weight for respect for users: ease of purchasing tickets

S_{SS} = Satisfaction score for safety and security

W_{SS} = Importance weight for safety and security

S_{P} = Satisfaction score for probity and confidentiality

W_{P} = Importance weight for probity and confidentiality

S_{FCON} = Satisfaction score for physical facilities: convenience

W_{FCON} = Importance weight for physical facilities: convenience

S_{FCOM} = Satisfaction score for physical facilities: comfort

W_{FCOM} = Importance weight for physical facilities: comfort

S_{FCLE} = Satisfaction score for physical facilities: cleanliness

W_{FCLE} = Importance weight for physical facilities: cleanliness

S_{U} = Satisfaction score for understanding the user

W_{U} = Importance weight for understanding the user

S_{ND} = Satisfaction score for service appropriate for users' needs: amenities for people with disabilities

W_{ND} = Importance weight for service appropriate for users' needs: amenities for people with disabilities

S_{NR} = Satisfaction score for service appropriate for users' needs: alternative route options where facility restrictions exist

W_{NR} = Importance weight for service appropriate for users' needs: amenities for people with disabilities: alternative route options where facility restrictions exist

PRODUCTIVE RELATIONSHIPS INDEX

The success of service interaction with regard to cultivating productive relationships can be evaluated with the aid of peer- and public reviews. These reviews assess how the transport users experience interacting with the service. The results from these reviews are then collectively combined and captured as a productive relationships index. The index-related considerations identified for inclusion can be seen in Table 60.

Table 60: Productive Relationships Index

Dimension	Quality Criteria	No.	Parameter
Tangibles	Employees	1	Knowledge and courtesy
Empathy	Access (to staff, services and information)	2	Approachability and ease of contact
	Communication (clear, appropriate and timely)	3	Keeping customers informed in a language they can understand
	Individualised attention	4	Making an effort to know customers and to understand their needs
Responsiveness	Willingness to help	5	Listening to customers and acknowledging their comments
	Provision of prompt services	6	Readily respond to concerns
	Problem resolution and complaint handling	7	Fulfilling promises and obligations
	Flexibility	8	Providing numerous interaction mediums

The performance and the overall importance of the index-related considerations presented in Table 60 were captured in the weighted average formula shown in Equation 27.

Equation 27: Productive Relationships Index

$$I_{Productive\ Relationships} = W_E\,.S_E + W_A\,.S_A + W_C\,.S_C + W_{IA}\,.S_{IA} + W_W\,.S_W + W_{PS}\,.S_{PS} + W_{PC}\,.S_{PC} + W_F\,.S_F$$

Where:

S_E = Satisfaction score for employees

W_E = Importance weight for employees

S_A = Satisfaction score for access (to staff, services and information)

W_A = Importance weight for access (to staff, services and information)

S_C = Satisfaction score for communication (clear, appropriate and timely)

W_C = Importance weight for communication (clear, appropriate and timely)

S_{IA} = Satisfaction score for individualised attention

W_{IA} = Importance weight for individualised attention

S_W = Satisfaction score for willingness to help

W_W = Importance weight for willingness to help

S_{PS} = Satisfaction score for prompt services

W_{PS} = Importance weight for prompt services

S_{PC} = Satisfaction score for problem resolution and complaint handling

W_{PC} = Importance weight for problem resolution and complaint handling

S_F = Satisfaction score for flexibility

W_F = Importance weight for flexibility

EMPLOYEE SATISFACTION INDEX

Employee satisfaction can be evaluated with the aid of an employee satisfaction survey. This survey assesses the employees' opinion and overall contentedness with regard to their job- and operating environment conditions. The results from this survey are then collectively combined and captured as an ESI. The index-related considerations identified for inclusion can be seen in Table 61.

Table 61: Employee Satisfaction Index

Dimension	Quality Criteria	No.	Parameter
Assurance	Consistency/regularity	1	System dependability (e.g. service provided at the promised time)
	Accuracy	2	Records kept accurately and error-free
	Competence of co-workers	3	Level of knowledge
	Respect for co-workers	4	Politeness towards each other
	Credibility	5	Acknowledged for services
	Probity and confidentiality	6	Personal information kept confidential
	Safety and security	7	Feel safe and at ease with daily operations
Tangibles	Physical facilities	8	Visually appealing and clean environment
	Equipment	9	Easy to use equipment
	Technology	10	Up to date technology
	Appearance of Co-workers	11	Well-dressed and neat in appearance
	Communication materials	12	Appropriate communication channels
Empathy	Access (to system and information)	13	Confidence instilled
	Communication (clear, appropriate and timely)	14	Expectations clear

Dimension	Quality Criteria	No.	Parameter
Empathy	Understanding the user	15	Best interests at heart (e.g. flexible operating hours)
	Individualised attention	16	Interaction among co-workers encouraged
Responsiveness	Willingness to help	17	Listening to employees and acknowledging their comments
	Provision of prompt services	18	Readily respond to concerns
	Problem resolution and complaint handling	19	Fulfilling promises and obligations
	Flexibility	20	Out-of-the-box thinking

The performance and the overall importance of the index-related considerations presented in Table 61 were captured in the weighted average formula shown in Equation 28.

Equation 28: Employee Satisfaction Index

$$I_{Employee\ Satisfaction} = W_{CR}\,.S_{CR} + W_A\,.S_A + W_{CC}\,.S_{CC} + W_R\,.S_R + W_C\,.S_C + W_P\,.S_P + W_{SS}\,.S_{SS} + W_F\,.S_F + W_E\,.S_E + W_T\,.S_T + W_{CW}\,.S_{CW} + W_{CM}\,.S_{CM} + W_{ASI}\,.S_{ASI} + W_{AC}\,.S_{AC} + W_U\,.S_U + W_{IA}\,.S_{IA} + W_W\,.S_W + W_{PS}\,.S_{PS} + W_{PC}\,.S_{PC} + W_F\,.S_F$$

Where:

S_{CR} = Satisfaction score for consistency/regularity

W_{CR} = Importance weight for consistency/regularity

S_A = Satisfaction score for accuracy

W_A = Importance weight for accuracy

S_{CC} = Satisfaction score for competence of co-workers

W_{CC} = Importance weight for competence of co-workers

S_R = Satisfaction score for respect for co-workers

W_R = Importance weight for respect co-workers

S_C = Satisfaction score for credibility

W_C = Importance weight for credibility

S_P = Satisfaction score for probity and confidentiality

W_P = Importance weight for probity and confidentiality

S_{SS} = Satisfaction score for safety and security

W_{SS} = Importance weight for safety and security

S_F = Satisfaction score for physical facilities

W_F = Importance weight for physical facilities

S_E = Satisfaction score for equipment

W_E = Importance weight for equipment

S_T = Satisfaction score for technology

W_T = Importance weight for technology

S_{CW} = Satisfaction score for co-workers

W_{CW} = Importance weight for co-workers

S_{CM} = Satisfaction score for communication materials

W_{CM} = Importance weight for communication materials

S_{ASI} = Satisfaction score for access (to system and information)

W_{ASI} = Importance weight for access (to system and information)

S_{AC} = Satisfaction score for access communication (clear, appropriate and timely)

W_{AC} = Importance weight for access communication (clear, appropriate and timely)

S_U = Satisfaction score for understanding the user

W_U = Importance weight for understanding the user

S_{IA} = Satisfaction score for individualised attention

W_{IA} = Importance weight for individualised attention

S_W = Satisfaction score for willingness to help

W_W = Importance weight for willingness to help

S_{PS} = Satisfaction score for provision of prompt services

W_{PS} = Importance weight for prompt services

S_{PC} = Satisfaction score for problem resolution and complaint handling

W_{PC} = Importance weight for problem resolution and complaint handling

S_F = Satisfaction score for flexibility

W_F = Importance weight for flexibility

6.3.3 SCORECARDS

For simplicity reasons, all of the performance measures pertaining to the same performance area have been grouped together into one scorecard. This resulted in the development of 13 scorecards. Nevertheless, singular assessment per performance measure is still the norm.

ACCESSIBILITY SCORECARD

The project's efforts towards catering for and including all users (and vehicles) were evaluated with the aid of a scorecard. The proposed scorecard assesses the project's success towards delivering an accessible network, from the user's viewpoint, by considering the characteristics of the transport network. This relates to the quality of the road and the transit line when taking into consideration the constraints imposed on certain routes to access general points of interest. Refer to Table 62.

Table 62: Accessibility Scorecard

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Characteristics of the Network: Quality of the Road or Transit Line*	Inadequate quality: transport network includes almost none users and no effort is made to improve accessibility	Adequate quality: transport network accessible to only some users but effort is made towards providing facilities, amenities or options for all	Good quality: transport network accessible to almost all users; only excludes one user type	Excellent quality: transport network accessible to all users by providing NMT facilities, park-and-ride facilities, amenities for people with disabilities and alternative route options where restrictions exist

ASSET MANAGEMENT SCORECARD

The project's efforts towards managing the operational performance of its assets were evaluated with the aid of a scorecard. The proposed scorecard assesses the following functions of operation: record, monitor and control. Refer to Table 63.

Table 63: Asset Management Scorecard

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Record*	Lack of recordings: no asset register	Inadequate recordings: minor discrepancies between assets recorded and assets in field OR missing some major asset-related information	Adequate recordings: all assets recorded in the asset register but some minor asset-related information is missing	Excellent recordings: all assets recorded in the asset register and all asset-related information over an asset's whole lifecycle documented

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Monitor: Accuracy and Quality Verification*	Lack of monitoring: no network surveillance system	Inadequate monitoring: mediocre network surveillance systems that have low to medium functionality OR little scope	Adequate monitoring: acceptable network surveillance systems that have medium to high functionality OR selective scope	Excellent monitoring: state of the art network surveillance systems that have high functionality (i.e. work or operate as should) and extensive scope
	Control: Tracking and Navigating	Lack of control: no positioning system	Inadequate control: mediocre positioning systems that have low to medium functionality OR poor applicability	Adequate control: acceptable positioning systems that have medium to high functionality OR selective applicability	Excellent control: state of the art positioning systems that have high functionality (i.e. work or operate as should) and extensive applicability

OPERATIONAL RESILIENCE SCORECARDS

SCALABILITY

The project's operational resilience with regard to its scalability was evaluated with the aid of a scorecard. The proposed scorecard assesses the ability of a system to change its scale in order to meet changing volumes of demand; without compromising its performance. The scalability dimension chosen for consideration is functional scalability (i.e. the ability of a system to take on new functions or tasks) and the feasibility factors considered are: time, cost and effort. Refer to Table 64.

Table 64: Scalability Scorecard

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Functional: Operational*	Infeasible: performance significantly compromised – effort of execution not justifiable as well as time and cost inefficient	Slightly feasible: performance slightly compromised - effort of execution questionable OR unnecessarily time consuming and costly	Moderately feasible: acceptable performance obtainable relatively effortlessly but slightly time consuming and costly	Highly feasible: performance highly comparable between initial and re-scaled situation – execution effortless as well as time and cost efficient

RESPONSIVENESS

The project's operational resilience with regard to its responsiveness was evaluated with the aid of two scorecards. That is, one for road-based transport modes and one for rail-based transport modes. This separation was needed, since volume (demand) responsiveness is innately greater for road-based public transport modes than for rail-based public transport modes. Therefore, the increments chosen for the scorecard relating to the rail-based public transport modes are larger than the increments chosen for the scorecard relating to the road-based public transport modes.

The proposed scorecards assess the ability of the system to meet traveller needs and to respond to market changes, within a reasonable time period, such that competitive advantage can be maintained. The responsiveness dimension chosen for consideration is volume and the factors considered relate to the system's level of flexibility. Refer to Table 65 and Table 66.

Table 65: Responsiveness Scorecard - Road-based Transport Modes

Description

Category

Score	**0**	**1**	**2**	**3**
Value	**0**	**50**	**75**	**100**
Volume: Demand	Inflexible: transport network only expandable by obtaining major additional infrastructure (e.g. building new primary routes)	Slightly flexible: transport network only expandable by either adding additional services OR obtaining minor additional infrastructure (e.g. building new links between routes)	Moderately flexible: transport network easily expanded by implementing ad-hoc routes, temporary transfer points and/or group pick-up services	Highly flexible: transport network has sufficient available capacity OR transport network simply expanded by adjusting existing routes, altering operations and/or utilising demand responsive technologies

Table 66: Responsiveness Scorecard - Rail-based Transport Modes

Description

Category

Score	**0**	**2**	**4**
Value	**0**	**50**	**100**
Volume: Demand	Inflexible: transport network only expandable by obtaining major additional infrastructure (e.g. building new railways)	Moderately flexible: transport network only expandable by either adding additional services OR obtaining minor additional infrastructure (e.g. rail carriages)	Highly flexible: transport network with sufficient available capacity OR transport network simply expanded by adjusting

			existing routes and/or altering operations

SERVICE EXPANSION SCORECARD

The project's efforts towards managing service expansion were evaluated with the aid of a scorecard. The proposed scorecard assesses the project's success towards adequately using the allocated funds for capacity building and infrastructure development. This relates to determining whether the project delivered acceptable infrastructure expansion, on time and as per the allocated budget. Refer to Table 67.

Table 67: Service Expansion Scorecard

Description

Category

Score	**0**	**1**	**2**	**3**
Value	**0**	**50**	**75**	**100**
Capacity Building and Infrastructure Development	Lack of service expansion: infrastructure stagnation	Inadequate service expansion: infrastructure expansion delivered with either poor quality OR severely late and/or over budget	Adequate service expansion: acceptable infrastructure delivered slightly late and/or over budget	Excellent service expansion: high quality infrastructure delivered on time and as per allocated budget

PRODUCTIVE RELATIONSHIPS SCORECARD

As mentioned previously, besides using the productive relationship index, service interaction can also be evaluated with the aid of a scorecard. The proposed scorecard assesses the project's success towards cultivating productive relationships by considering the general type and trend of the postings made by the users on the representative social media platforms. Refer to Table 68.

Table 68: Productive Relationships Scorecard

Description

Category

Score	**0**	**1**	**2**	**3**
Value	**0**	**50**	**75**	**100**
Type and Trend of Postings	Negative recordings: mostly destructive criticism such as expressions of distrust, dissatisfaction and disappointment	Mediocre recordings: balance between positive- and negative user recordings	Satisfactory recordings: mostly constructive criticism and implementable feedback	Positive recordings: mostly encouraging comments and favourable feedback

TRAVELLER INFORMATION PROVISION SCORECARD

The project’s success towards providing innovative world-class customer services (based on its traveller information provision) was evaluated with the aid of a scorecard. The proposed scorecard assesses the system’s ability to provide information services that are proactive, effective and enabling in service delivery. The customer service delivery methods chosen for consideration are: assist, confirm, notify and advise. Refer to Table 69.

Table 69: Traveller Information Provision Scorecard

Description

Category

Score	**0**	**1**	**2**	**3**
Value	**0**	**50**	**75**	**100**
Assist: Trip Planning (Pre-trip and in-trip)	Lack of assistive information	Limited pull services (i.e. lack two or more: door-to-door, multimodal and all user types)	Moderate pull services: intermittent trip planning assistance (i.e. lack either door-to-door, multimodal or all user types)	Excellent pull services: door-to-door trip planning assistance incorporating all mode options (i.e. NMT, private- and public transport) and available to all user types
Confirm: Traffic and Transit Information	Lack of confirmative information	Limited push services: information confirmed (and updated) irregularly	Moderate push services: information confirmed (and updated) regularly but only on some communication mediums	Excellent push services: information confirmed (and updated) in real-time on all representative communication mediums
Notify: Incident Notification	Lack of notification services	Limited notification services: delayed notification	Moderate notification services: timely notification but only on some communication mediums	Excellent notification services: real-time notification on all representative communication mediums
Advise: Route Guidance (In-trip and post-trip)	Lack of advisory information	Limited advisory services: traditional methods with only intermittent guidance	Moderate advisory services: less advanced systems (i.e. lack either real-time information or user needs assessment) with both in-trip and post-trip guidance	Excellent advisory services: smart systems (i.e. use real-time information and incorporate users’ needs) with both in-trip and post-trip guidance

PERFORMANCE AND QUALITY OF INTERACTION MEDIUMS SCORECARD

The project's success towards providing innovative world-class customer services (based on its interaction mediums) was evaluated with the aid of a scorecard. Since these interaction mediums have a direct impact on the customer's experience of the service, the proposed scorecard assesses the system's ability to provide inventory and technology that are associated with a high quality and performance. Refer to Table 70.

Table 70: Performance and Quality of Interaction Mediums Scorecard

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Inter-personal Interaction: Workforce*	Lack of inter-personal interaction	Mediocre interaction: personnel that lack two or more: appropriate appearance, courteousness, helpfulness and knowledgeability	Satisfactory interaction: personnel that lack either appropriate appearance, courteousness, helpfulness or knowledgeability	Exceptional interaction: personnel that are appropriately dressed, courteous, helpful and knowledgeable in their field of expertise
	Self-service Systems: Service Inventory and Technology	Lack of self-service systems	Limited systems: inventory and technology that either have low to medium functionality OR lacks one or more: applicability, simplicity and understanding	Moderate systems: inventory and technology that either have medium to high functionality OR possibly lacks applicability, simplicity or understanding	Excellent systems: inventory and technology with high functionality (i.e. work or operate as should) that are applicable, simple to use and easy to understand

ENVIRONMENTAL SCORECARDS

POLLUTION MITIGATION

The project's efforts towards mitigating pollution were evaluated with the aid of a scorecard. The proposed scorecard assesses the project's success towards implementing emission control technologies and reducing activities. The former mentioned include technologies that facilitate vehicle-related weight reduction, emission reduction and energy recovery. The latter mentioned include the modernisation to hybrid vehicles, the promotion of public transport, the use of equipment that promotes seamless traffic flow, roadside testing of diesel-driven vehicles as well as the initiatives that support clean fuel. Refer to Table 71.

Table 71: Pollution Mitigation Scorecard

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Emission Control Technologies and Reducing Activities*	Lack of mitigation: no effort is made towards implementing mitigation strategies	Mediocre mitigation: policies to encourage an efficient transport system and mitigation initiatives actively pursued, but not yet employed	Satisfactory mitigation: transport system implements mitigation strategies, but not actively and not everywhere	Excellent mitigation: transport system implements mitigation strategies wherever possible and practicable

WEATHER CONDITIONS: IMPACT MITIGATION

The project's efforts towards mitigating the impact of weather conditions on driving behaviour were evaluated with the aid of a scorecard. The proposed scorecard assesses the project's success towards implementing weather control technologies and activities. The former mentioned include the presence of streetlights and electric cat eyes that automatically turn on when darkness is detected as well as the presence of reflective paint that glows under the glare of a vehicle's headlights. The latter mentioned include the initiatives that support adverse weather notifications and that enforce information such as reduced speed limits on message signs. Refer to Table 72.

Table 72: Weather Conditions - Impact Mitigation Scorecard

Description

	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Weather Control Technologies and Reducing Activities*	Lack of mitigation: no effort is made towards implementing mitigation strategies	Mediocre mitigation: policies to encourage an efficient transport system and mitigation initiatives actively pursued, but not yet employed	Satisfactory mitigation: transport system implements mitigation strategies, but not actively and not everywhere	Excellent mitigation: transport system implements mitigation strategies wherever possible and practicable

NOISE EXPOSURE MITIGATION

The project's efforts towards mitigating noise exposure were evaluated with the aid of a scorecard. The proposed scorecard assesses the project's success towards implementing noise screening at noise source (e.g. noise barriers) and noise protection at noise receivers (e.g. soundproof windows). Refer to Table 73.

Table 73: Noise Exposure Mitigation Scorecard

		Description			
	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Noise Screening and - Protection*	Lack of mitigation: no effort is made towards implementing mitigation strategies	Mediocre mitigation: policies to encourage an efficient transport system and mitigation initiatives actively pursued, but not yet employed	Satisfactory mitigation: transport system implements mitigation strategies, but not actively and not everywhere	Excellent mitigation: transport system implements mitigation strategies wherever possible and practicable

ENERGY EFFICIENCY

The project's efforts towards promoting energy efficiency were evaluated with the aid of a scorecard. Energy efficiency can be evaluated by considering both renewable energy- and waste management programs. However, for simplicity reasons, only renewable energy programs were assessed with the proposed scorecard. The main consideration field is thus the presence of renewable energy sources. For example: hybrid- or biofuel operated (transit) vehicles, solar- and wind powered devices as well as naturally occurring landfill gas to power facilities. Refer to Table 74.

Table 74: Energy Efficiency Scorecard

		Description			
	Score	**0**	**1**	**2**	**3**
	Value	**0**	**50**	**75**	**100**
Category	*Renewable Energy Sources*	Inefficient: no effort is made towards utilising renewable energy sources	Poor efficiency: policies to encourage an efficient transport system and renewable energy initiatives actively pursued, but not yet employed	Moderate efficiency: transport system uses renewable energy sources, but not actively and not everywhere	High efficiency: transport system utilises renewable energy sources wherever possible and practicable

If desired, this scorecard could be augmented to also assess, for example, the energy efficiency of facilities, the total megawatts of renewable energy contracted and the total volume of waste disposed to landfill sites.

6.3.4 VALUE FUNCTIONS

In this section, the identified measure's measurement environment, per performance sub area, is given. This includes an overview of the measure's relating interested party (i.e. the party from whom the data required for value elicitation was obtained), the tendency of the value function (i.e. increase or decrease), the nature of the measure (i.e. benefit or cost) and the pre-determined data points (or ranges) considered in developing the value function.

For explanation purposes, an example of how to interpret the pre-determined data points pertaining to the first measure proposed (i.e. travel time factor) is given. The other measures' pre-determined data points (or ranges) can be interpreted by adopting similar logic.

Note: this section does not include any reference to the measures' relating measurement time frames, since suggestions for applicable time frames have already been made in Section 6.2.1. Moreover, it is highly probable that different projects demand different time frames. Therefore, the applicability of the time frames are a matter of the project's perception of what constitutes satisfactory service delivery.

TRAVEL TIME VARIABILITY

TRAVEL TIME FACTOR

The average peak period travel time to the free flow travel time; expressed as a ratio.

Interested party: Private transport user
Tendency of the value function: Decrease
Nature of the value function: Cost
Data points: 1.25, 1.5, 1.75 and 2

Explanation:
A travel time factor of, for example, 1.25 is representative of a peak period travel time that is 1.25 times longer than the free flow travel time.

ON-TIME PERFORMANCE

The number of transit vehicles arriving at times as stipulated in their timetables to the total number of transit vehicles in the representative fleet; expressed as a percentage.

Interested party: Public transport user
Tendency of the value function: Increase

Nature of the value function: Benefit

Data points: 95, 90, 85 and 75

INFORMATION VALIDITY

INFORMATION REFRESH RATE

The rate at which information is refreshed (e.g. updating images) to obtain or maintain real-time accuracy; expressed in seconds.

Interested party: Private- and public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data points: 30, 60, 90 and 120

LATENCY TO POSTING UPDATES

The time it takes to update and/or correct information (e.g. incident occurrence updates and timetable corrections) in the event of change; expressed in minutes.

Interested party: Private- and public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 2, 2 to 3, 3 to 4 and 4 to 5

INFORMATION ACCURACY

The period of time for which the information portrayed to the public is accurate (i.e. correct) to the total time it was portrayed; expressed as a percentage.

Interested party: Operator/contractor in private- and public transport

Tendency of the value function: Increase

Nature of the value function: Benefit

Data points: 96, 97, 98 and 99

INFORMATION AVAILABILITY

The period of time for which the information portrayed to the public is available (i.e. accessible) to the total time it was portrayed; expressed as a percentage.

Interested party: Operator/contractor in private- and public transport

Tendency of the value function: Increase

Nature of the value function: Benefit

Data points: 96, 97, 98 and 99

ACCESSIBILITY

ACCESS TIME

The average access time to access recreational points of interest; expressed in minutes.

Interested party: Private transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 5, 5 to 10, 10 to 15, 15 to 20 and 20 to 30

ACCESS DISTANCE

The average access distance to access recreational points of interest; expressed in kilometres.

Interested party: Public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 0.5, 0.5 to 1, 1 to 1.5 and 1.5 to 2

CONNECTIVITY

COMMUTING TIME

The average citizen's total commuting time as a proportion of their (working) day; expressed as one-way commuting time in minutes. Note: a working day is taken as 8 hours; 480 minutes.

Interested party: Private- and public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges representing one-way commuting time for private transport: smaller than 20, 20 to 30, 30 to 45 and 45 to 60

Data ranges representing one-way commuting time for public transport: smaller than 30, 30 to 45, 45 to 60 and 60 to 90

TRANSFER DISTANCE

The number of transfers between modes to be under "x" metres to the total number of transfers; expressed as a percentage.

Interested party: Public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges representing transfer distances in kilometres: smaller than 0.5, 0.5 to 1, 1 to 1.5 and 1.5 to 2

REGULARITY

SERVICE FREQUENCY

The rate at which transit vehicles arrives at stops/stations; measured for peak periods and expressed in minutes.

Interested party: Public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data points: smaller than 5, 5 to 10, 10 to 15 and 15 to 20

INCIDENT MANAGEMENT

DETECTION TIME

The time it takes the operators to detect an incident; measured from incident occurrence time and expressed in seconds.

Interested party: Operator/contractor in private transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 90, 90 to 120, 120 to 150 and 150 to 180

VERIFICATION TIME

The time it takes the operators to verify and classify the incident according to incident type; measured from incident detection time and expressed in seconds.

Interested party: Operator/contractor in private transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 30, 30 to 60, 60 to 90 and 90 to 120

NOTIFICATION TIME

The time it takes the operators to notify the partner authorities of the incident; measured from incident verification time and expressed in seconds.

Interested party: Operator/contractor in private transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 30, 30 to 60, 60 to 90 and 90 to 120

RESPONSE TIME

The time it takes the authorities to reach the scene of the incident; measured from incident verification time and expressed in minutes.

Interested party: Operator/contractor in private transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 9, 9 to 12, 12 to 15 and 15 to 18

ALERT TIME

The time it takes the operators to notify the travelling public of the incident; measured from incident verification time and expressed per representative communication medium in minutes. The communication mediums considered are: VMS or EMS, website or application, SMS and e-mail.

Interested party: Operator/contractor in private- and public transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 1, 1 to 2, 2 to 3 and 3 to 4

CLEARANCE TIME

The time it takes the authorities to clear the incident scene; measured from incident verification time and expressed per incident crash type (i.e. severity) in minutes. The incident crash types considered are: crashes with no injuries, crashes with light to severe injuries and crashes with fatal injuries.

Interested party: Operator/contractor in private transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges for crashes with no injuries: smaller than 60, 60 to 70, 70 to 80 and 80 to 90

Data ranges for crashes with light to severe injuries: smaller than 70, 70 to 90, 90 to 110 and 110 to 130

Data ranges for crashes with fatal injuries: smaller than 120, 120 to 150, 150 to 180 and 180 to 210

SERVICE QUALITY

LOS

The number of road segments assigned with a LOS of C or better to the total of road segments under consideration; measured for peak periods and expressed as a percentage.

Interested party: Employer/client in private transport

Tendency of the value function: Increase

Nature of the value function: Benefit

Data ranges: 55 to 65, 65 to 75, 75 to 85 and 85 to 95

LOAD FACTOR

The proportion of the average transit vehicle load to its capacity; measured for peak periods.

Interested party: Employer/client in public transport

Tendency of the value function: Increase

Nature of the value function: Benefit

Data ranges: bigger than 1.2, 1 to 1.2, 0.8 to 1, 0.6 to 0.8, 0.4 to 0.6 and smaller than 0.4

STANDING DENSITY

The average number of pedestrians per square meter of the facility’s platform; measured for peak periods.

Interested party: Employer/client in public transport

Tendency of the value function: Decrease

Nature of the value function: Cost

Data points: 1, 2, 3, 4 and 5

NETWORK TRAVEL SPEED

The average travel speed on freeways in peak periods; expressed as kilometres per hour.

Interested party: Private transport user

Tendency of the value function: Increase

Nature of the value function: Benefit

Data ranges: 50 to 60, 40 to 50, 30 to 40 and 20 to 30

QUEUE TIME

The average queueing times at major road segments or intersections; expressed in minutes. Queues could exist due to, for example, defective traffic signals, incidents and road works

Interested party: Private transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 2, 2 to 5, 5 to 10 and 10 to 15

WAITING TIME

The average time spend waiting for transit vehicles to arrive at stops/stations; expressed in minutes.

Interested party: Public transport user

Tendency of the value function: Decrease

Nature of the value function: Cost

Data ranges: smaller than 5, 5 to 10, 10 to 15 and 15 to 20

SERVICE UTILISATION

DEGREE OF SATURATION

The proportion of the network's demand (i.e. volume: v) to its supply (i.e. capacity: c); measured for peak periods. In private transport, the v/c proportion is assed for major roads and freeways. In public transport, the v/c proportion is assed for the transit line.

Interested party: Employer/client in private- and public transport

Tendency of the value function: Increase

Nature of the value function: Benefit

Data ranges: 1, 0.8 to 1, 0.6 to 0.8, 0.4 to 0.6 and smaller than 0.4

SYSTEM AVAILABILITY

SYSTEM UPTIME

The period of time for which the system is operable (i.e. in working condition) to the time it was supposed to be operable; expressed as a percentage.

Interested party: Operator/contractor in private- and public transport
Tendency of the value function: Increase
Nature of the value function: Benefit
Data points: 96, 97, 98 and 99

EQUIPMENT QUALITY

MEAN TIME BETWEEN FAILURES

The average elapsed time between inherent failures of a system; expressed in years. In public transport, the MTBF is presented per representative ITS equipment group. These are: fleet management (i.e. APTS-related) equipment and fare management (i.e. AFC-related) equipment.

Interested party: Operator/contractor in private- and public transport
Tendency of the value function: Increase
Nature of the value function: Benefit
Data ranges: 2 to 3, 3 to 4, 4 to 5 and 5 to 6

DATA QUALITY

ERROR RATES

The number of erroneous units of data (occurrences) to the total number of units of data transmitted; expressed as a percentage. In public transport, the errors rates are presented per representative ITS equipment group. These are: fleet management (i.e. APTS-related) equipment and fare management (i.e. AFC-related) equipment.

Interested party: Operator/contractor in private- and public transport
Tendency of the value function: Decrease
Nature of the value function: Cost
Data ranges: smaller than 1, 1 to 2, 2 to 3 and 3 to 4

PREVENTATIVE MAINTENANCE

FULFILMENT

The number of tickets fulfilled (i.e. scheduled logs) to the number of planned tickets; expressed as a percentage.

Interested party: Operator/contractor in private- and public transport
Tendency of the value function: Increase
Nature of the value function: Benefit
Data points: 95, 90, 85 and 80

CORRECTIVE MAINTENANCE

MEAN TIME TO REPAIR

The average time to repair a failed asset; measured from asset log time and expressed in hours. In public transport, the MTTR is presented per representative ITS equipment group. These are: fleet management (i.e. APTS-related) equipment and fare management (i.e. AFC-related) equipment.

Interested party: Operator/contractor in private- and public transport
Tendency of the value function: Decrease
Nature of the value function: Cost
Data ranges: smaller than 24, 24 to 48, 48 to 72 and 72 to 96

LOGGING ATTENDANCE

REACTION TIME

The average time taken to react to inquiries, queries, complaints and compliments; measured from log time and expressed per communication medium in hours. The communication mediums considered are: call centre and website or application.

Interested party: Operator/contractor in private- and public transport
Tendency of the value function: Decrease
Nature of the value function: Cost
Data ranges: smaller than 12, 12 to 24, 24 to 36 and 36 to 48

HELPFULNESS

The total number of compliments compared to the total number of complaints, expressed per service provider as a ratio.

Interested party: Employer/client in private- and public transport
Tendency of the value function: Increase
Nature of the value function: Benefit
Data ranges: bigger than 2, 1.5 to 2, 1 to 1.5, 0.5 to 1 and smaller than 0.5

SOCIAL JUSTICE

TRANSPORT EXPENDITURE

The percentage of a household's monthly income that goes towards their transport expenditure.

Interested party: Employer/client in private- and public transport
Tendency of the value function: Decrease
Nature of the value function: Cost
Data ranges: smaller than 10, 10 to 20, 20 to 30 and 30 to 40

SOCIAL EQUALITY

DEGREE OF URBAN DENSIFICATION

The percentage of the urban population that can conveniently access major roads and freeways.

Interested party: Employer/client in private transport
Tendency of the value function: Increase
Nature of the value function: Benefit
Data ranges: smaller than 20, 20 to 40, 40 to 60, 60 to 80 and 80 to 100

6.3.5 INCREASE-DECREASE: SCORE BANDS

STRICTLY DECREASING MEASURES

Ten measures have been classified as strictly decreasing measures. These measures were associated with fractional decay k_D. In order to assess these measures, five situations of decay have been identified. These situations and their associated satisfaction values V were represented by the score bands depicted in Equation 29.

Equation 29: Fractional Decay Score Bands

If $k_D > 0$	Then $V = 0$
If $k_D = 0$	Then $V = 25$
If $-0.0.5 \leq k_D < 0$	Then $V = 50$
If $-0.10 \leq k_D < -0.05$	Then $V = 75$
If $k_D < -0.10$	Then $V = 100$

All of the strictly decreasing measures were evaluated with the aid of Equation 29. In the next sub-sections, the specific circumstances relating to these measures are outlined.

PUBLIC SAFETY INCIDENT STATISTICS

In evaluating public safety incident statistics, the following circumstances with regard to Equation 22 prevail:

N = The number of public-related incident occurrences.

The fractional decay needs to be computed separately for public travel safety and personal safety. The former mentioned needs to be evaluated by determining the total number of occurrences per incident type (i.e. crash: no injuries, crash: light to severe, crash: fatalities and vehicle break-downs). The latter mentioned needs to be evaluated by determining the total number of property crime incidents (e.g. theft- and vehicle hijacking occurrences) while travelling on major roads, transit lines or at transit facilities.

STAFF SAFETY INCIDENT STATISTICS

In evaluating staff safety incident statistics, the following circumstances with regard to Equation 22 prevail:

N = The number of staff-related incident occurrences.

Staff safety encompasses the safety of the staff and/or the authorities both at, and while traveling to, the scene of the incident. Therefore, the fractional decay needs to computed separately for the total number of adverse health conditions and the total number of secondary incidents resulting from attending the scene of the incident.

QUEUE LENGTH

In evaluating queue length, the following circumstances with regard to Equation 22 prevail:

N = The average length of queues in vehicles for major road segments or at major intersections.

t = Peak periods.

The fractional decay needs to be computed for all modes that do not run to a scheduled timetable (i.e. private vehicle and taxi).

DEFECT LOGS

In evaluating defect logs, the following circumstances with regard to Equation 22 prevail:

N = The number of tickets logged.

The fractional decay needs to be computed for all the assets that required rectification.

SERVICE ENHANCEMENTS: PRIVATE TRANSPORT

In evaluating service enhancements, the following circumstances with regard to Equation 22 prevail:

N = The number of fatalities (in the private transport environment).

The fractional growth needs to be computed for the project as a whole.

ABSENTEEISM

In evaluating absenteeism, the following circumstances with regard to Equation 22 prevail:

N = The average number of absent days.

The fractional decay needs to be computed per employee and averaged for all employees within a certain division.

AIR QUALITY

In evaluating air quality, the following circumstances with regard to Equation 22 prevail:

N = The emission intensity (i.e. the level of emissions per unit of regional GDP).

The fractional decay needs to be computed separately for air pollutants and GHG emissions.

WEATHER-RELATED INCIDENT STATISTICS

In evaluating weather-related incident statistics, the following circumstances with regard to Equation 22 prevail:

N = The number of (purely) weather-related incident occurrences.

The fractional decay needs to be computed collectively for the public- and staff incident occurrences.

NOISE EXPOSURE

In evaluating noise exposure, the following circumstances with regard to Equation 22 prevail:

N = The sound intensity (i.e. the sound power per unit of area).

The fractional decay needs to be computed for the project as a whole.

ENERGY USE

In evaluating energy use, the following circumstances with regard to Equation 22 prevail:

N = The energy intensity (i.e. the level of energy per unit of production or unit of regional GDP).

The fractional decay needs to be computed for the project as a whole.

STRICTLY INCREASING MEASURES

Four measures have been classified as strictly increasing measures. These measures were associated with fractional growth k_G. In order to assess these measures, five situations of growth have been identified. These situations and their associated satisfaction values V were represented by the score bands depicted in Equation 30.

Equation 30: Fractional Growth Score Bands

If $k_G < 0$	Then $V = 0$
If $k_G = 0$	Then $V = 25$
If $0 < k_G \leq 0.0.5$	Then $V = 50$
If $0.05 < k_G \leq 0.10$	Then $V = 75$
If $k_G > 0.10$	Then $V = 100$

All of the strictly increasing measures were evaluated with the aid of Equation 30. In the next sub-sections, the specific circumstances relating to these measures are outlined.

BUSINESS OPPORTUNITIES

In evaluating business opportunities, the following circumstances with regard to Equation 22 prevail:

N = The number of jobs created.

The fractional growth needs to be computed for the total number of jobs created as a result of the existence of the service. For example: the jobs created for project construction and -operation.

CAPITAL GAIN

In evaluating capital gain, the following circumstances with regard to Equation 22 prevail:

N = The ROI (i.e. the benefit of an investment divided by its associated costs).

The fractional growth needs to be computed for the project as a whole.

SERVICE ENHANCEMENTS: PUBLIC TRANSPORT

In evaluating service enhancements, the following circumstances with regard to Equation 22 prevail:

N = The ridership numbers (in the public transport environment).

The fractional growth needs to be computed for the project as a whole.

SOCIAL MEDIA ATTRACTIVENESS

In evaluating the social media attractiveness, the following circumstances with regard to Equation 22 prevail:

N = The size of the social community.

The fractional growth needs to be computed per social media platform.

INDEX MEASURES

All four of the index measures proposed have been classified as strictly increasing measures. These measures were associated with fractional growth k_G and were thus also evaluated with the aid of Equation 30.

In the next sub-sections, the specific circumstances relating to these measures are outlined.

TRAVELLER EXPERIENCE INDEX

In evaluating the traveller experience index, the following circumstances with regard to Equation 22 prevail:

N = The value obtained from Equation 24.

The fractional growth needs to be computed only for the private transport environment.

CSI

In evaluating the CSI, the following circumstances with regard to Equation 22 prevail:

N = The values obtained from Equation 25 and Equation 26.

The fractional growth needs to be computed for both the private- and public transport environment.

PRODUCTIVE RELATIONSHIPS INDEX

In evaluating the productive relationships index, the following circumstances with regard to Equation 22 prevail:

N = The value obtained from Equation 27.

The fractional growth needs to be computed per social media platform.

EMPLOYEE SATISFACTION INDEX

In evaluating the employee satisfaction index, the following circumstances with regard to Equation 22 prevail:

N = The value obtained from Equation 28.

The fractional growth needs to be computed per division or per department.

SPECIAL MEASURES

Three measures have been classified as special measures. In the next sub-sections, the specific circumstances relating to these measures are outlined. In each of the following equations, V represents the associated satisfaction values.

MODE PREFERENCE

In evaluating mode preference, the following circumstances with regard to Equation 22 prevail:

N = The proportion of mode share within overall transport demand.

Since it is, in general, desirable that public transport be favoured or that fractional growth in public transport use be evident, a special case of score bands representing these measure specific desires have been developed. Refer to Equation 31. MS_{public} represents public transport's proportion of mode share within overall transport demand.

Equation 31: Mode Preference Score Bands

If $MS_{public} \leq 0.4$	OR $k_G < 0$	Then $V = 0$
If $0.4 < MS_{public} < 0.6$	OR $k_G = 0$	Then $V = 50$
If $MS_{public} \geq 0.6$	OR $k_G > 0$	Then $V = 100$

MS_{public} needs to be computed as the average public transport passenger trips of morning- and evening peak periods. The fractional growth k_G needs to be computed for the all-day share of public transport passenger trips.

REMAINING USEFUL LIFE OF FLEET

In evaluating the remaining useful life of the fleet, the following circumstances with regard to Equation 22 prevail:

N = The average remaining useful life of the fleet.

Since it is desired that the age value either remains constant or that fractional growth be evident, a special case of score bands representing these measure specific desires have been developed. Refer to Equation 32.

Equation 32: Remaining Useful Life of Fleet Score Bands

If $k_G < 0$	Then $V = 0$
If $k_G = 0$	Then $V = 50$
If $k_G > 0$	Then $V = 100$

The fractional growth k_G needs to be computed per transit vehicle type (as obtained from its representative transit vehicle age distribution graph) and averaged for all transit vehicle types.

FINANCIAL FEASIBILTY

In evaluating financial feasibility, the following circumstances with regard to Equation 22 prevail:

N = The ratio of the project's benefits to its associated costs.

Since it is desired that the benefit cost (BC) ratio be one, bigger than one or that fractional growth be evident, a special case of score bands representing these measure specific desires have been developed. Refer to Equation 33.

Equation 33: Financial Feasibility Score Bands

If $BC < 1$	OR $k_G < 0$	Then $V = 0$
If $BC = 1$	OR $k_G = 0$	Then $V = 50$
If $BC > 1$	OR $k_G > 0$	Then $V = 100$

The BC ratio can represent either the ratio obtained from the benefit cost analysis or the ratio obtained from the social benefit cost analysis. Moreover, the fractional growth k_G needs to be computed for the project as a whole.

Note: for the purpose required herein, financial feasibility was not calculated by considering any type of benefit to cost ratio. The measures pertaining to (social) wealth were rather evaluated individually as fractional growth and the measures pertaining to both expenditure and social distress were evaluated with the aid of fractional decay. That is, the former mentioned was assessed by using Equation 30 and the latter mentioned by using Equation 29.

6.4 MEASUREMENT DATA

6.4.1 DATA ANALYSIS

For the execution of the statistical analysis of the data obtained from the surveys, this author received assistance from a Professor in Statistics at the University of Stellenbosch.

STATISTICAL ANALYSIS

As can be seen in Table 17, only 39 responses were obtained in the private transport user survey and 91 responses in the public transport user survey. Therefore, since it was initially desired (deemed sufficient) to obtain 200 responses, statistical analysis was used to determine the feasibility and validity of these “non-adequate” number of responses.

A brief discussion on the statistical analysis conducted for the transport user surveys follows. This analysis was executed by using the software package STATISTICA. If desired, all of STATISTICA’s output data can be viewed by referring to the attached CD. The content of this CD is listed in Appendix F.

RESPONSE DISTRIBUTIONS

2-D histograms (with boxplots) were used to depict the distribution of the responses obtained. These response distributions were developed for each (pre-determined and user-specified) data point pertaining to each of the representative measures in the respective private/public transport user survey. Evidently, an immense number of response distributions were developed. Therefore, only the 2-D histograms (with boxplots) corresponding to one of the representative measures in the <u>private</u>

transport user survey are considered in more detail. The (randomly) chosen measure is the: travel time factor.

Refer to Figure 48 to Figure 52.

While Figure 48 to Figure 51 depict the distribution of the responses (observations) obtained for the pre-determined data points, Figure 52 depicts the distribution of the responses (observations) obtained for the user-specified data point. These distributions are all graphically depicted by the histogram and by the boxplot. The boxplot is represented by the green shape below each of the histograms. The green rectangular part of this shape depicts the area where 50% of the responses obtained were found to be located. The green lines stemming from this green rectangle depict the ranges where 0% to 25% and the 75% to 100% of the responses obtained were found to be located. Moreover, in each of these figures, the median-, mean-, standard deviation-, minimum- and maximum values of the responses obtained are stipulated. The mean value is also depicted as a red square. Lastly, the presence of any outlier responses is depicted by a pink triangle.

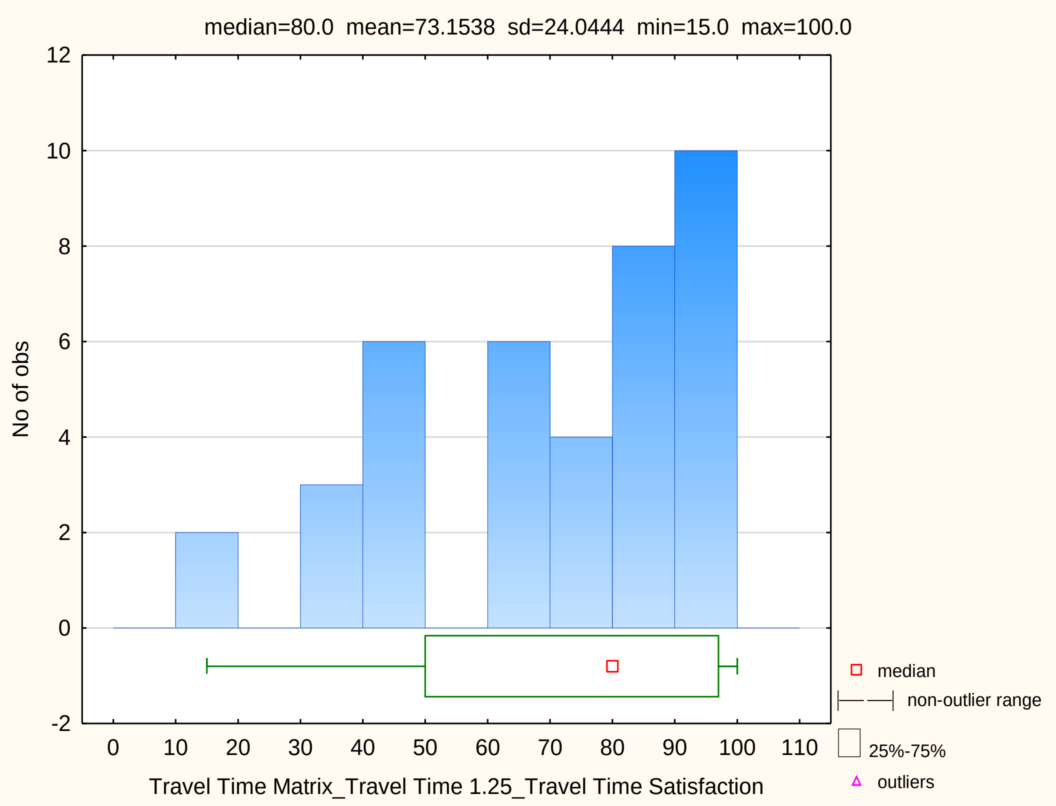


Figure 48: Response Distribution - Travel Time Factor 1.25

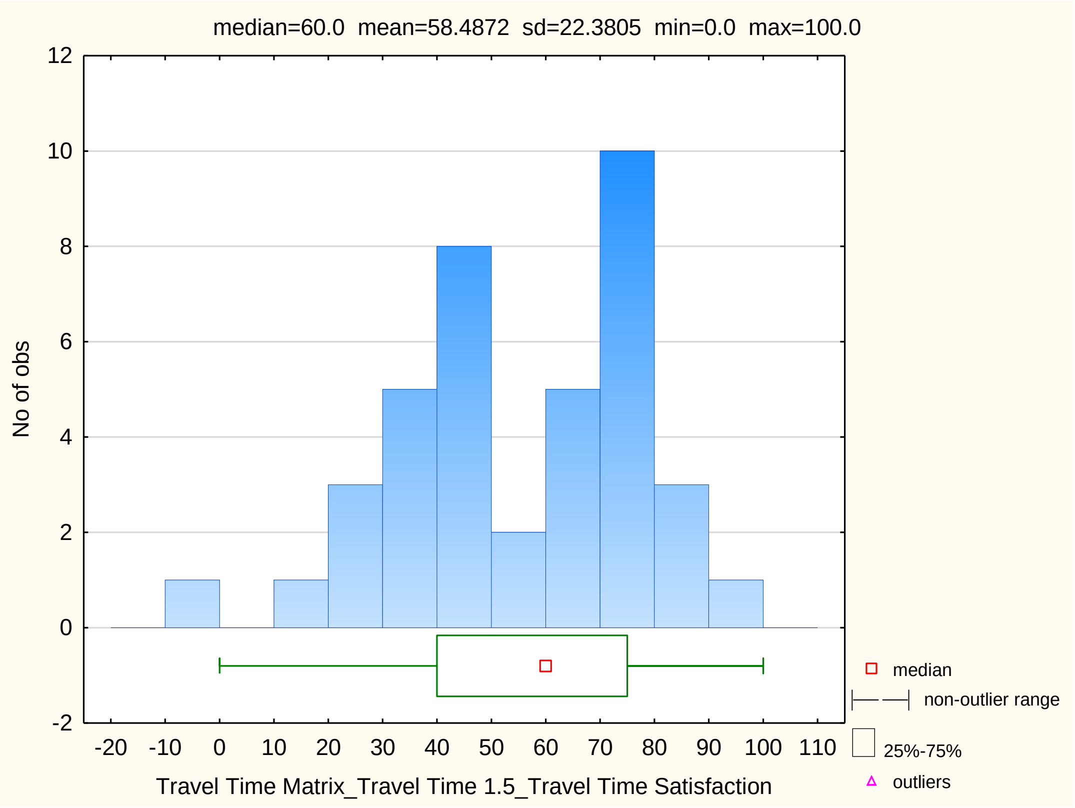


Figure 49: Response Distribution - Travel Time Factor 1.5

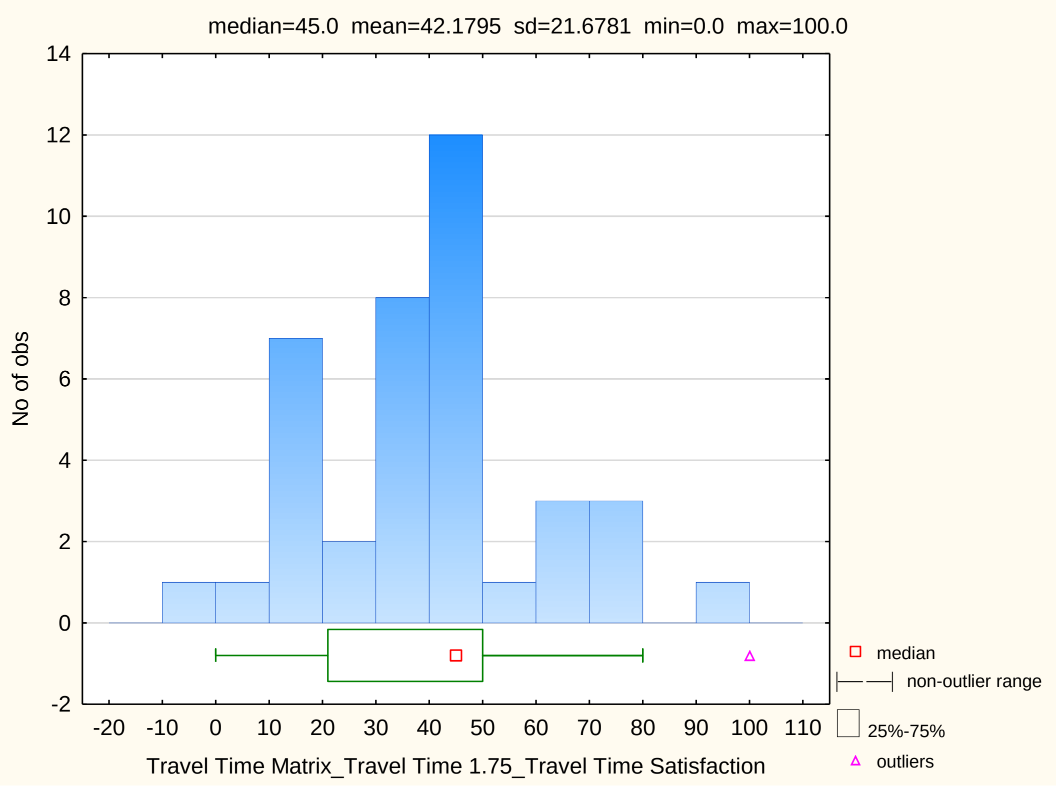


Figure 50: Response Distribution - Travel Time Factor 1.75

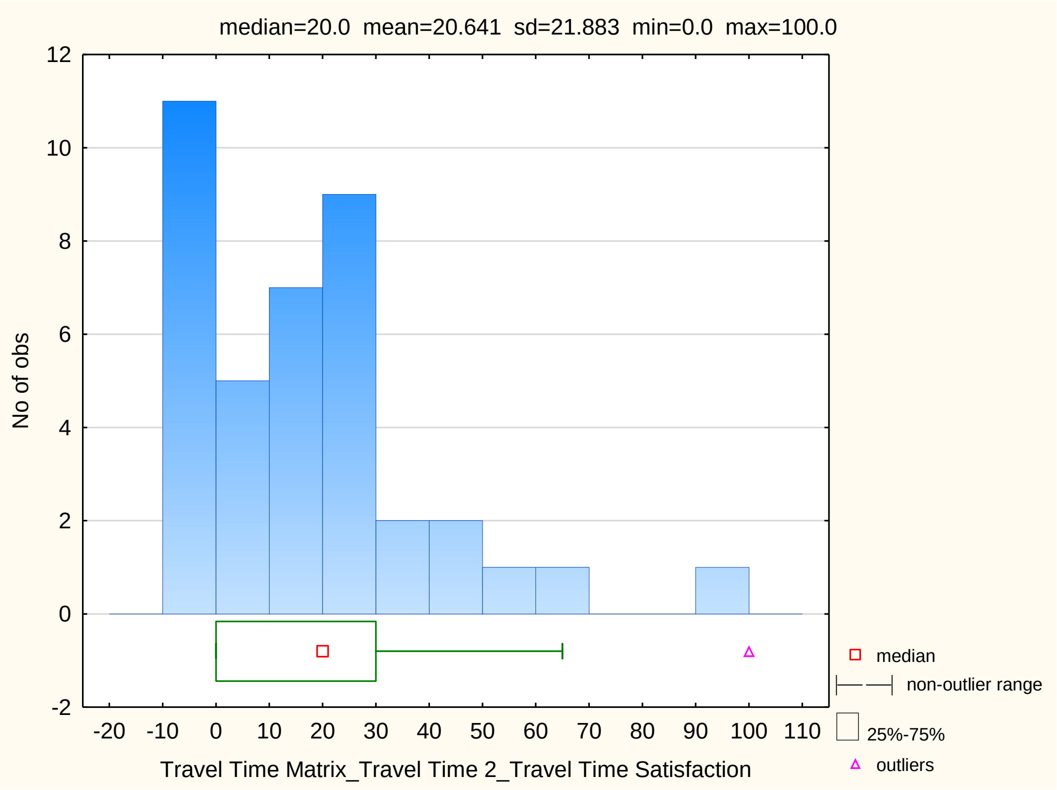


Figure 51: Response Distribution - Travel Time Factor 2

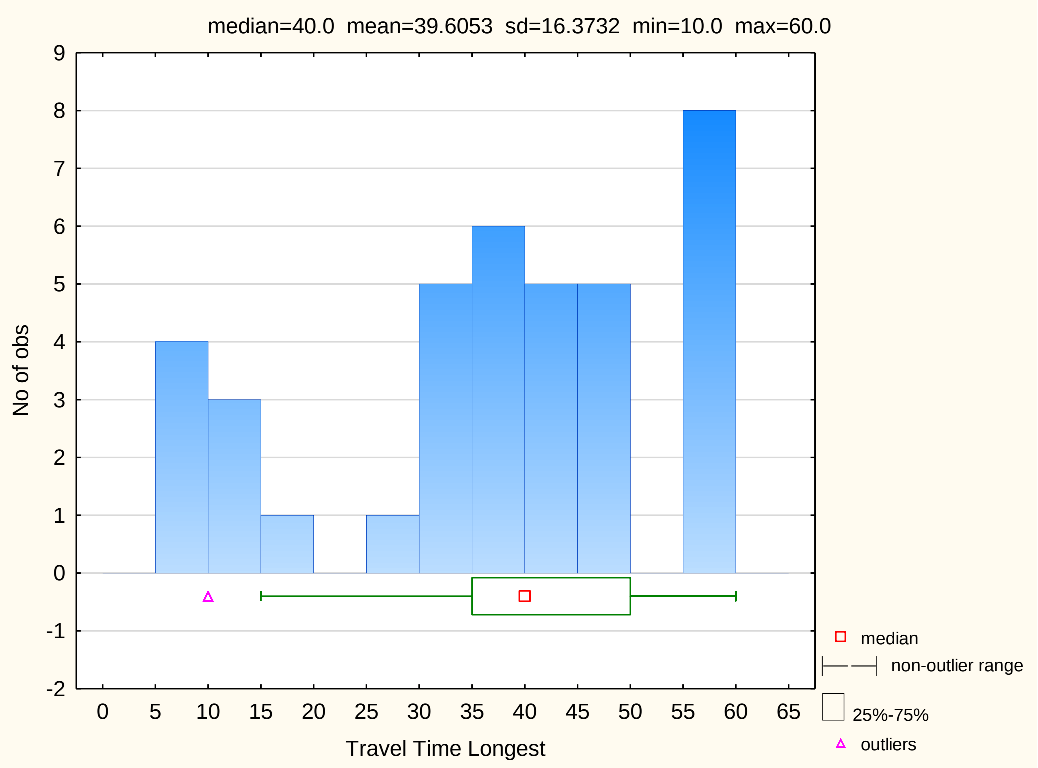


Figure 52: Response Distribution - Travel Time Longest

Figure 52 is essentially representative of the private transport users' thresholds with regard to their lenience towards travel time. That is, with the aid of this figure, it can be determined what constitutes the longest travel time that they would tolerate or deem to be satisfactory; after which they would associate anything longer with zero satisfaction. In this case, the median value is 40 minutes. Therefore, based on the formulation of the travel time factor, this means that the private transport users were willing to have a travel time during peak periods that is twice as long as the travel time for the same trip in off-peak periods.

CONFIDENCE INTERVALS

Since the mean of the sample is naturally not the same as the mean of the population, a range of values that act as good estimates of the unknown population mean is needed. This is referred to as the confidence interval.

In the aforementioned 2-D histograms (with boxplots) no reference to such confidence intervals is made. Therefore, the bootstrap method was implemented. The bootstrap method is a non-parametric method for establishing the 95% confidence interval without demanding any assumptions regarding which distribution the responses follow. The output of the bootstrap method is the identification of a lower- and an upper value to the 95% confidence interval.

As an example, the descriptive statistics relating to the previously discussed measure: travel time factor are shown in Table 75.

Table 75: Confidence Intervals - Bootstrap Method

Data Point	N	Mean	Median	Min.	Max.	Std. Dev.	Bootstrap Lower	Bootstrap Upper
Travel Time Factor 1.25	39	73.15	80	15	100	24.04	65.39	80.33
Travel Time Factor 1.5	39	58.49	60	0	100	22.38	51.41	65.26
Travel Time Factor 1.75	39	42.18	45	0	100	21.68	35.51	49.10
Travel Time Factor 2	39	20.64	20	0	100	21.88	14.80	28.79
Travel Time Longest	38	39.61	40	10	60	16.37	34.47	45.00

As can be seen from Table 75, for the data point: travel time factor 1.25, 39 responses were obtained. This formed the sample that was used to evaluate this data point. The mean of this sample is 73.15, the median of the sample is 80, the minimum value obtained is 15, the maximum value obtained is 100 and the standard deviation of the responses is 24.04. Based on the aforementioned, the 95%

bootstrap interval is identified to be between 65.39 (i.e. bootstrap lower) and 80.33 (i.e. bootstrap upper). Therefore, for this given data point, there is a 95% chance that the true mean of the population would be contained between the values 65.39 and 80.33.

The range of the values representing the 95% confidence interval is directly influenced by the size of the sample considered. That is, the smaller the sample, the wider the confidence intervals. For the application required herein, the confidence intervals identified for each data point pertaining to each of the representative measures in the respective private/public transport user survey were deemed sufficient.

ANALYSIS OF THE INDEX RANKINGS

A mixed, repeated measures, ANOVA model was used to rank all of the index-related considerations and to test for significant differences between the ranks obtained.

As an example, the responses obtained for each of the separate empirical indicators relating to the CSI in the public transport user survey are considered in more detail. As mentioned previously, the survey responders were asked to intuitively rank the specific index-related considerations. The null hypothesis was then used to assess these ranks. The null hypothesis was taken as the situation where all of the ranks obtained for all of the specific index-related considerations are the same. This hypothesis is rejected if the p-value is less than the significance level. The significance level is the probability of rejecting the null hypothesis given that it is true. In this case, the significance level was set at 0.05. In essence, it is desirable to have a p-value that is less than 0.05 and to hence reject the null hypothesis.

Refer to Figure 53:.

In Figure 53:, the p-value corresponding to the CSI index and the ranks obtained for each of the corresponding index-related considerations are stipulated. In this case, the p-value is less than 0.05. This indicates that the ranks obtained are indeed not equal. That is, the specific index-related considerations each has their own unique rank. Moreover, the letters depicted in Figure 53: were used to represent the degree of difference between the ranks obtained. If the same letter is repeated consecutively, it indicates that the ranks (where the consecutive letters occur) are close to one another. That is, there is no significant different between the ranks obtained for these respective index-related considerations. For the application required herein, the ranks computed for each of the index-related considerations relating to each of the identified composite measures were deemed valid.

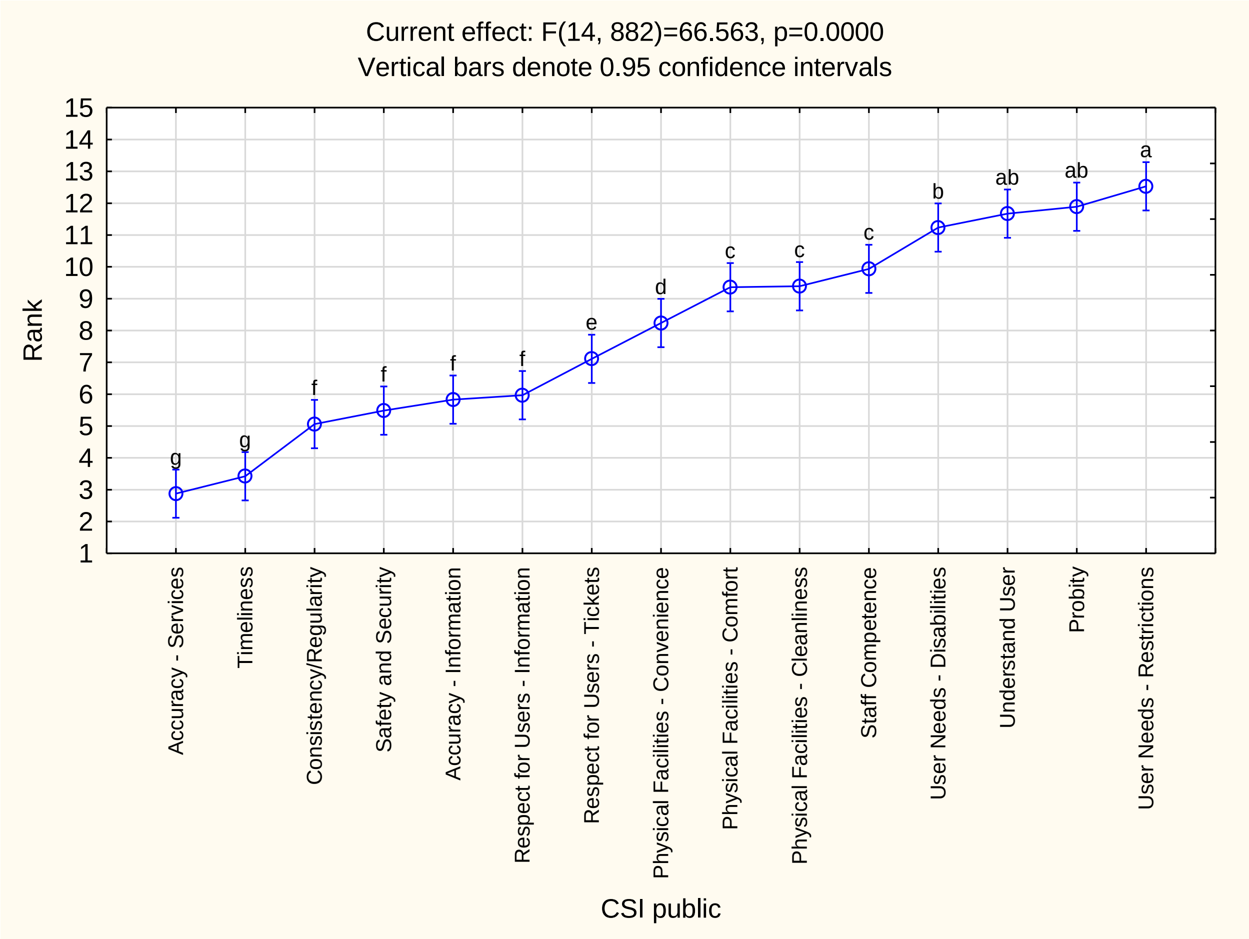


Figure 53: Index Rankings - CSI

6.5 MEASUREMENT MODEL

6.5.1 BACK-END DESIGN

In this section, the data obtained from the surveys are summarised to include a discussion on the value- and weight elicitation of the performance-related aspects. Moreover, this section concludes with a discussion on the (importance) weights (as computed from the ranks obtained) for all of the index-related considerations pertaining to the composite measures.

VALUE ELICITATION

The discussion on the value elicitation encompasses an outline, per sustainability perspective, of the representative measures' unit, nature (i.e. cost measure: C or benefit measure: B) and value ranges (i.e. minimum- and maximum performance scores). Moreover, an overview of the representative measures' value functions are shown. If the same measure is relevant to both the private- and the public transport environment, the measure's respective value functions are presented separately. Lastly, where deemed necessary, the differences (or similarities) among these value functions are highlighted.

PRACTICES

The measurement system of all of the measures relating to this perspective has been identified to be binary. Therefore, only one of the relating performance categories is considered in more detail. The (randomly) chosen performance category is: legal compliance. Refer to Table 76.

Table 76: Value Elicitation - Legal Compliance

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Legal Sources	**Legislations and Acts**	Transport	Binary	B	No = 0	Yes = 1
		Environment	Binary	B	No = 0	Yes = 1
		Labour	Binary	B	No = 0	Yes = 1
		Safety and Security	Binary	B	No = 0	Yes = 1
		Communications	Binary	B	No = 0	Yes = 1

Since the assessment procedure was similar for all of the measures whose measurement system has been identified to be binary, only the value function of one representative measure is presented here. The (randomly) chosen performance measure is: transport. Refer to Figure 54.

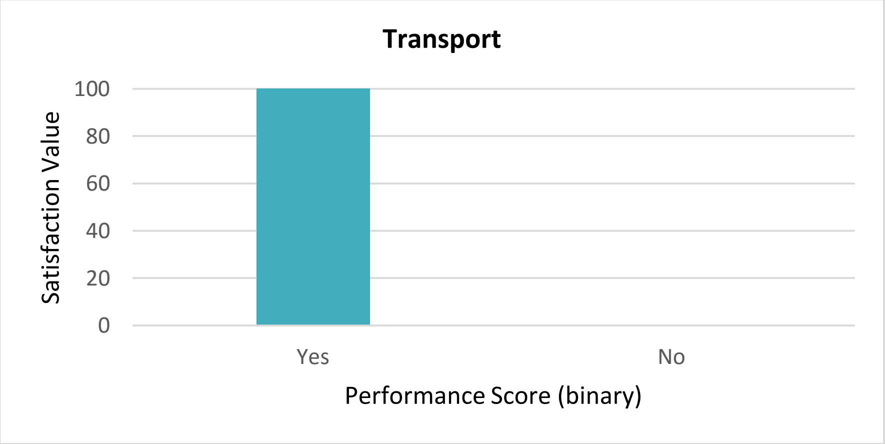


Figure 54: Transport Value Function

From Figure 54 it is evident that a "Yes" performance score correlates to a satisfaction value of 100 and a "No" performance score correlates to a satisfaction value of 0.

PROCESSES

Refer to Table 77 to Table 79. If the measure's format is red, it is only applicable to the private transport environment. If the measure's format is blue, it is only applicable to the public transport environment.

Table 77: Value Elicitation - Operational Performance

PERFORMANCE AREA	PERFORMANCE SUB AREA		PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Service Reliability	**Travel Time Variability**	**Travel Time Duration**	Travel Time Factor	Peak travel time to free flow travel time	C	1.25	2.25
		Schedule Adherence	On-time Performance	% of time transit vehicle arrives on-time	B	70	95
	Information Validity	**Timeliness**	Information Refresh Rate	Seconds	C	30 30	180 150
			Latency to Posting Updates	Minutes	C	2 2	6 5
		Accurate and Available	Accuracy	% of time information is correct	B	90 95	99 99
			Availability	% of time information is accessible	B	90 85	99 99
	Public Travel and Personal Safety	**Incident Statistics**	Crash Incidents and Break-downs	Decay Rate	C	-0.2	0.1
			Property Crime Incidents	Decay Rate	C	-0.2	0.1
Service Convenience	**Accessibility**	**Access Point Proximity**	Access Time	Minutes	C	5	30
			Access Distance	Kilometres	C	0.5	2
		Network Characteristics	Quality of Road and Transit Line	Score	B	0	3

PERFORMANCE AREA	PERFORMANCE SUB AREA		PERFORMANCE MEASURE		UNIT	C/B	MIN. SCORE	MAX. SCORE
Service Convenience	**Connectivity**	**Access Options**	Commuting Time		Minutes	C	20	52.5
							30	90
			Transfer Distance		Kilometres	C	0.5	2
	Regularity	**Mode Preference**	Modal Split		Growth Rate	B	-0.2	0.2
		Periodicity	Service Frequency		Rate in Minutes	C	5	20
Operational Seamlessness	**Incident Management**	**Time Measures**	Detection Time		Seconds	C	90	180
			Verification Time		Seconds	C	30	120
			Notification Time		Seconds	C	30	120
			Response Time		Minutes	C	9	18
			Alert Time	VMS/ EMS	Minutes	C	1	5
							1	4
				Website/ App			1	5
							1	4
				SMS			1	4
				Email			1	4
			Clearance Time	No Injuries	Minutes	C	60	90
				Light to Severe			70	150
				Fatal			120	200
		Staff Safety Measures	Adverse Health Conditions		Decay Rate	C	-0.2	0.1
			Secondary Incidents		Decay Rate	C	-0.2	0.1
Operating Efficiency	**Service Quality**	**Density and Congestion**	LOS		% of major road segments assigned with a LOS of C or better	B	30	90

PERFORMANCE AREA	PERFORMANCE SUB AREA		PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Operating Efficiency	**Service Quality**	**Density and Conges-tion**	Load Factor	Transit vehicle load to capacity	B	0.4	1.2
			Standing Density	Pedestrians per square meter	C	1	5
		Mobility	Network Travel Speeds	Kilometre per hour	B	25	55
			Queue Length	Decay Rate	C	-0.2	0.1
			Queue Time	Minutes	C	2	15
			Waiting Time	Minutes	C	5	20
	Service Utilisation	**Demand-Supply**	Degree of Saturation	Network/ transit line volume to capacity	B	0.4	1

*Additional Notes

Alert time can be measured from the viewpoint of VMS/EMS, website/application, SMS or email. Moreover, clearance time can be measured by considering crashes with no injuries, crashes with light to severe injuries or crashes with fatalities. However, for the latter mentioned circumstances, only one fatality is assumed.

Since the modal split measure in Table 77 has been identified as a special increase-decrease measure, its value function is considered here. Refer to Figure 55.

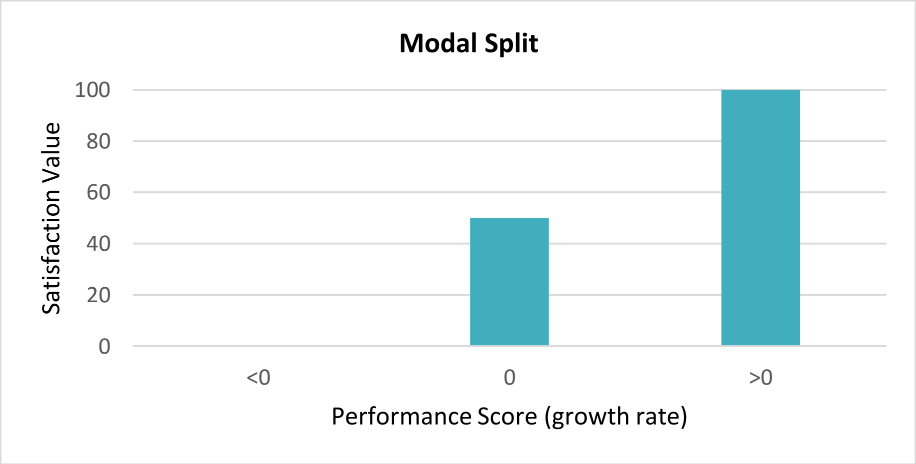


Figure 55: Modal Split Value Function

From Figure 55 it is evident that a growth rate of less than 0 correlates to a satisfaction value of 0, a growth rate of exactly 0 correlates to a satisfaction value of 50 and a growth rate of more than 0 correlates to a satisfaction value of 100.

Table 78: Value Elicitation - Technology Reliability

PERFORMANCE AREA	PERFORMANCE SUB AREA		PERFORMANCE MEASURE		UNIT	C/B	MIN. SCORE	MAX. SCORE
System Health	**System Availability**	**System Functionality**	System Uptime		% of time system is operable	B	95	99
							86	99
System Performance	**Equipment Quality**	**Value Evaluation**	MTBF	MTBF	Years	B	2	5.5
				MTBF: Fleet				
				MTBF: Fare				
	Data Quality	**Data Verification and Validation**	Error Rate	Error Rate	% of erroneous data occurrences	C	1	5
				Error Rate: Fleet			1	5
				Error Rate: Fare			1	4.5

**Additional Notes*

Both MTBF and error rate have, with regard to the public transport environment, two measures pertaining to them. That is, one based on ITS fleet management (APTS-related) equipment and one based on ITS fare management (AFC-related) equipment.

Table 79: Value Elicitation - Asset Management and Maintenance

PERFORMANCE AREA	PERFORMANCE SUB AREA		PERFORMANCE MEASURE		UNIT	C/B	MIN. SCORE	MAX. SCORE
Asset Management	**Operations Management**	**Record**	Asset Register		Score	B	0	3
		Monitor	Network Surveillance System		Score	B	0	3
		Control	Positioning System		Score	B	0	3
		Evaluate	Status Report or e-System		Binary	B	No = 0	Yes = 1
Asset Maintenance	**Preventative**	**Scheduled Logs**	Fulfilment		% of tickets fulfilled	B	75	95
	Corrective	**Defect Logs**	Tickets Logged		Decay Rate	C	-0.2	0.1
			MTTR	MTTR	Hours	C	24	96
				MTTR: Fleet				

			MTTR: Fare				

**<u>Additional Notes</u>*

MTTR has, with regard to the public transport environment, two measures pertaining to it. That is, one based on ITS fleet management (APTS-related) equipment and one based on ITS fare management (AFC-related) equipment.

Only the value functions of the measures for which data acquisition was required, are considered in more detail here. Refer to Figure 56 to Figure 107.

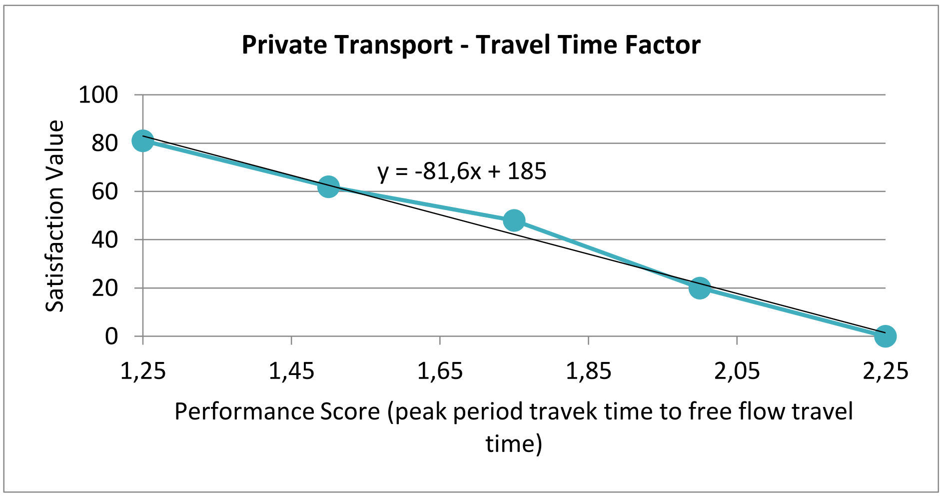


Figure 56: Private Transport - Travel Time Factor Value Function

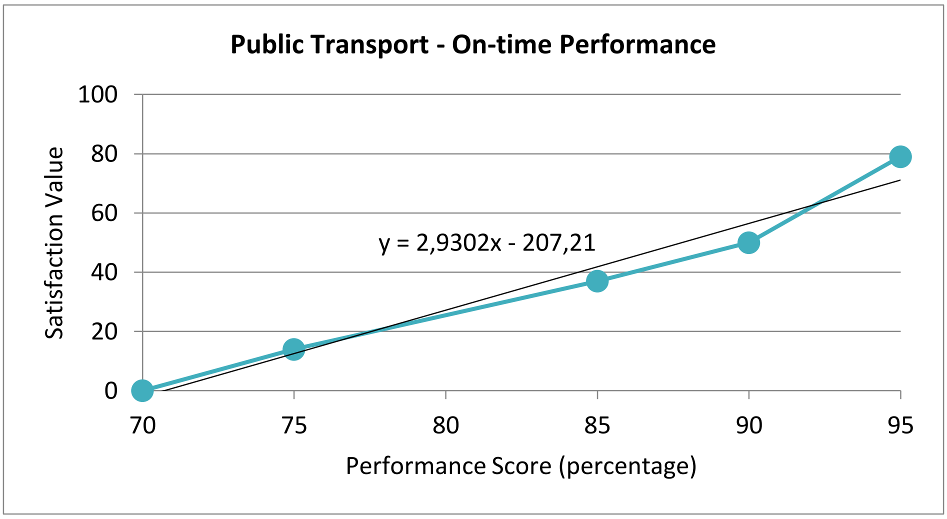


Figure 57: Public Transport - On-time Performance Value Function

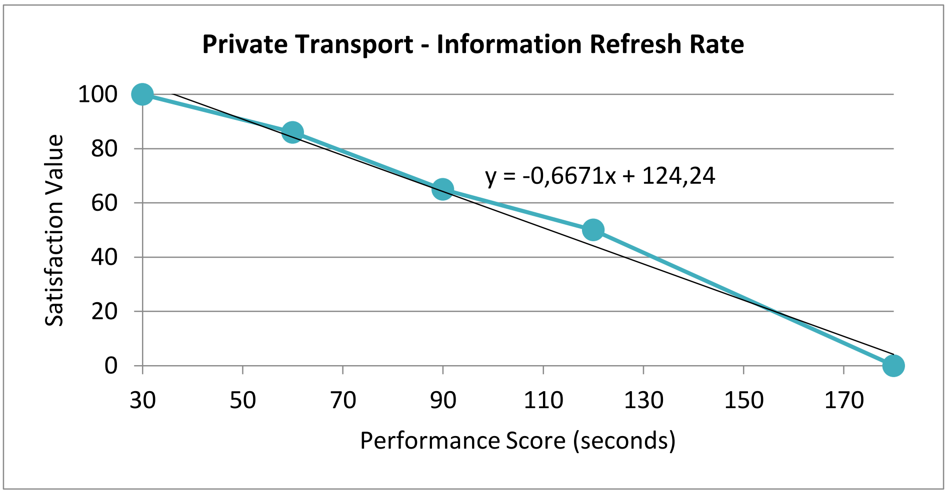


Figure 58: Private Transport - Information Refresh Rate Value Function

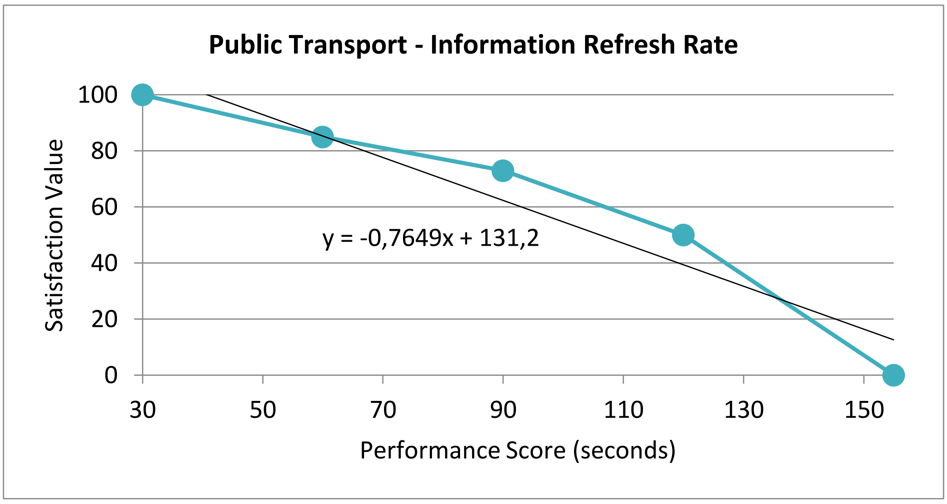


Figure 59: Public Transport - Information Refresh Rate Value Function

From Figure 58 and Figure 59 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that information refresh rate is equally important in the private- and the public transport environment.

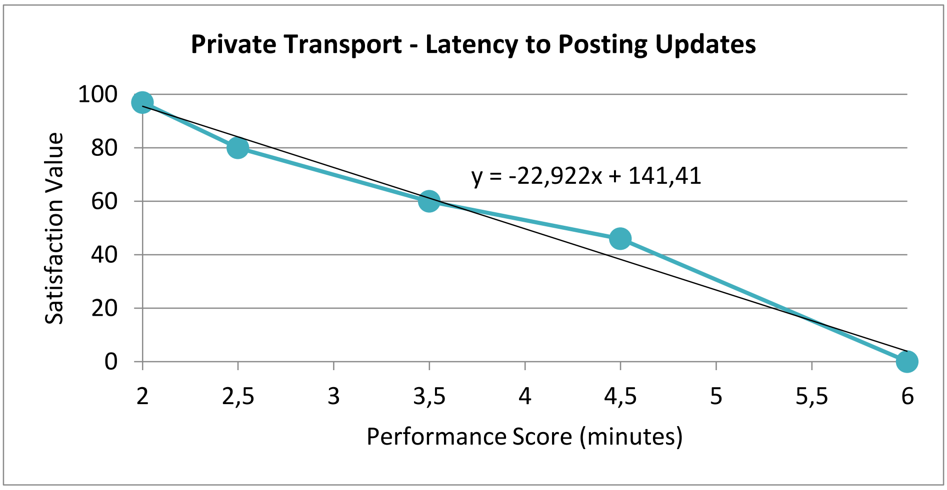


Figure 60: Private Transport - Latency to Posting Updates Value Function

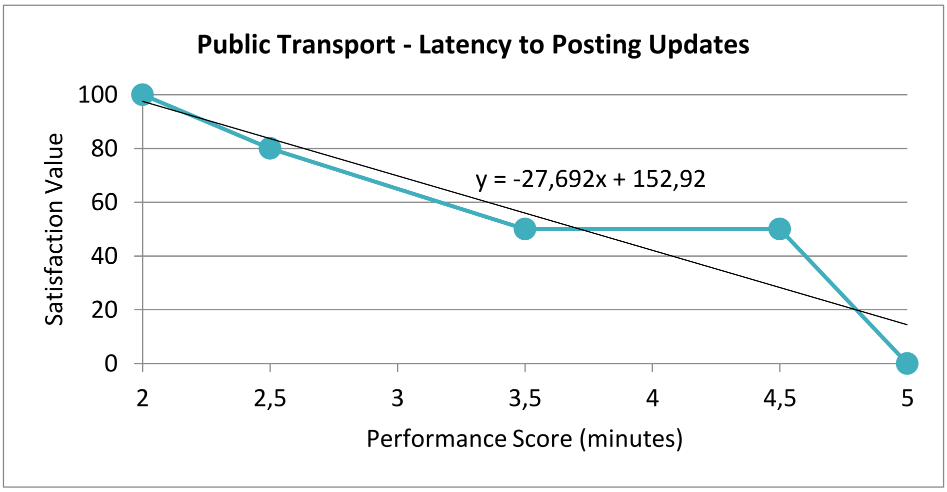


Figure 61: Public Transport - Latency to Posting Updates Value Function

From Figure 60 and Figure 61 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that latency to posting updates is equally important in the private- and the public transport environment.

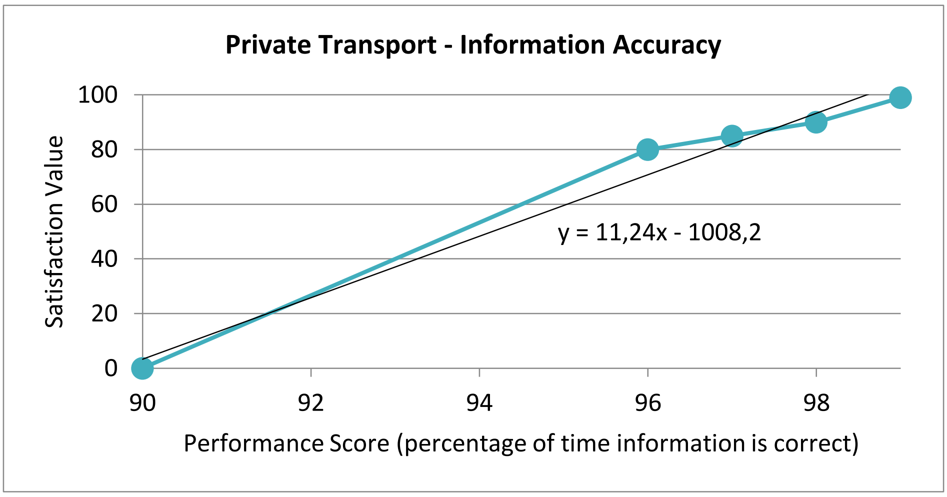


Figure 62: Private Transport - Information Accuracy Value Function

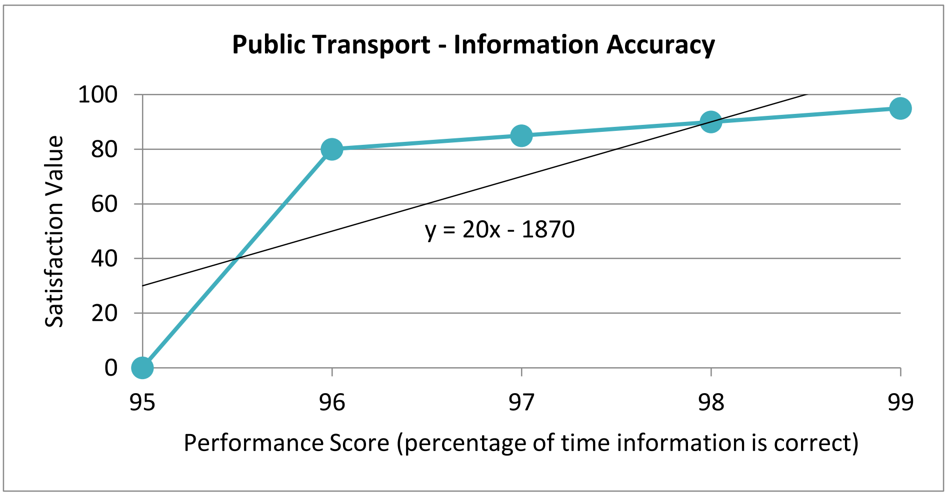


Figure 63: Public Transport - Information Accuracy Value Function

From Figure 62 and Figure 63 it is evident that the respective standardised value functions differ noticeably. At first glance, it may appear that the provision of accurate information is more important in the public- than in the private transport environment. However, by considering these figures more closely, it can be seen that the underlining nature in both of these operating environments is very similar. Both the private- and the public transport environment aim to provide their users with the correct information more than (approximately) 96% of the time. The public transport environment is merely less lenient towards providing inaccurate information. This could be due to the fact that inaccurate information (with regard to timetables and schedules) could result in the loss of patronage and hence the loss of revenue. Nevertheless, between the point of 96% and the point of 90%, the associated satisfaction in the private transport environment declines drastically.

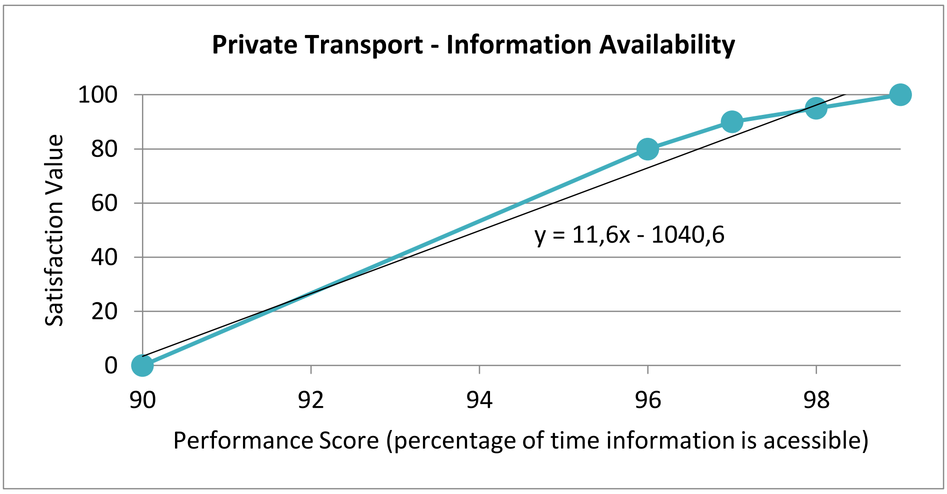


Figure 64: Private Transport - Information Availability Value Function

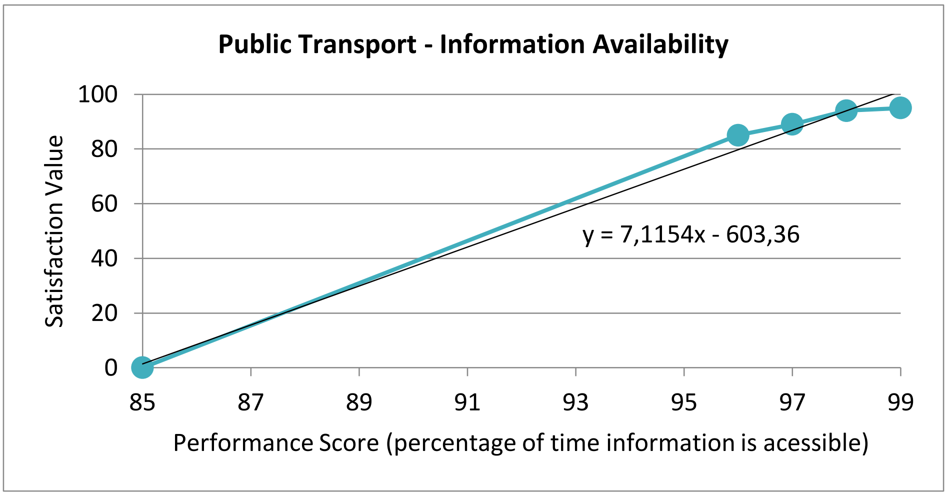


Figure 65: Public Transport - Information Availability Value Function

From Figure 64 and Figure 65 it is evident that the respective standardised value functions differ noticeably. At first glance, it may appear that the availability of information is more important in the private- than in the public transport environment. However, by considering these figures more closely, it can be seen that the underlining nature in both of these operating environments is very similar. Both the private- and the public transport environment aim to achieve information availability of (approximately) 96% or more. The private transport environment is merely less lenient towards not having the relevant information accessible to their users. This could be due to the fact that the private transport systems are, currently, better fit to manage information availability. Nevertheless, between the point of 96% and the point of 85%, the associated satisfaction in the public transport environment declines drastically.

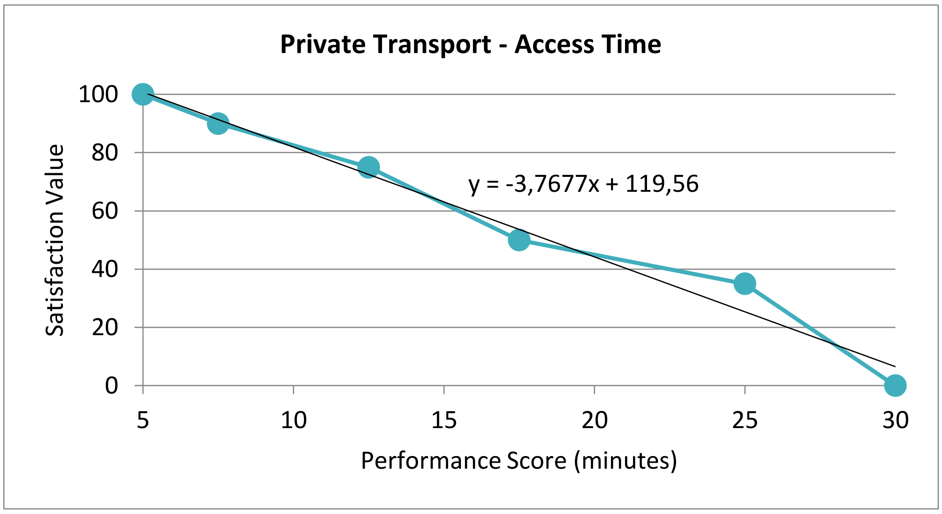


Figure 66: Private Transport - Access Time Value Function

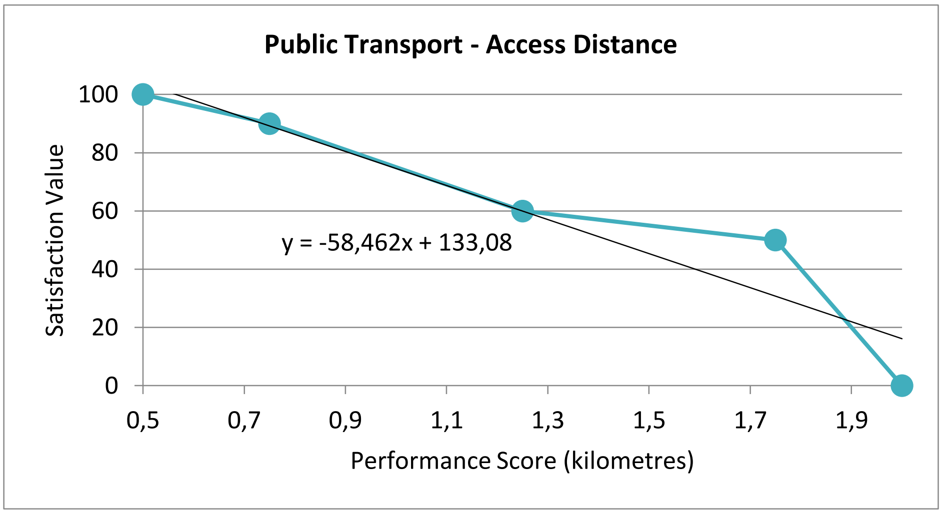


Figure 67: Public Transport - Access Distance Value Function

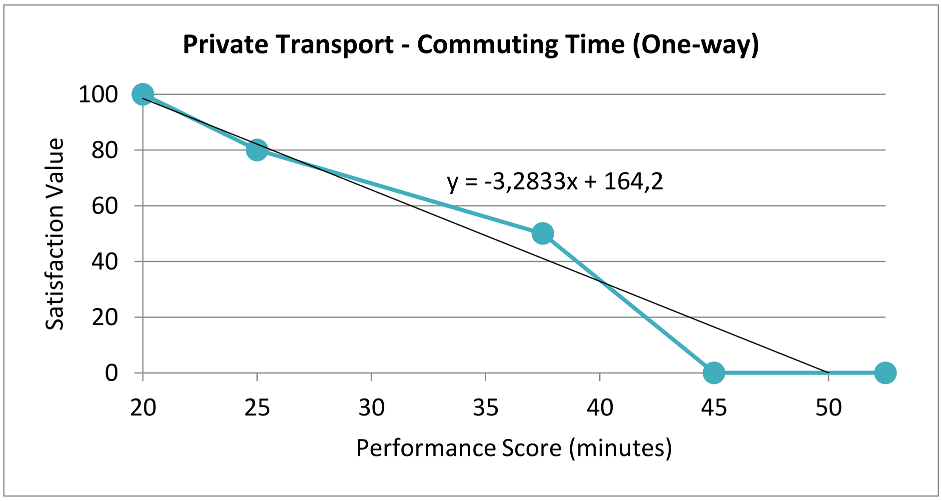


Figure 68: Private Transport - Commuting Time Value Function

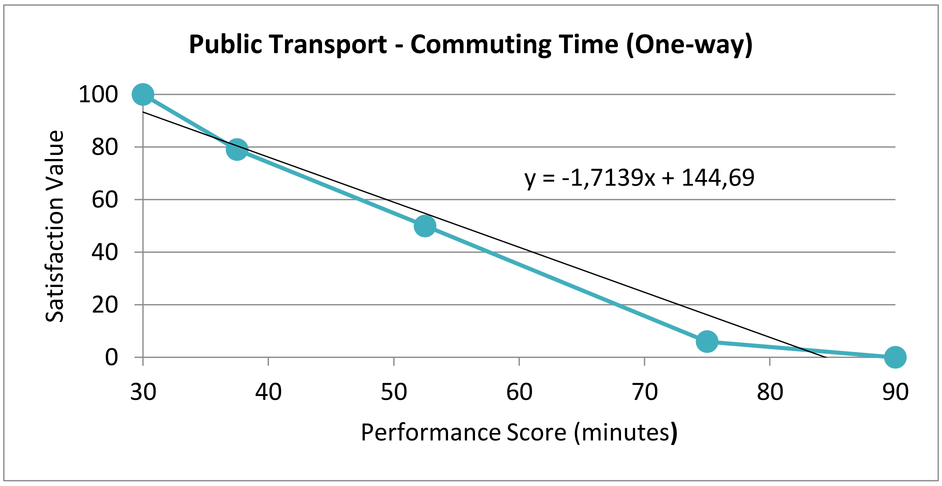


Figure 69: Public Transport - Commuting Time Value Function

From Figure 68 and Figure 69 it is evident that the respective standardised value functions differ significantly. From these figures it can be deducted that, in the public transport environment, users are more lenient towards longer commuting times. The expectation of, and tolerance towards, longer commuting times could be due to numerous reasons. For example: many (captive) public transport users are located at the outskirts of the commercial- and industrial nodes. These users thus not only have to commute long distances, but also have limited availability and options of transit services. As a result, they have long commuting times and they most probably have to walk long distances to reach the stop/station or they have to wait long periods for the transit vehicles to arrive.

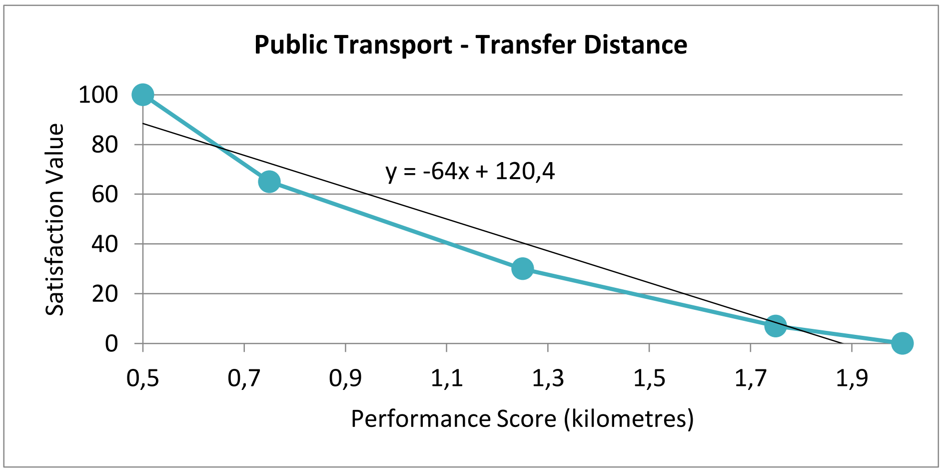


Figure 70: Public Transport - Transfer Distance Value Function

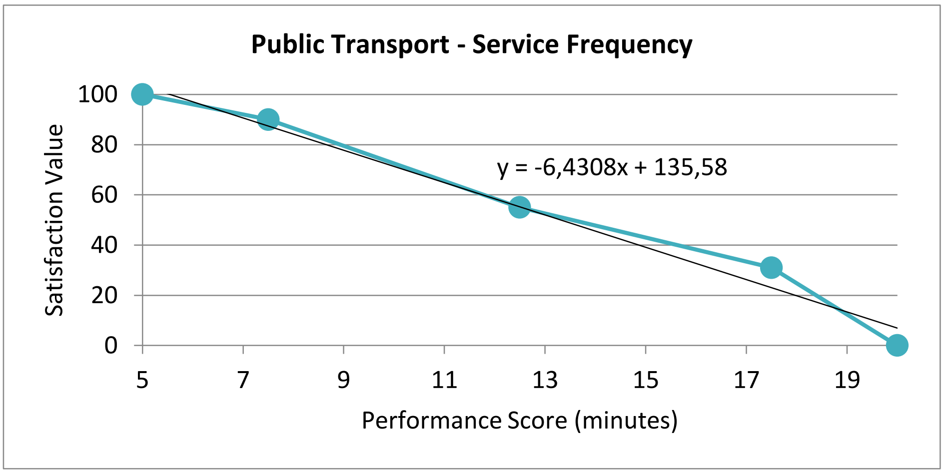


Figure 71: Public Transport - Service Frequency Value Function

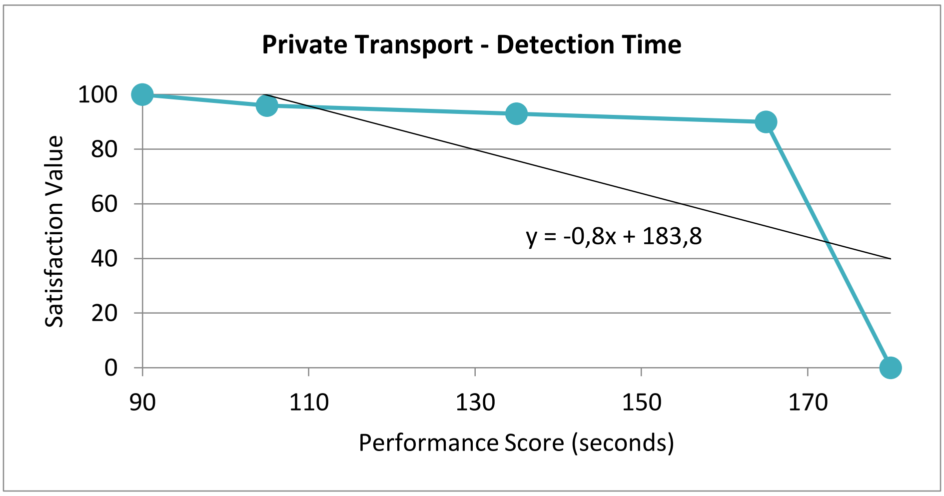


Figure 72: Private Transport - Detection Time Value Function

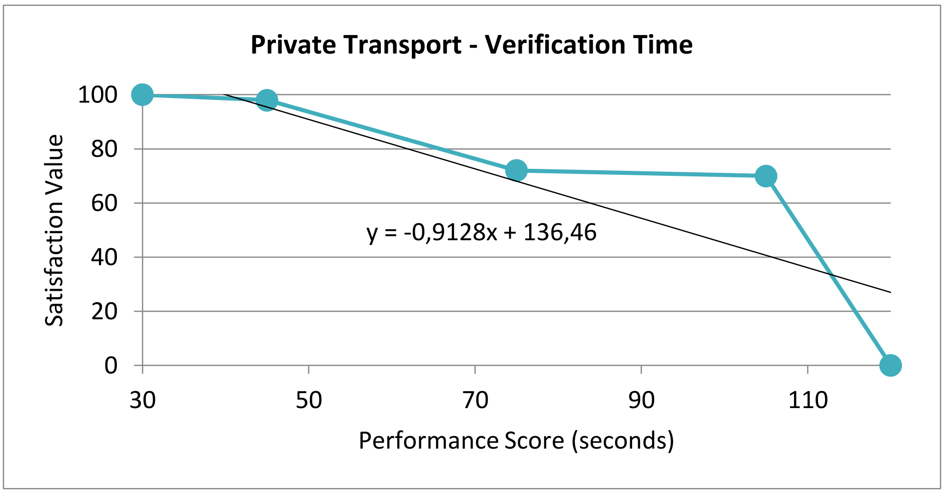


Figure 73: Private Transport - Verification Time Value Function

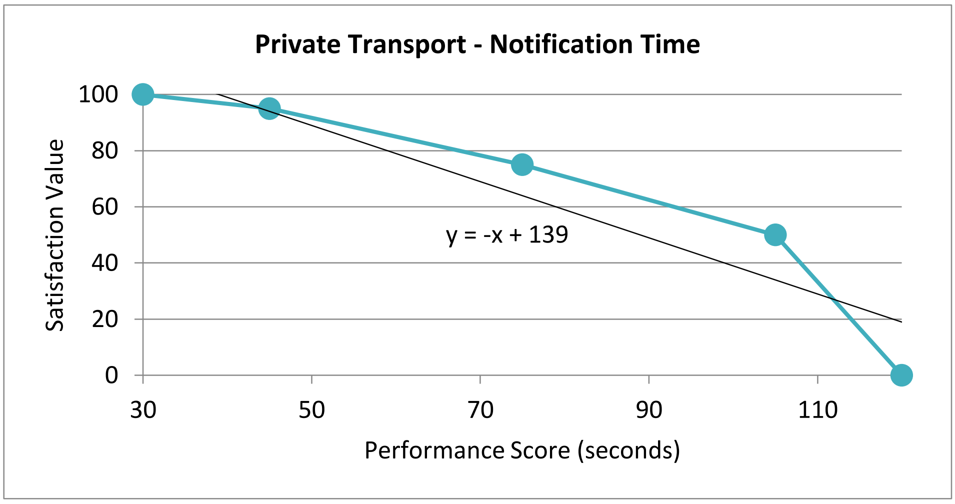


Figure 74: Private Transport - Notification Time Value Function

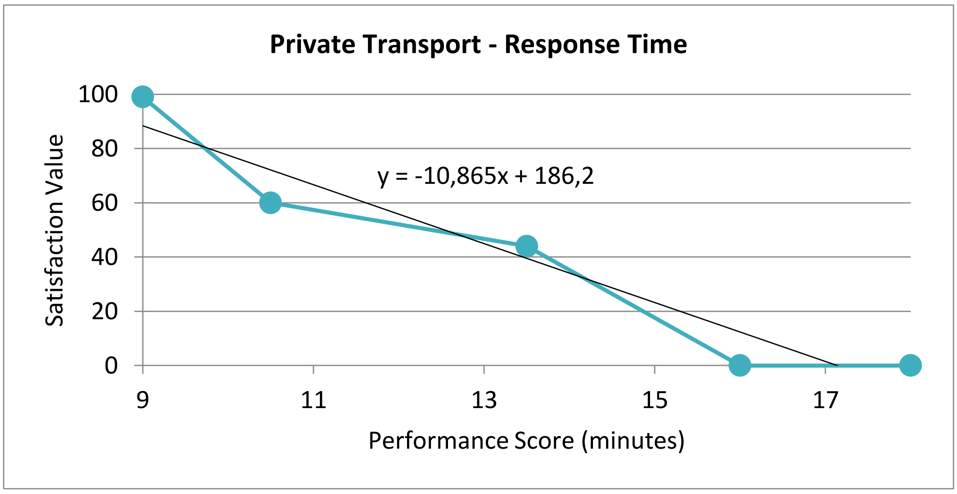


Figure 75: Private Transport - Response Time Value Function

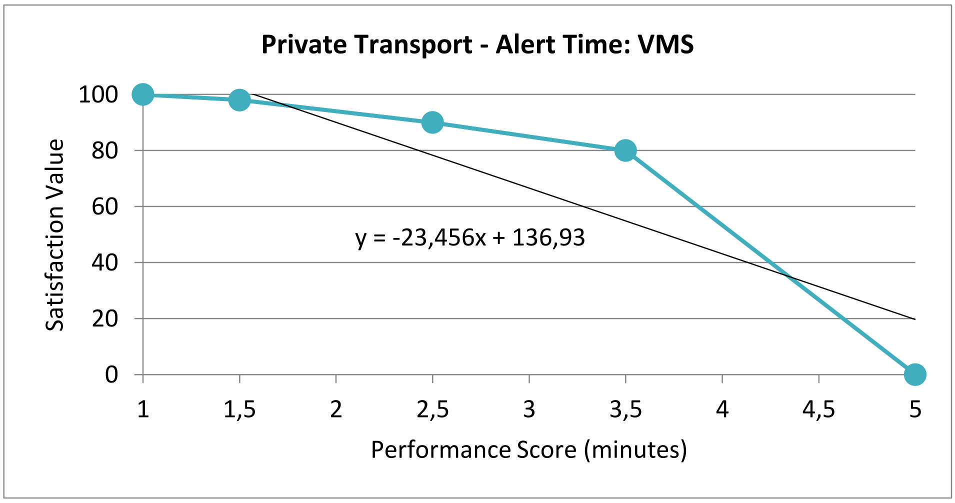


Figure 76: Private Transport - Alert Time (VMS) Value Function

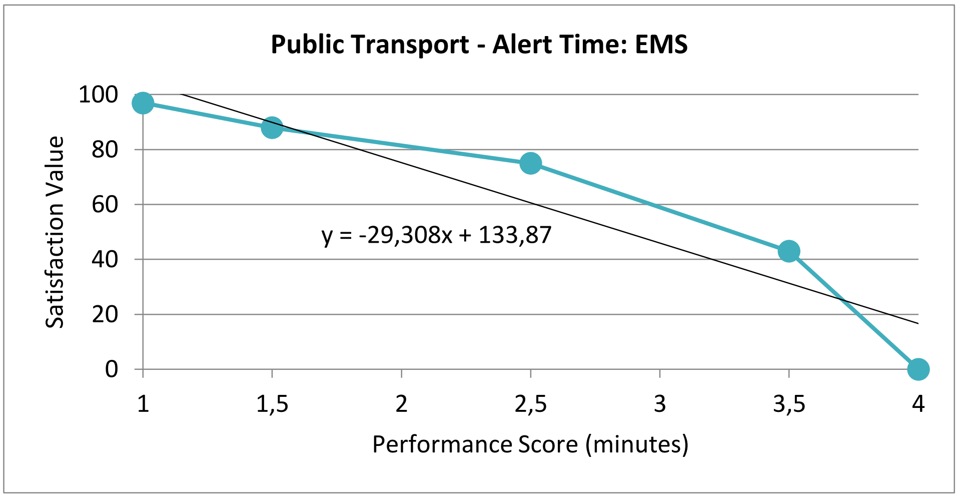


Figure 77: Public Transport - Alert Time (EMS) Value Function

From Figure 76 and Figure 77 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that alert time is equally important for VMS and EMS.

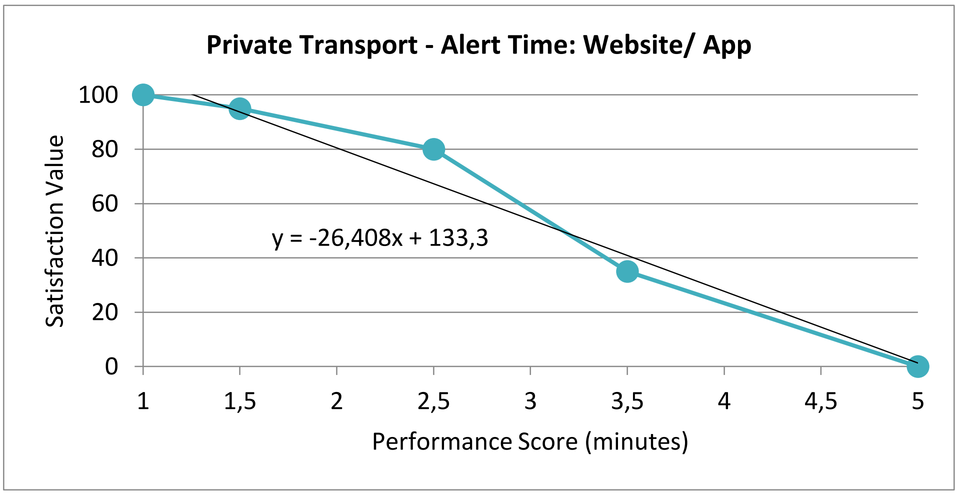


Figure 78: Private Transport - Alert Time (Website/App) Value Function

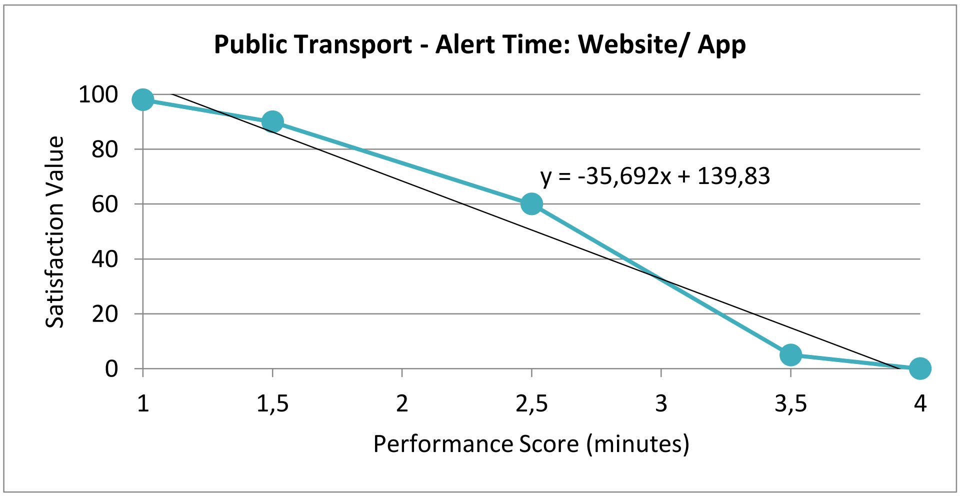


Figure 79: Public Transport - Alert Time (Website/App) Value Function

From Figure 78 and Figure 79 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that alert time (via website or application) is equally important in the private- and the public transport environment.

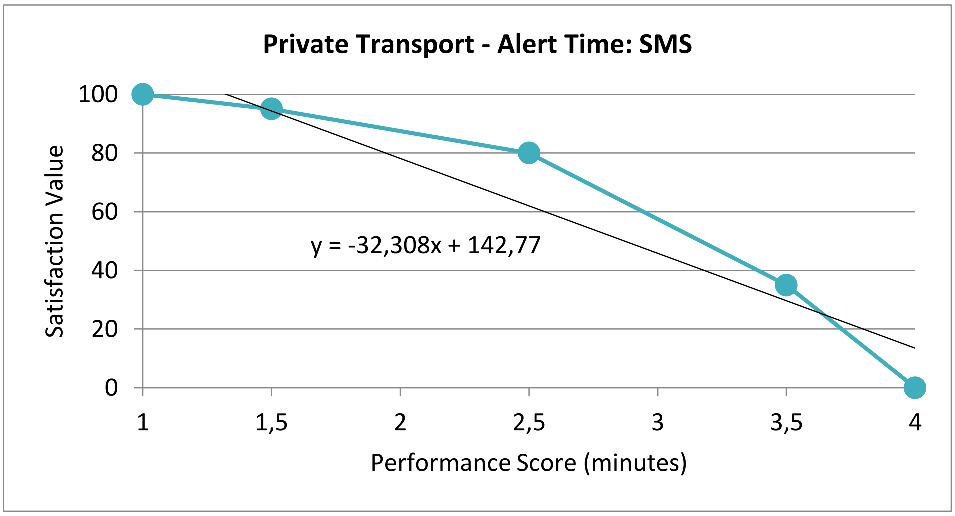


Figure 80: Private Transport - Alert Time (SMS) Value Function

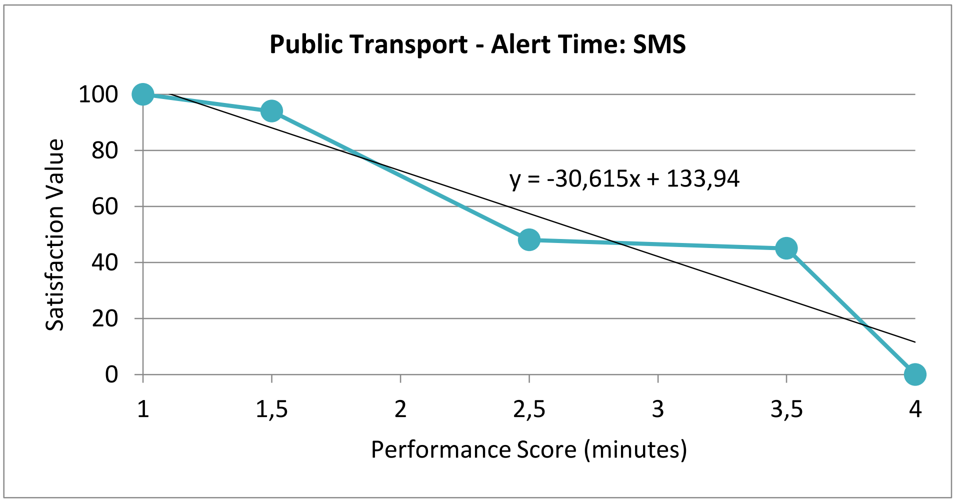


Figure 81: Public Transport - Alert Time (SMS) Value Function

From Figure 80 and Figure 81 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that alert time (via SMS) is equally important in the private- and the public transport environment.

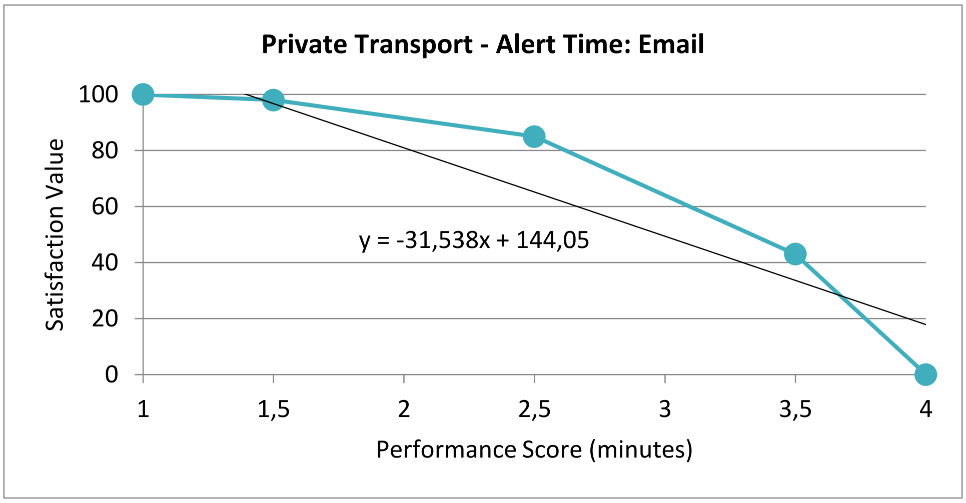


Figure 82: Private Transport - Alert Time (Email) Value Function

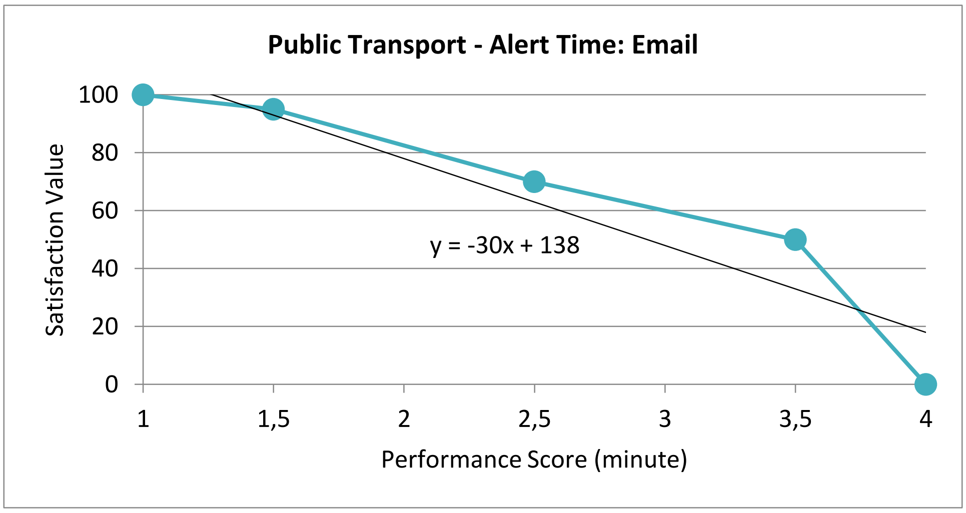


Figure 83: Public Transport - Alert Time (Email) Value Function

From Figure 82 and Figure 83 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that alert time (via email) is equally important in the private- and the public transport environment.

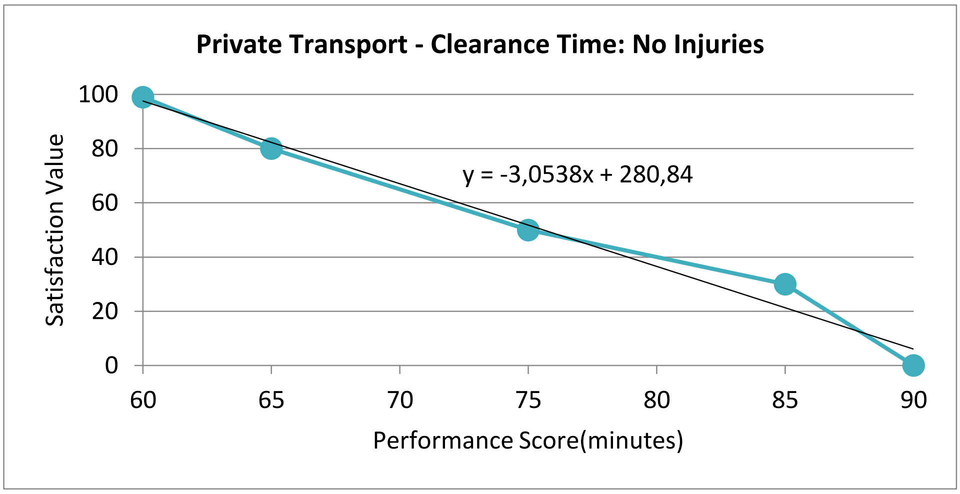


Figure 84: Private Transport - Clearance Time (No Injuries) Value Function

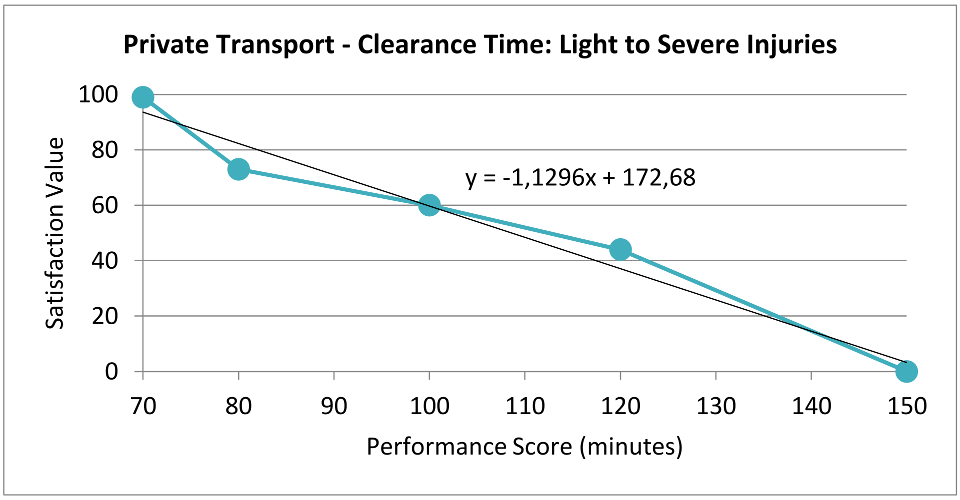


Figure 85: Private Transport - Clearance Time (Light to Severe) Value Function

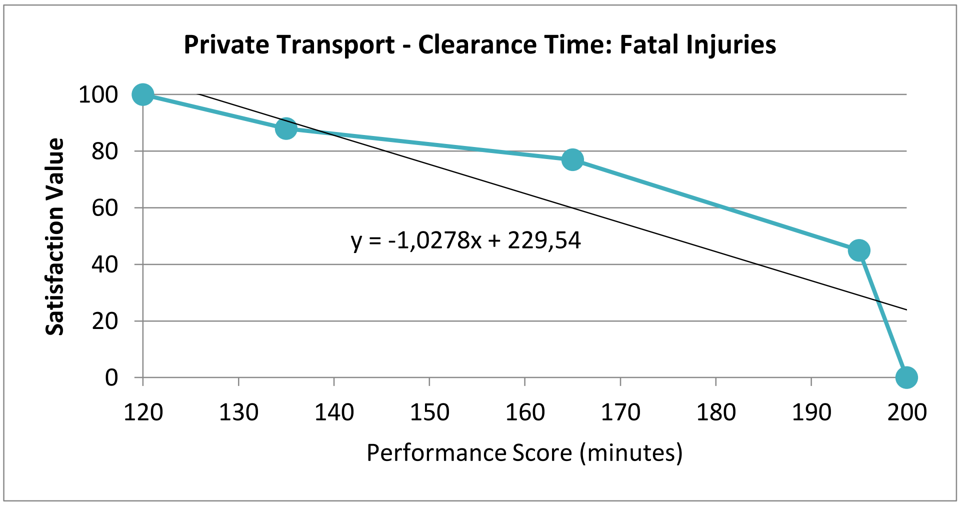


Figure 86: Private Transport - Clearance Time (Fatal) Value Function

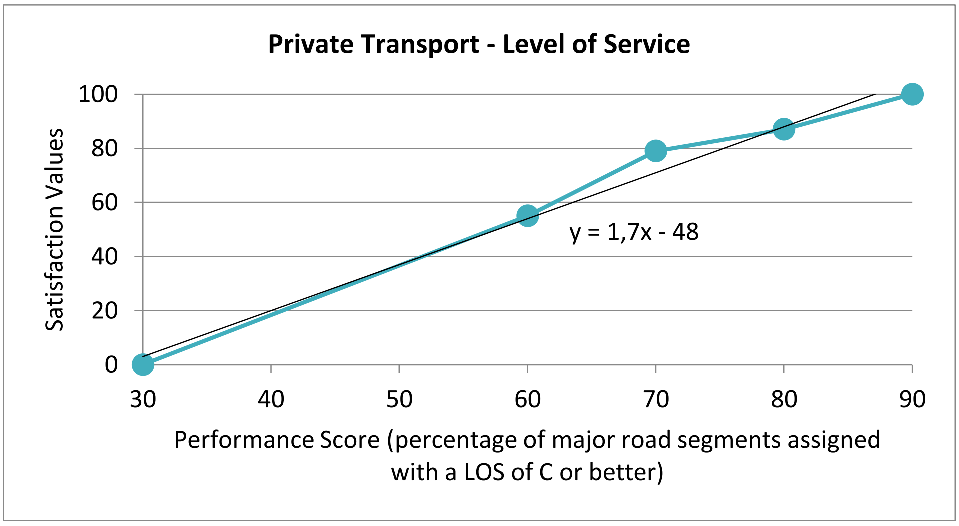


Figure 87: Private Transport - Level of Service Value Function

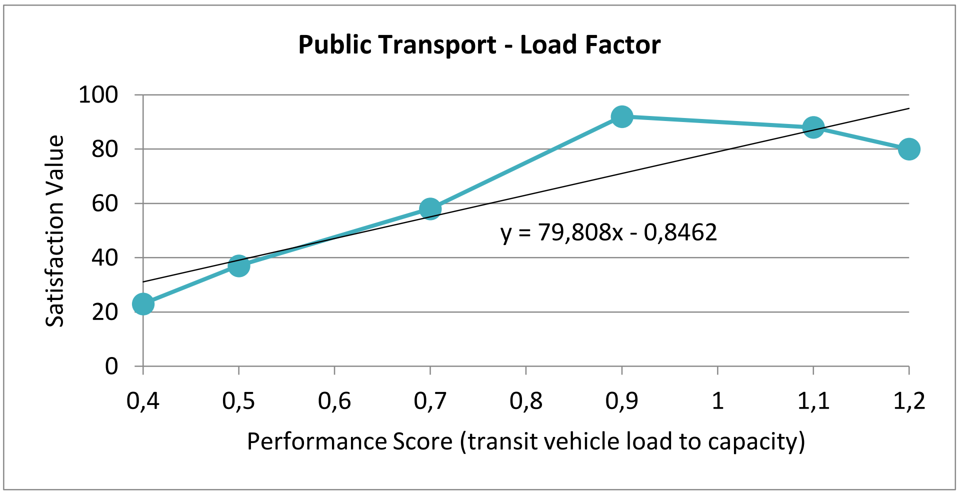


Figure 88: Public Transport - Load Factor Value Function

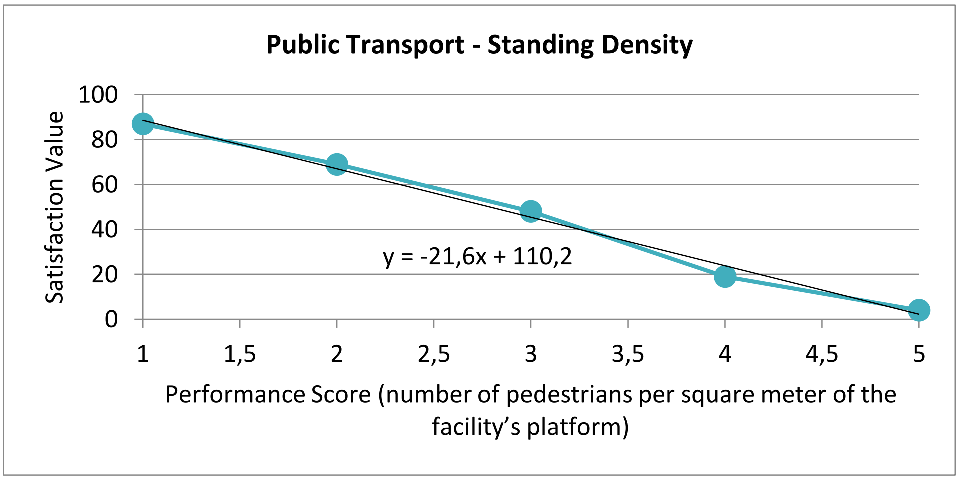


Figure 89: Public Transport - Standing Density Value Function

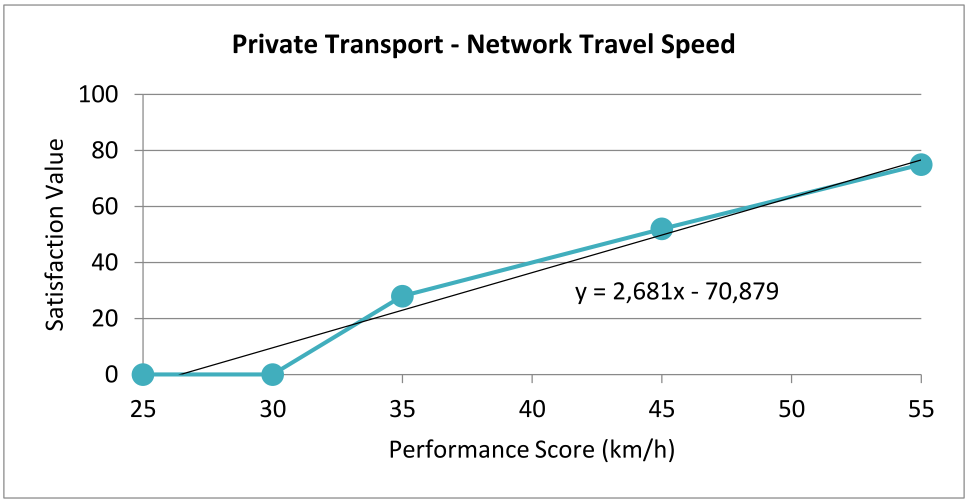


Figure 90: Private Transport - Network Travel Speed Value Function

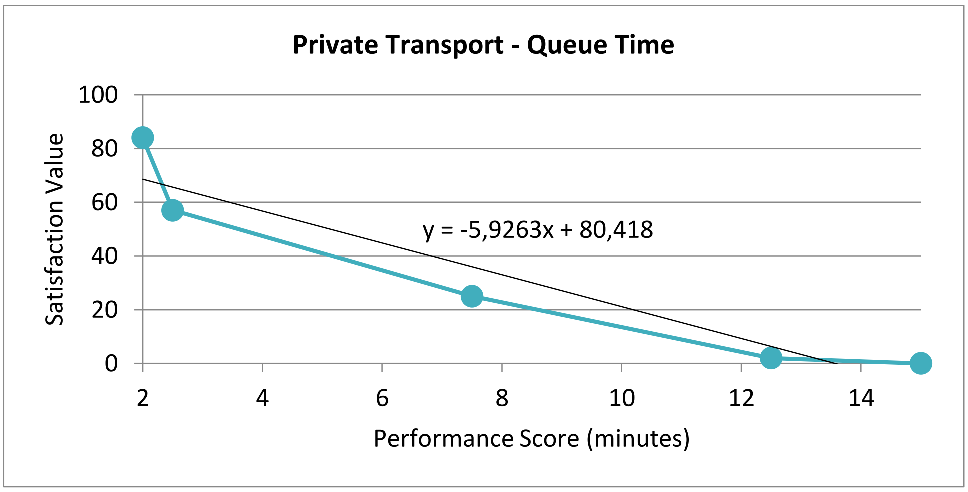


Figure 91: Private Transport - Queue Time Value Function

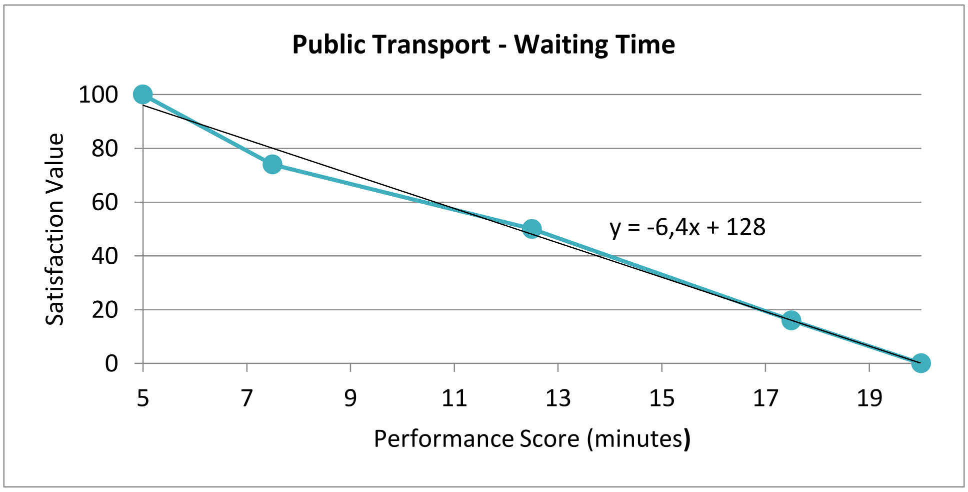


Figure 92: Public Transport - Waiting Time Value Function

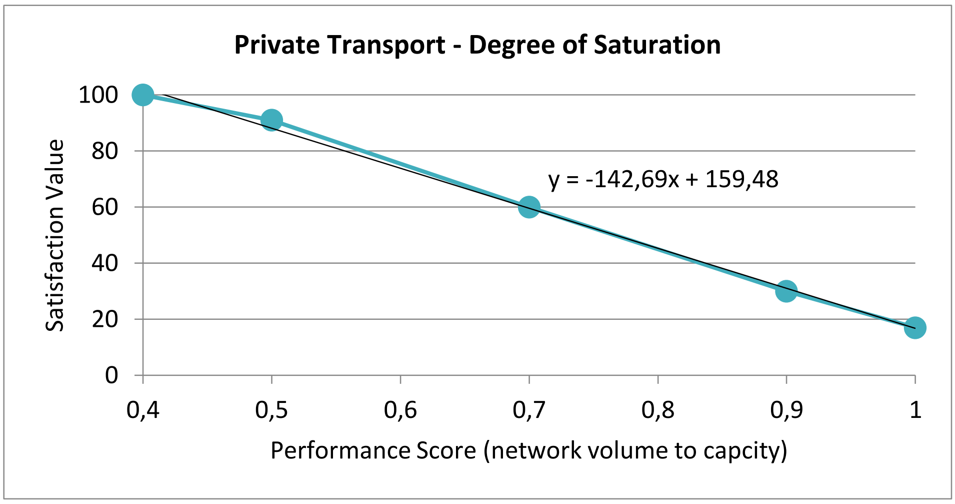


Figure 93: Private Transport - Degree of Saturation Value Function

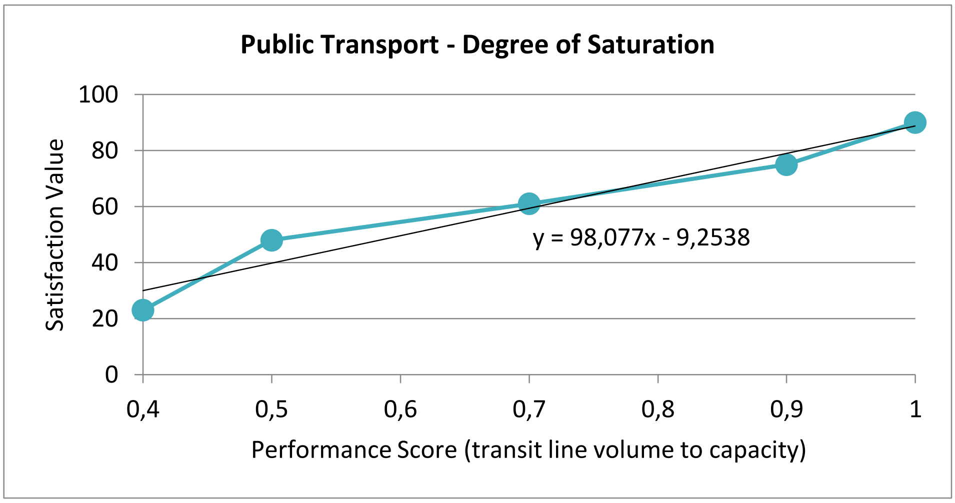


Figure 94: Public Transport - Degree of Saturation Value Function

From Figure 93 and Figure 94 it is evident that the respective standardised value functions differ significantly. In the private transport environment it is aimed to provide seamless traffic operations. This entails carefully managing the network volume such that satisfactory operating flow conditions can be maintained. A network operating close to capacity can result in the onset of break-down conditions. Similar reasoning is apparent to the public transport environment. However, the higher the patronage, the more revenue is generated. Therefore, a high transit line volume is desirable. If the transit line then becomes saturated, its capacity can easily be increased by merely expanding the transit service (e.g. adding an additional transit line or -vehicle).

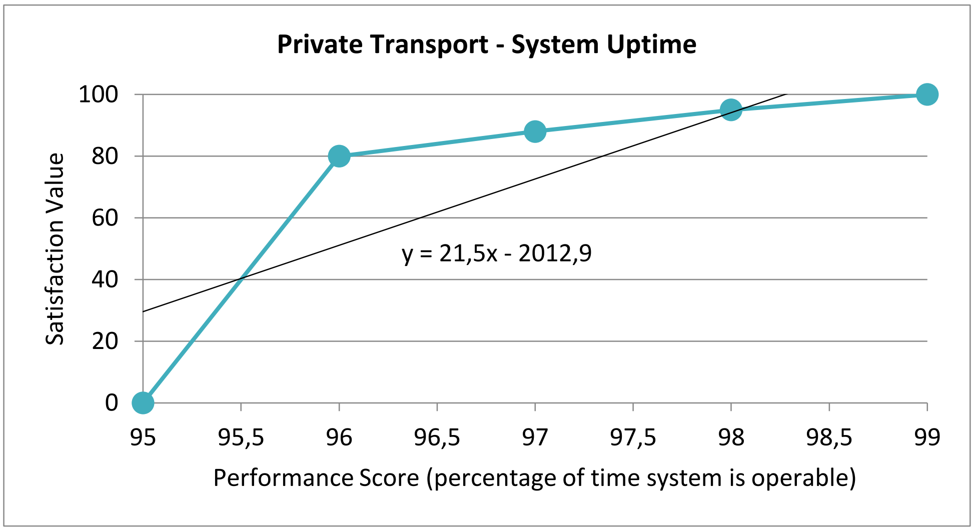


Figure 95: Private Transport - System Uptime Value Function

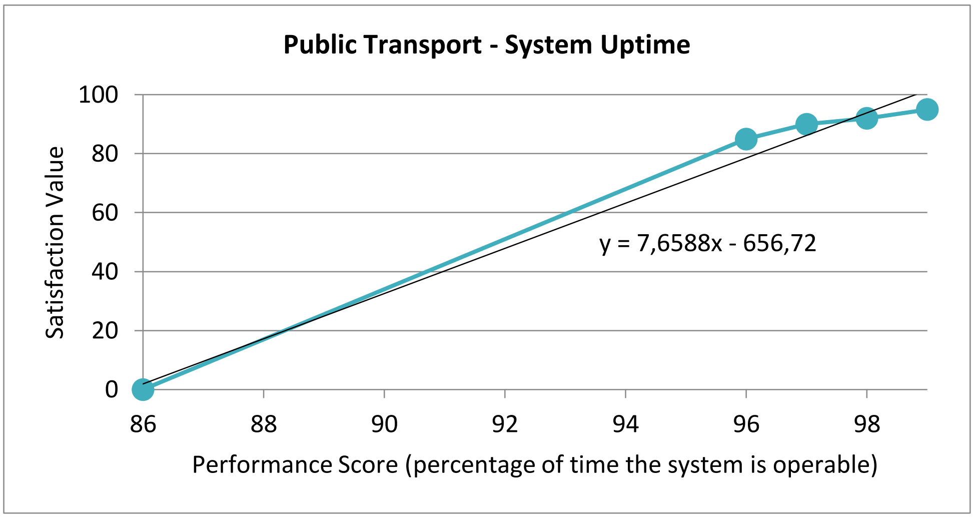


Figure 96: Public Transport - System Uptime Value Function

From Figure 95 and Figure 96 it is evident that the respective standardised value functions differ noticeably. At first glance, it may appear that the management of system uptime is more important in the private- than in the public transport environment. However, by considering these figures more closely, it can be seen that the underlining nature in both of these operating environments is very similar. Both the private- and the public transport environment aim to have their respective systems operable and in working condition more than (approximately) 96% of the time. The public transport environment is merely more lenient towards having an inoperable system. Nevertheless, between the point of 96% and the point of 86%, the associated satisfaction in the public transport environment declines drastically.

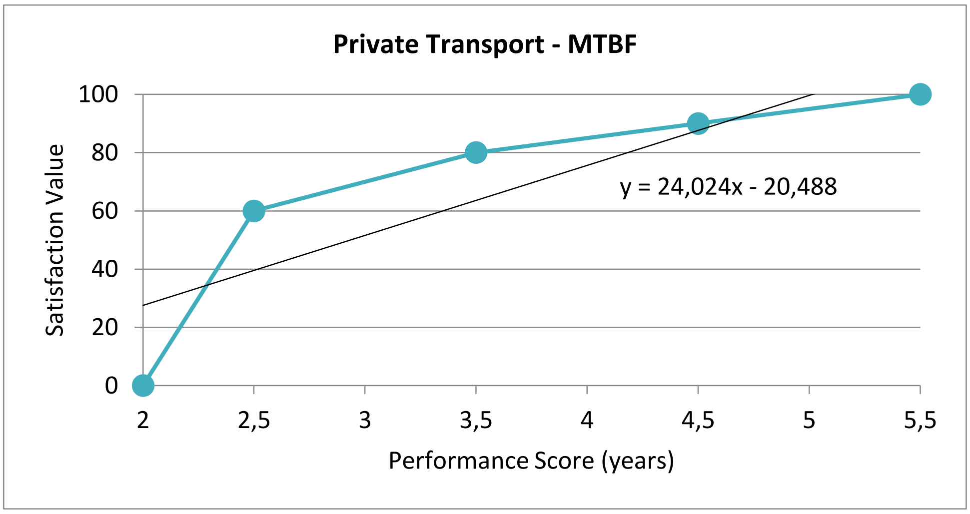


Figure 97: Private Transport - MTBF Value Function

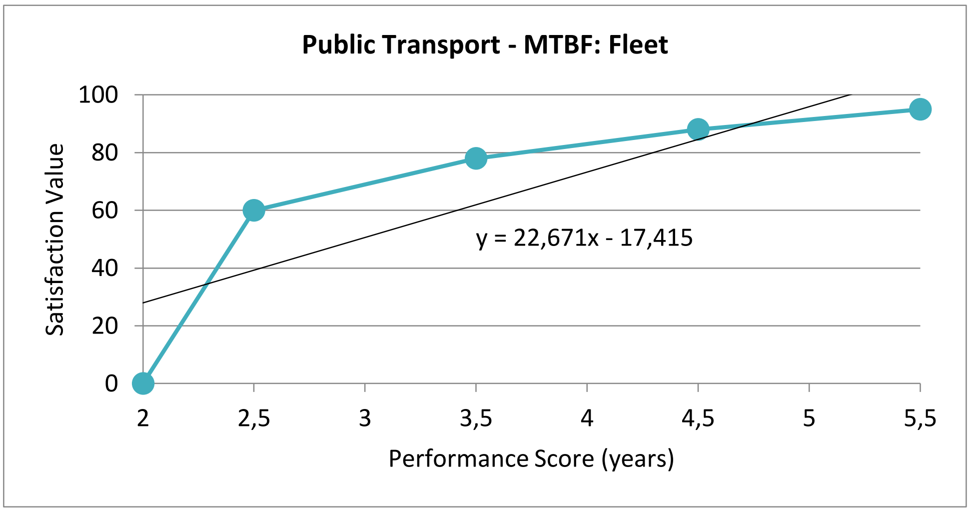


Figure 98: Public Transport - MTBF (Fleet) Value Function

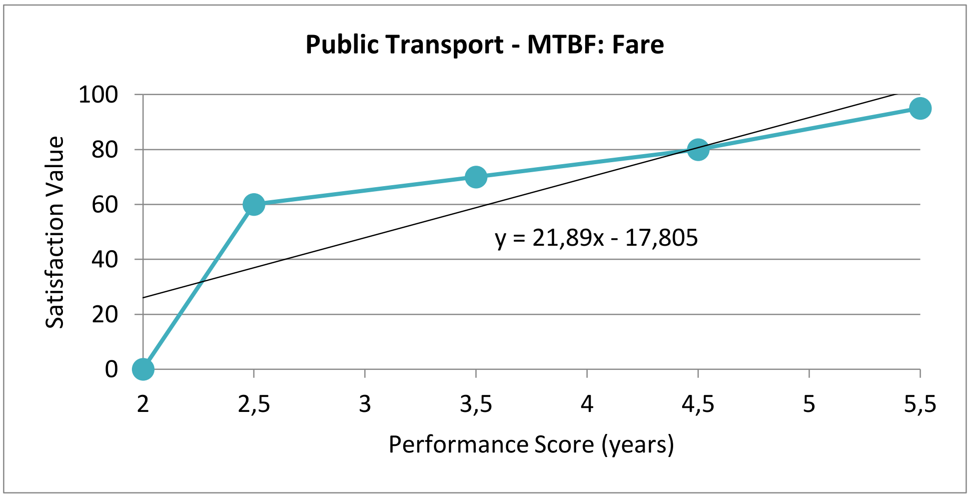


Figure 99: Public Transport - MTBF (Fare) Value Function

From Figure 98 and Figure 99 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that MTBF is equally important for fleet- and fare management equipment.

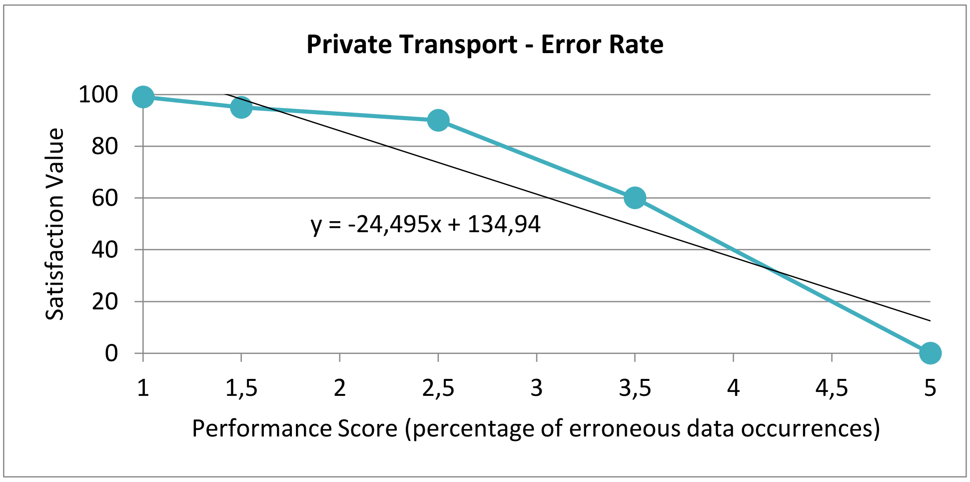


Figure 100: Private Transport - Error Rate Value Function

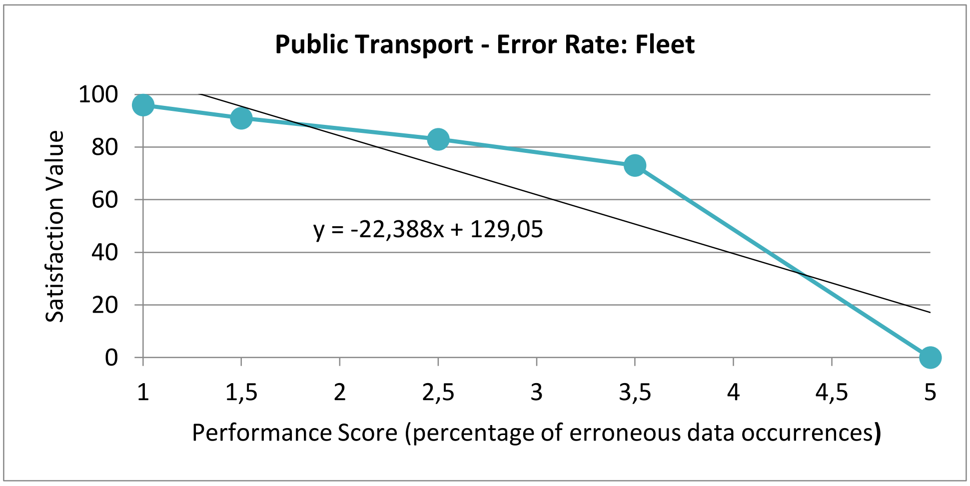


Figure 101: Public Transport - Error Rate (Fleet) Value Function

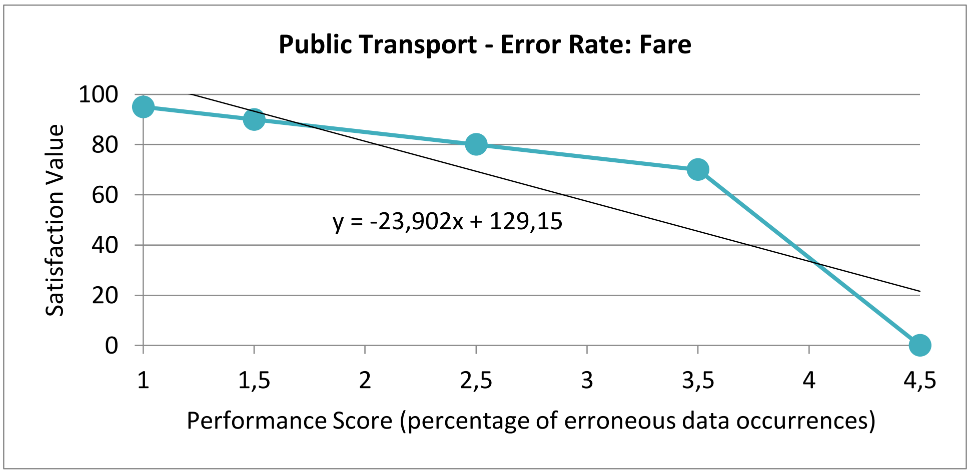


Figure 102: Public Transport - Error Rate (Fare) Value Function

From Figure 101 and Figure 102 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that error rate is equally important for fleet- and fare management equipment.

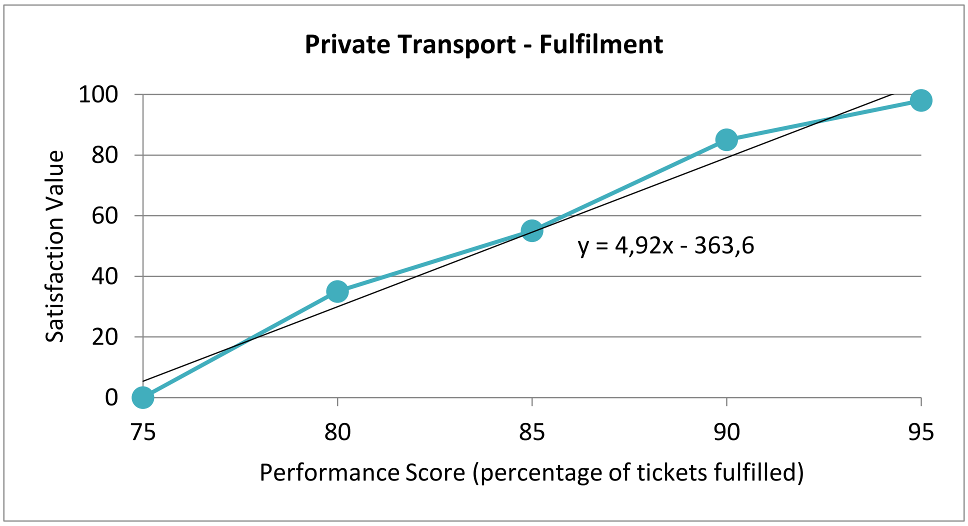


Figure 103: Private Transport - Fulfilment Value Function

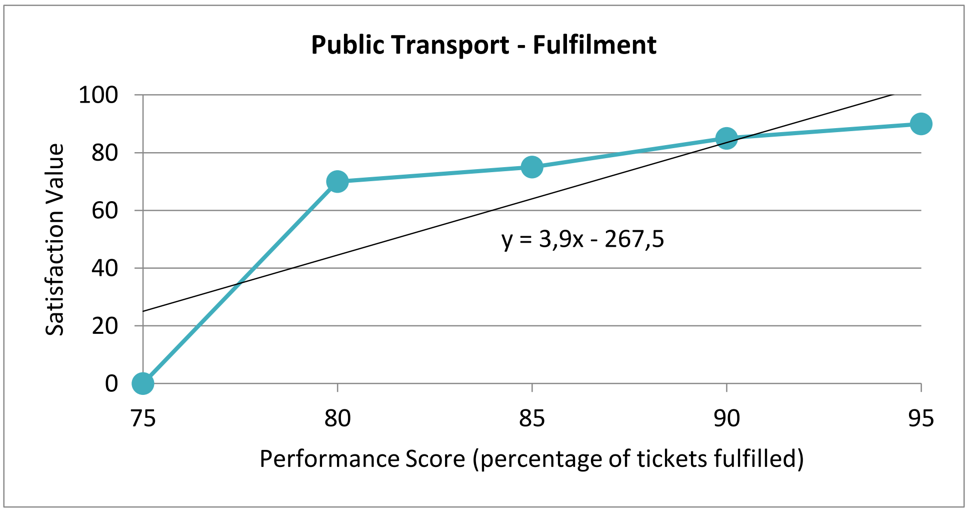


Figure 104: Public Transport - Fulfilment Value Function

From Figure 103 and Figure 104 it is evident that the respective standardised value functions differ noticeably. From these figures it can be deducted that fulfilment is more important in the private- than in the public transport environment. No apparent reason for this occurrence exists. However, from the point where 90% of tickets are fulfilled, the satisfaction values between the two value functions correspond with one another.

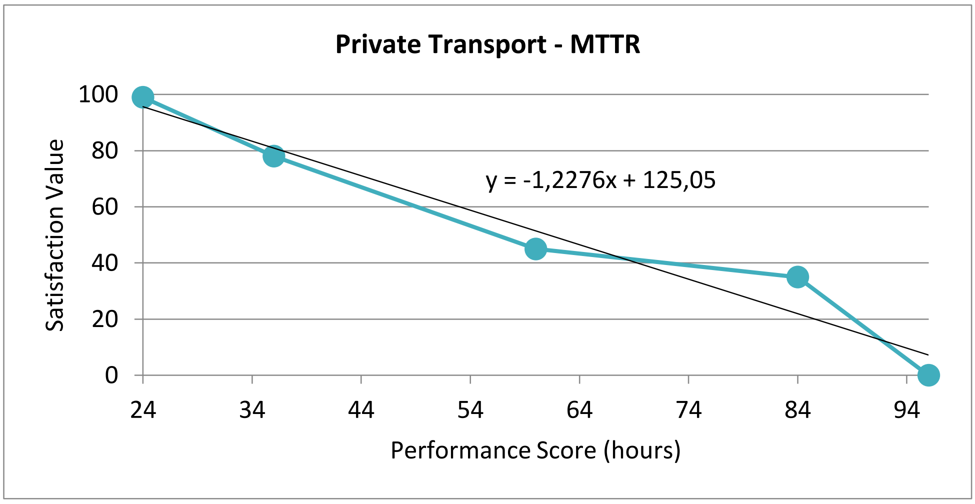


Figure 105: Private Transport - MTTR Value Function

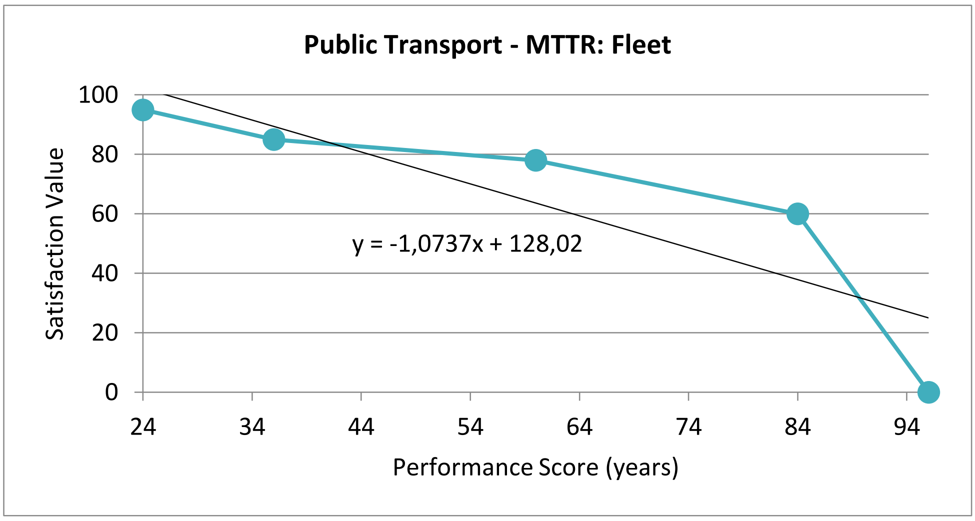


Figure 106: Public Transport - MTTR (Fleet) Value Function

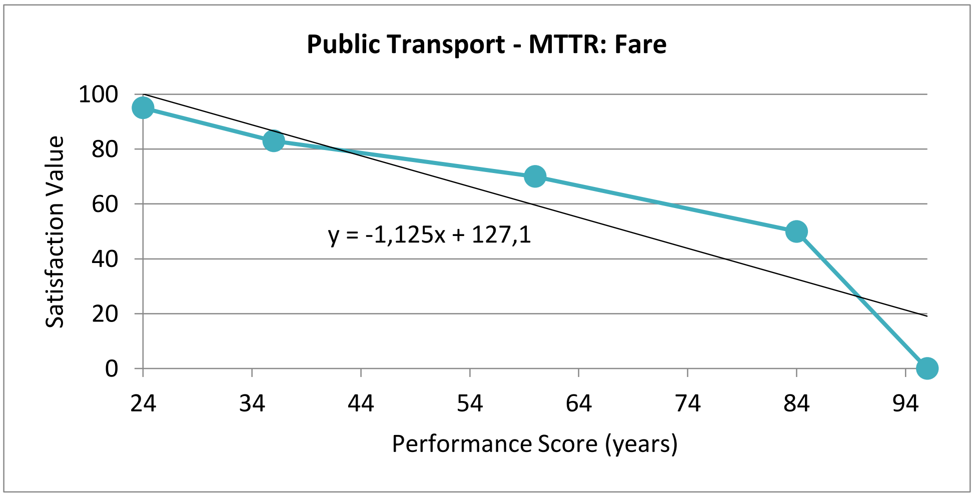


Figure 107: : Public Transport - MTTR (Fare) Value Function

From Figure 106 and Figure 107 it is evident that the respective standardised value functions differ only slightly. From these figures it can be deducted that MTTR is equally important for fleet- and fare management equipment.

PROFIT

Refer to Table 80 and Table 81. If the measure's format is red, it is only applicable to the private transport environment. If the measure's format is blue, it is only applicable to the public transport environment.

Table 80: Value Elicitation - Economic Performance

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Economic Sustainability	**System Adaptability**	Scalability	Score	B	0	3
		Responsiveness	Score	B	0	3
		Responsiveness	Score	B	0	4
	System Preservation	Traveller Experience	Growth Rate	B	-0.1	0.2
		Average Remaining Useful Life of Fleet	Growth Rate	B	-0.2	0.2
Economic Vitality	**Economic Development**	Jobs Created	Growth Rate	B	-0.1	0.2
	Economic Growth	Capacity Building and Infrastructure Development	Score	B	0	3
Socio-Economic Prosperity	**(Social) Benefits**	Energy and Environment	Growth Rate	B	-0.1	0.2
		Safety	Growth Rate	B	-0.1	0.2
		Efficiency	Growth Rate	B	-0.1	0.2
		Customer Satisfaction	Growth Rate	B	-0.1	0.2
		Mobility	Growth Rate	B	-0.1	0.2
		Productivity	Growth Rate	B	-0.1	0.2

The measure: average remaining useful life of fleet in Table 80 has also been identified as a special increase-decrease measure. Its value function can be seen in Figure 108.

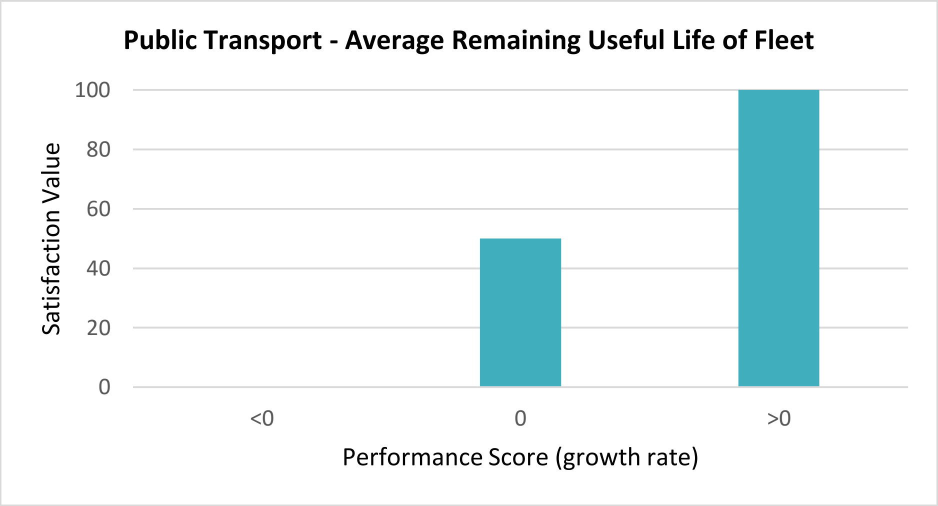


Figure 108: Public Transport - Average Remaining Useful Life of Fleet Value Function

From Figure 108 it is evident that a growth rate of less than 0 correlates to a satisfaction value of 0, a growth rate of exactly 0 correlates to a satisfaction value of 50 and a growth rate of more than 0 correlates to a satisfaction value of 100.

Table 81: Value Elicitation - Financial Performance

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Financial Feasibility	**Non-recurring Costs**	Long-term Assets	Decay Rate	C	-0.2	0.1
	Recurring Costs	Selling Expenses	Decay Rate	C	-0.2	0.1
		General and Administrative Expenses	Decay Rate	C	-0.2	0.1
	Miscellaneous Costs	Fines, Law Suits and Environmental Damage Costs	Decay Rate	C	-0.2	0.1
	Social Costs	Congestion, Accidents and Pollution	Decay Rate	C	-0.2	0.1
Investment Management	**Investment Performance**	ROI	Growth Rate	B	-0.1	0.2

Due to the similarity in the assessment procedure followed for the measures presented in Table 80 and Table 81, only the value functions of three measures are considered in more detail here. That is, one measure representing the scorecard measures and two measures representing the index measures. The latter mentioned encompasses both a growth rate and a decay rate example. Refer to Figure 109 to Figure 111.

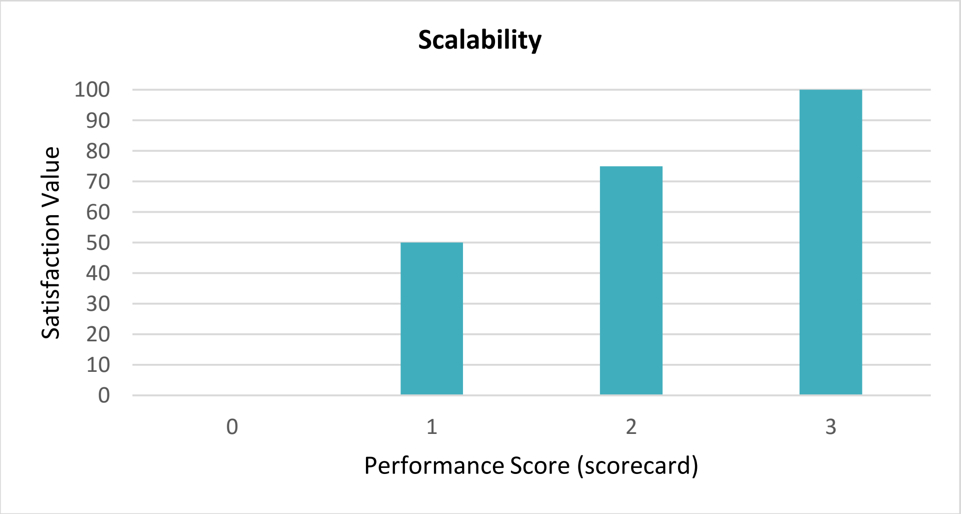


Figure 109: Scalability Value Function

From Figure 109 it is evident that a score of 0 correlates to a satisfaction value of 0, a score of 1 correlates to a satisfaction value of 50, a score of 2 correlates to a satisfaction value of 75 and a score of 3 correlates to a satisfaction value of 100.

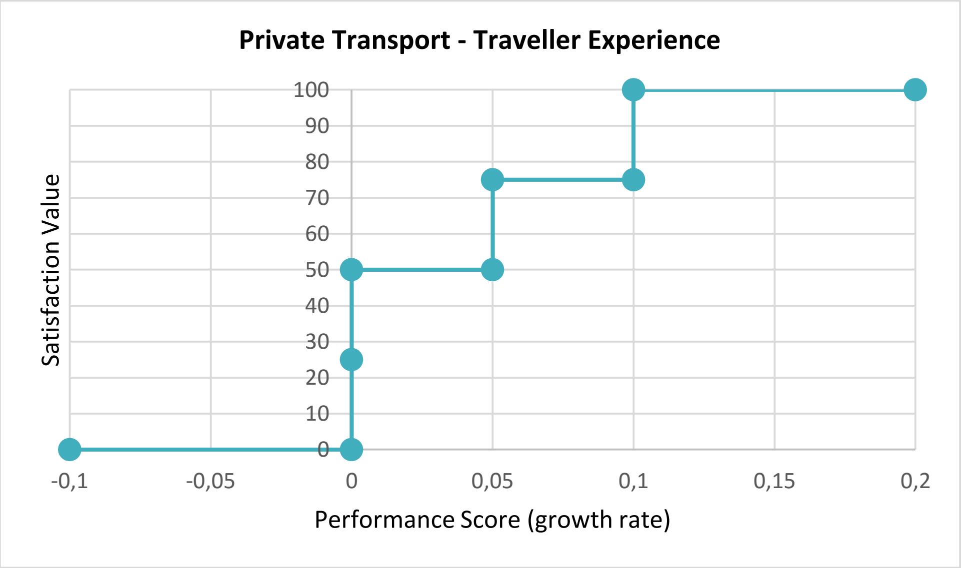


Figure 110: Private Transport - Traveller Experience Value Function

From Figure 110 it is evident that a growth rate between -0.1 and 0 correlate to a satisfaction value of 0, a growth rate of exactly 0 correlates to a satisfaction value of 25, a growth rate between 0 and 0.05 correlate to a satisfaction value of 50, a growth rate between 0.05 and 0.1 correlate to a satisfaction value of 75 and a growth rate between 0.1 and 0.2 correlate to a satisfaction value of 100. The aforementioned aligns with what was stipulated in Section 6.3.5. However, this figure also includes the most extreme end points deemed permissible and/or feasible by this author. That is, the worst growth rate of -0.1 and the best growth rate of 0.2.

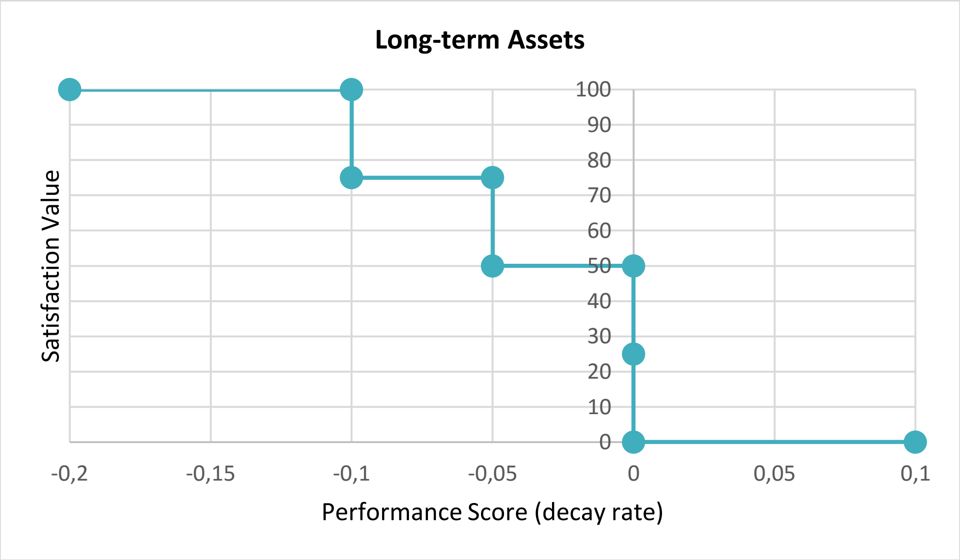


Figure 111: Long-term Assets Value Functions

From Figure 111 it is evident that a decay rate between 0 and 0.1 correlate to a satisfaction value of 0, a decay rate of exactly 0 correlates to a satisfaction value of 25, a decay rate between 0 and -0.05 correlate to a satisfaction value of 50, a decay rate between -0.05 and -0.1 correlate to a satisfaction value of 75 and a decay rate between -0.1 and -0.2 correlate to a satisfaction value of 100. The aforementioned aligns with what was stipulated in Section 6.3.5. However, this figure also includes the most extreme end points deemed permissible and/or feasible by this author. That is, the worst decay rate of 0.1 and the best decay rate of -0.2.

PEOPLE

Refer to Table 82 to Table 85. If the measure's format is red, it is only applicable to the private transport environment. If the measure's format is blue, it is only applicable to the public transport environment.

Table 82: Value Elicitation - Public Relations

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Marketing	**Service Promotion**	Customer Satisfaction	Growth Rate	B	-0.1	0.2
		Service Enhancements	Growth Rate	B	-0.1	0.2
Networking	**Service Interaction**	Social Media Attractiveness	Growth Rate	B	-0.1	0.2

PERFORMANCE AREA	PERFORMANCE SUB AREA		PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Networking	**Service Interaction**	Productive Relationships	Type and Trend of Postings	Score	B	0	3
			Peer and Public Reviews	Growth Rate	B	-0.1	0.2

**Additional Notes*

Productive relationships can either be measured by evaluating the type and the trend of the postings made by the users on the representative social media platforms or by using peer- and public reviews to evaluate the success of service interaction with regard to cultivating productive relationships. The former mentioned is evaluated with the aid of a scorecard and the latter mentioned is evaluated with the aid of productive relationships index.

Table 83: Value Elicitation - Customer Service

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE		UNIT	C/B	MIN. SCORE	MAX. SCORE
Traveller Information Provision	**Assist**	Trip Planning		Score	B	0	3
	Confirm	Transit and Traffic Information		Score	B	0	3
	Notify	Incident Notification		Score	B	0	3
	Advise	Route Guidance		Score	B	0	3
General Support Information	**Logging Attendance**	Reaction Time	Call Centre	Hours	C	12	48
			Website/ App				
		Helpfulness		Compliments per Complaints	B	0.5	2
	Inter-personal Interaction	Personnel Performance		Score	B	0	3
	Self-service Systems	Quality of Interaction Mediums		Score	B	0	3

**Additional Notes*

Reaction time can either be measured from the viewpoint of a call centre or a website/ application.

Table 84: Value Elicitation - Social Sustainability

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Sustainable Service Delivery	**Social Justice**	Transport Expenditure	% of a household's monthly income	C	10	35
		Discounted Fares	Binary	B	No = 0	Yes = 1
	Social Equality	Degree of Urban Densification	% of the population that can access major roads and freeways	B	20	90
		Amenities for Disabled People	Binary	B	No = 0	Yes = 1
Sustainable Living	**Social Development**	Usability Study	Binary	B	No = 0	Yes = 1
		Community Development Programs	Binary	B	No = 0	Yes = 1

Table 85: Value Elicitation - Human Resource Management

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Employee Performance Management	**Employee Satisfaction**	Employee Contentment	Growth Rate	B	-0.1	0.2
	Employee Commitment	Absenteeism Scores	Growth Rate	B	-0.1	0.2
	Employee Engagement	Focus Groups	Binary	B	No = 0	Yes = 1
		Trauma Counselling	Binary	B	No = 0	Yes = 1
	Employee Development	Training Services	Binary	B	No = 0	Yes = 1
		Progress Evaluation	Binary	B	No = 0	Yes = 1

Only the value functions of the measures for which data acquisition was required, are considered in more detail here. Refer to Figure 112 to Figure 120.

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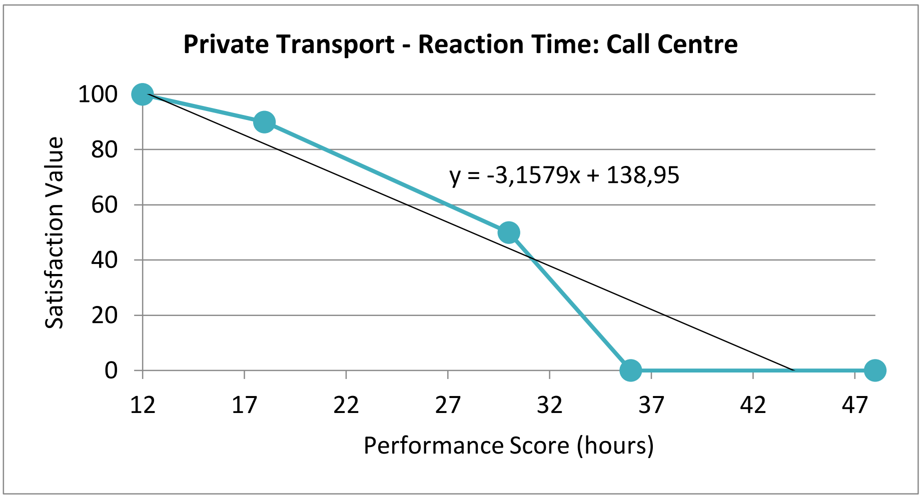

Figure 112: Private Transport - Reaction Time (Call Centre) Value Function

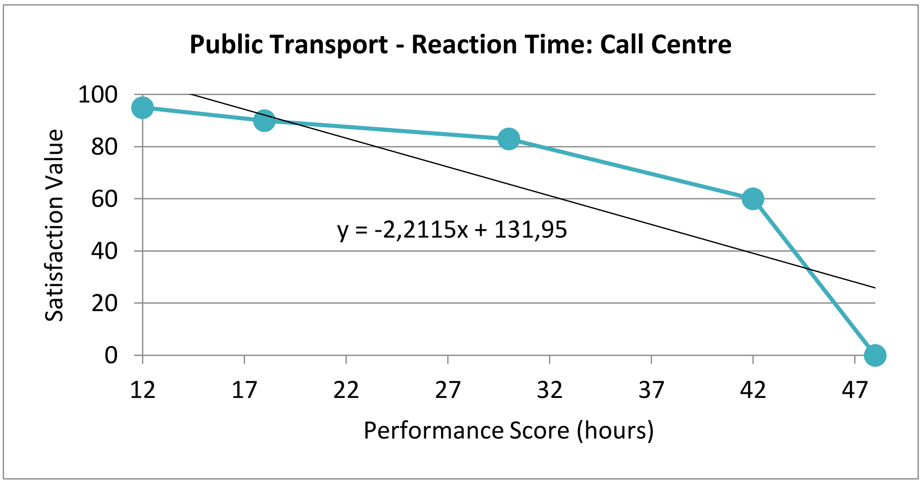

Figure 113: Public Transport - Reaction Time (Call Centre) Value Function

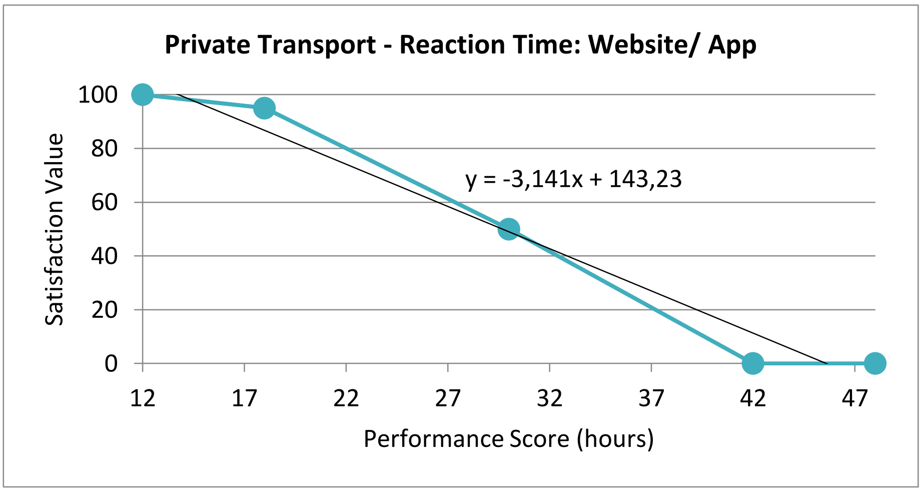

Figure 114: Private Transport - Reaction Time (Website/App) Value Function

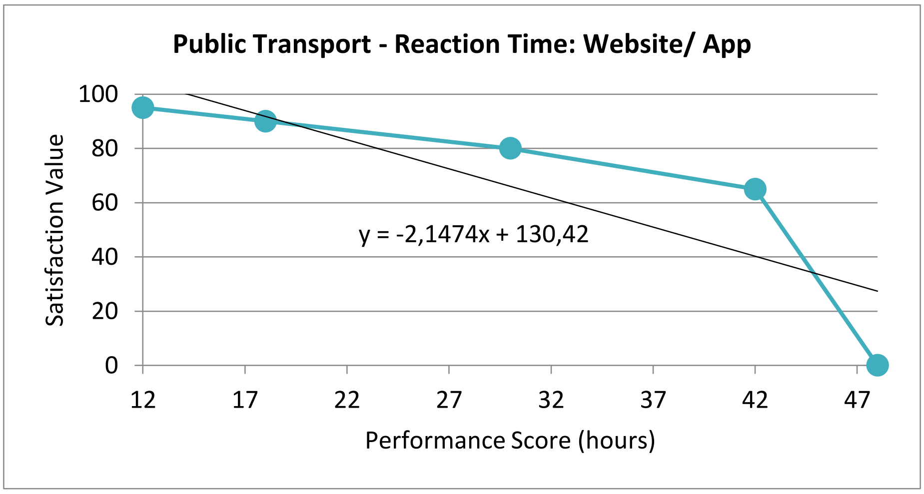

Figure 115: Public Transport - Reaction Time (Website/App) Value Function

From Figure 112 to Figure 115 it is evident that the respective standardised value functions differ noticeably. From these figures it can be deducted that reaction time (regardless of the representative communication medium) is more important in the private- than in the public transport environment. In each of these cases, the reaction time in the private transport environment, which correlates to zero satisfaction, is much shorter than that in the public transport environment. No apparent reason for this occurrence exists. However, this could be due to the fact that while public transport users have the opportunity to express their concerns (in person) to, for example, the bus driver or the kiosk operator, private transport users do not have this facility. Therefore, for private transport users, it is more important to get a prompt response from the call centre and a website or an application.

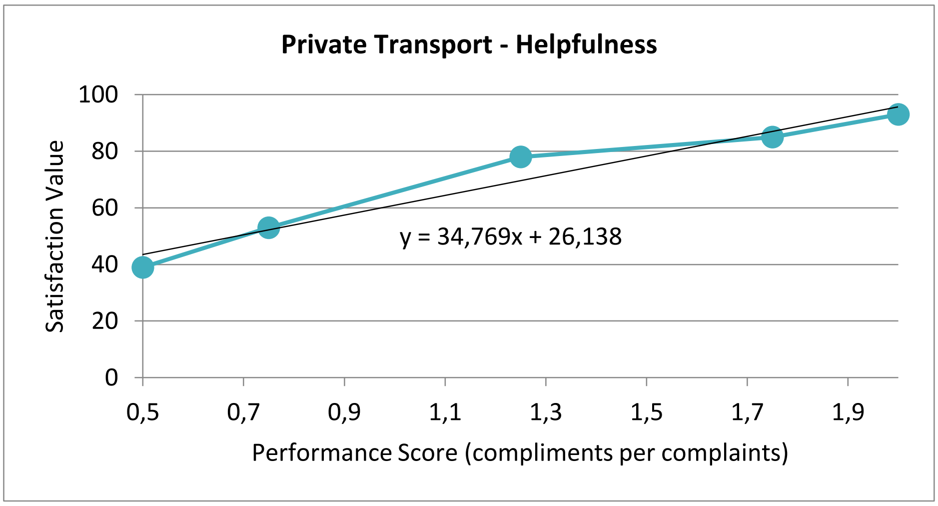

Figure 116: Private Transport - Helpfulness Value Function

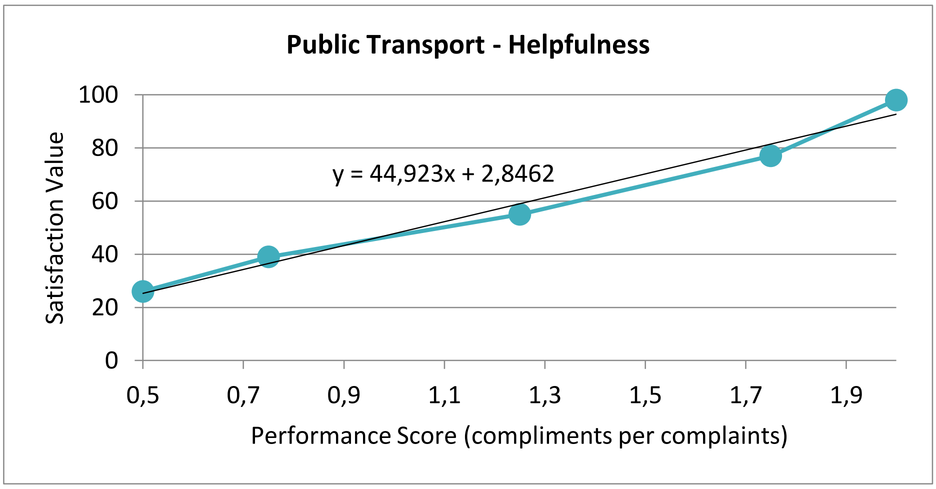

Figure 117: Public Transport - Helpfulness Value Function

From Figure 116 and Figure 117 it is evident that the respective standardised value functions differ significantly. From these figures it can be deducted that helpfulness is more important in the public- than in the private transport environment. While the absolute worst helpfulness ratio in the private transport environment correlates to a satisfaction in the vicinity of 40%, the absolute worst helpfulness ratio in the public transport environment correlates to a satisfaction in the vicinity of 25%. This could be due to the fact that, as mentioned previously, the public transport users have the opportunity to interact (in person) with, for example, the bus driver or the kiosk operator. Since these people directly influence the user's perception of the service, it is important to evaluate the user's satisfaction with them. In this case, in the form of a ratio representing the number of compliments per the number of complaints.

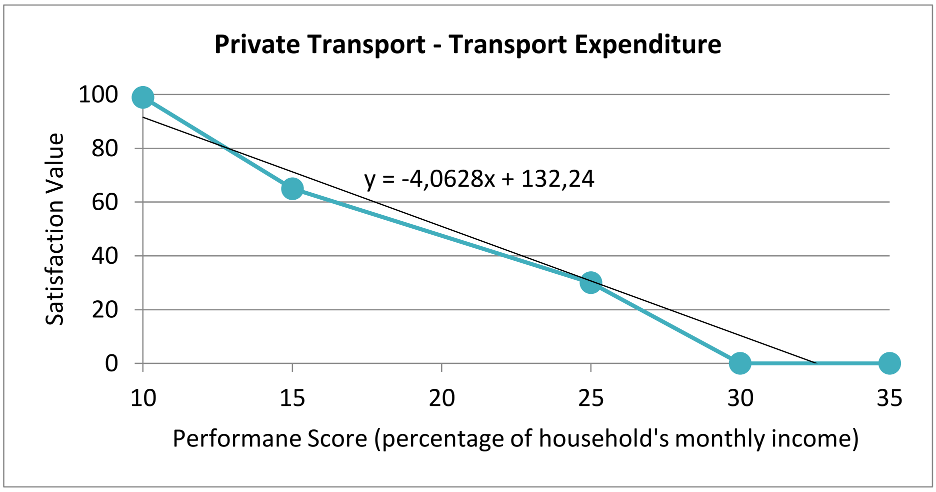

Figure 118: Private Transport - Transport Expenditure Value Function

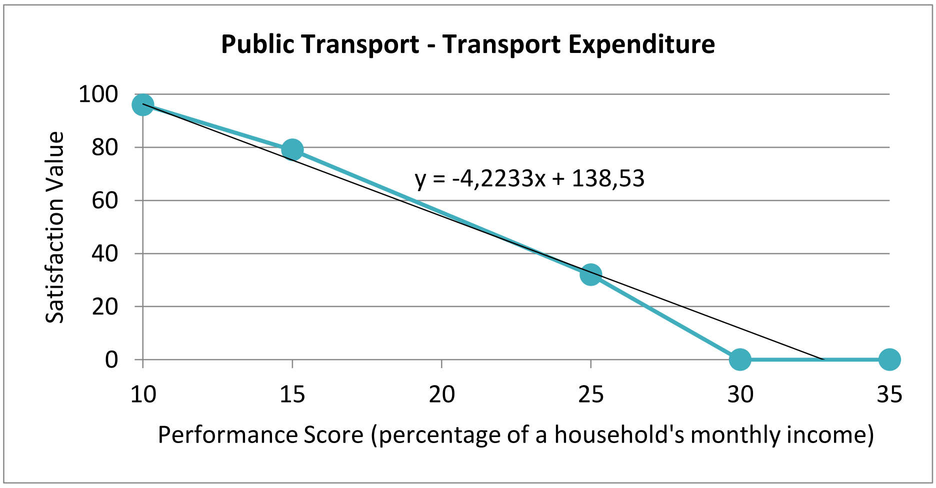

Figure 119: Public Transport - Transport Expenditure Value Function

From Figure 118 and Figure 119 it is evident that the respective standardised value functions differ noticeably. From these figures it can be deducted that a greater transport expenditure is more acceptable in the public- than in the private transport environment. Even though the differences between the two value functions are minor, it is still apparent that the public transport environment is more lenient towards their users having a greater transport expenditure. This could be due to the fact that a significant percentage of the (captive) public transport users falls within the lower income group of the country. Therefore, it is understandable that they spend a greater percentage of their income on their transport needs.

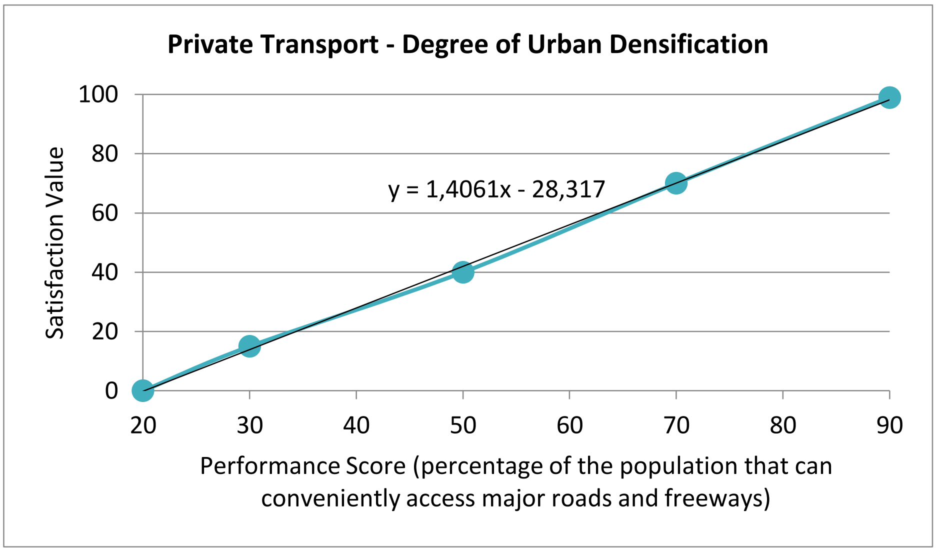

Figure 120: Private Transport - Degree of Urban Densification Value Function

PLANET

Refer to Table 86 to Table 89.

Table 86: Value Elicitation - Air Quality Management

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Air Pollution Monitoring	**Mobile Source and GHG Emissions**	Priority Pollutants Governance	Binary	B	No = 0	Yes = 1
		Pollution Mitigation	Score	B	0	3
		Emission Intensity	Decay Rate	C	-0.2	0.1

Table 87: Value Elicitation - Climate Change Management

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Weather Monitoring	**Driving Behaviour**	Weather Conditions Governance	Binary	B	No = 0	Yes = 1
		Impact Mitigation	Score	B	0	3
		Number of Weather-related Incidents	Decay Rate	C	-0.2	0.1

Table 88: Value Elicitation - Noise Management

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Noise Exposure Monitoring	**Noise Sources and Receivers**	Noise Exposure Governance	Binary	B	No = 0	Yes = 1
		Noise Exposure Mitigation	Score	B	0	3
		Sound Intensity	Decay Rate	C	-0.2	0.1

Table 89: Value Elicitation - Energy Management

PERFORMANCE AREA	PERFORMANCE SUB AREA	PERFORMANCE MEASURE	UNIT	C/B	MIN. SCORE	MAX. SCORE
Energy Use Monitoring	**Energy Efficiency**	Energy Consumption Governance	Binary	B	No = 0	Yes = 1
		Energy Use Mitigation	Score	B	0	3
		Energy Intensity	Decay Rate	C	-0.2	0.1

Note: no value functions need to be discussed here, since all of the applicable value functions have already been addressed.

WEIGHT ELICITATION

The discussion on the weight elicitation encompasses an outline, per sustainability perspective, on the weights of importance corresponding to each of the performance-related aspects. This includes the importance weights associated with each of the identified performance categories, performance areas, performance sub areas, measurement fields and performance measures. As mentioned previously, the importance weights associated with each of the five sustainability perspectives were not obtained.

Note: for explanation purposes, an example computation of the within- and out of family weights pertaining to Table 90 is given.

PRACTICES

Refer to Table 90 to Table 94.

Table 90: Weight Elicitation - Legal Compliance

WITHIN FAMILY WEIGHT

LEVEL	PERFORMANCE-RELATED ASPECT	Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		OUT OF FAMILY WEIGHT
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Legal Compliance*	0.248	87							
2	*Legal Sources*			1	100					
3	*Legislations and Acts*					1	100			
4	**Transport**							0.243	90	0.060
4	**Environment**							0.208	77	0.052
4	**Labour**							0.178	66	0.044
4	**Safety and Security**							0.203	75	0.050
4	**Communications**							0.168	62	0.042

As can be seen in Table 90, each within family (normalised) weight with the same parent node for each weight level adds up to one.

Weight Level 4: $0.243 + 0.208 + 0.178 + 0.203 + 0.168 = 1$

Weight Level 3 and 2: $1 = 1$

Weight Level 1: $0.248 + 0.214 + 0.171 + 0.168 + 0.199 = 1$

The out of family weights can be computed by multiplying the representative within family (normalised) weight at each weight level with one another. This is indicated by the encircled weights in Table 90.

Transport Out of Family Weight: $0.248 \times 1 \times 1 \times 0.243 = 0.060$

Note: all out of family weights, within the same perspective (i.e. value tree), also add up to one.

Table 91: Weight Elicitation - Regulatory Enforcement

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Regulatory Enforcement*	0.214	75							
2	*Regulators*			0.413	52					
3	*Governing Bodies*					1	100			
4	**Involvement**							1	100	0.088
2	*Regulatory Documents*			0.587	74					
3	*Regulations and Policies*					1	100			
4	**Standards**							0.299	88	0.038
4	**Manuals**							0.238	70	0.030
4	**Guidelines and Instructions**							0.238	70	0.030
4	**Statements, Plans and Frameworks**							0.224	66	0.028

Table 92: Weight Elicitation - Research and Development

		WITHIN FAMILY WEIGHT								
LEVEL	**PERFORMANCE-RELATED ASPECT**	**Weight Level 1**		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		**OUT OF FAMILY WEIGHT**
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Research and Development*	0.171	60							
2	*Research Support*			0.556	75					
3	*Research Development*					1	100			
4	**Public Engagement**							1	100	0.095
2	*Creativity Support*			0.444	60					
3	*Project Development*					1	100			
4	**Innovation Management**							0.444	60	0.034
4	**Continuous Improvement**							0.556	75	0.042

Table 93: Weight Elicitation - Institutional Liaison

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Institutional Liaison*	0.168	59							
2	*Institutional Coordination and Cooperation*			0.538	70					
3	*Operational Alignment*					0.5	75			
4	**Activity Integration**							0.444	64	0.020
4	**Technical Compatibility**							0.556	80	0.025
3	*Strategy Alignment*					0.5	75			
4	**Collaborative Relationships**							1	100	0.045
2	*Institutional Robustness*			0.462	60					
3	*Business Continuity*					1	100			
4	**Risk Management**							1	100	0.078

Table 94: Weight Elicitation - Data Governance

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Data Governance*	0.199	70							
2	*Data Management*			1	100					
3	*Information System Governance Procedures*					1	100			
4	**Data Collection**							0.149	80	0.030
4	**Data Accuracy**							0.158	85	0.032
4	**Data Retention**							0.130	70	0.026
4	**Data Security**							0.184	99	0.037
4	**Data Quality**							0.149	80	0.030
4	**Data Fusion**							0.117	63	0.023
4	**Data Accessibility**							0.112	60	0.022

PROCESSES

Refer to Table 95 to Table 97.

Table 95: Weight Elicitation - Operational Performance

		WITHIN FAMILY WEIGHT										
LEVEL	**PERFORMANCE-RELATED ASPECT**	**Weight Level 1**		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		**Weight Level 5**		**OUT OF FAMILY WEIGHT**
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
1	*Operational Performance*	0.365	74									
2	*Service Reliability*			0.287	90							
3	*Travel Time Variability*					0.369	80					
4	*Travel Time Duration*							0.471	80			
5	**Travel Time Factor**									1	100	0.018
4	*Schedule Adherence*							0.529	90			
5	**On-time Performance**									1	100	0.020
3	*Information Validity*					0.263	57					
4	*Timeliness*							0.5	85			
5	**Information Refresh Rate**									0.429	60	0.006
5	**Latency to Posting Updates**									0.571	80	0.008
4	*Accurate and Available*							0.5	85			
5	**Accuracy**									0.599	100	0.008

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT										OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		Weight Level 5		
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
5	**Availability**									0.401	67	0.006
3	*Public Travel and Personal Safety*					0.369	80					
4	*Incident Statistics*							1	100			
5	**Crash Incidents and Break-downs**									0.692	90	0.027
5	**Property Crime Incidents**									0.308	40	0.012
2	*Service Convenience*			0.245	77							
3	*Accessibility*					0.418	81					
4	*Access Point Proximity*							0.464	65			
5	**Access Time**									0.600	75	0.010
5	**Access Distance**									0.400	50	0.007
4	*Network Characteristics*							0.536	75			
5	**Quality of Road and Transit Line**									1	100	0.020
3	*Connectivity*					0.325	63					

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		Weight Level 5		OUT OF FAMILY WEIGHT
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
4	*Access Options*							1	100			
5	**Commuting Time**									0.546	95	0.016
5	**Transfer Distance**									0.454	79	0.013
3	*Regularity*					0.258	50					
4	*Mode Preference*							0.433	65			
5	**Modal Split**									1	100	0.010
4	*Periodicity*							0.567	85			
5	**Service Frequency**									1	100	0.013
2	*Operational Seamlessness*			0.207	65							
3	*Incident Management*					1	100					
4	*Time Measures*							0.625	100			
5	**Detection Time**									0.165	90	0.008
5	**Verification Time**									0.138	75	0.007
5	**Notification Time**									0.165	90	0.008
5	**Response Time**									0.184	100	0.009

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT										OUT OF FAMILY WEIGHT
		Weight Level 1		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		**Weight Level 5**		
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
5	**Alert Time**									0.164	89	0.008
5	**Clearance Time**									0.184	100	0.009
4	*Staff Safety Measures*							0.375	60			
5	**Adverse Health Conditions**									0.400	50	0.011
5	**Secondary Incidents**									0.600	75	0.017
2	*Operating Efficiency*			0.261	82							
3	*Service Quality*					0.504	71					
4	*Density and Congestion*							0.448	65			
5	**LOS**									0.333	50	0.007
5	**Load Factor**									0.333	50	0.007
5	**Standing Density**									0.333	50	0.007
4	*Mobility*							0.552	80			
5	**Network Travel Speeds**									0.178	50	0.005
5	**Queue Length**									0.274	77	0.007
5	**Queue Time**									0.263	74	0.007

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT										OUT OF FAMILY WEIGHT
		Weight Level 1		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		**Weight Level 5**		
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
5	**Waiting Time**									0.285	80	0.008
3	*Service Utilisation*					0.496	70					
4	*Demand-Supply*							1	100			
5	**Degree of Saturation**									1	100	0.047

Table 96: Weight Elicitation -Technology Reliability

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT										OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		Weight Level 5		
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
1	*Technology Reliability*	0.315	64									
2	*System Health*			0.419	65							
3	*System Availability*					1	100					
4	*System Functionality*							1	100			
5	**System Uptime**									1	100	0.132
2	*System Performance*			0.581	90							
3	*Equipment Quality*					0.435	50					
4	*Value Evaluation*							1	100			
5	**MTBF**									1	100	0.080
3	*Data Quality*					0.565	65					
4	*Data Verification and Validation*							1	100			
5	**Error Rate**									1	100	0.103

Table 97: Weight Elicitation - Asset Management and Maintenance

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT										OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		Weight Level 5		
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
1	*Asset Management and Maintenance*	0.320	65									
2	*Asset Management*			0.503	80							
3	*Operations Management*					1	100					
4	*Record*							0.253	70			
5	**Asset Register**									1	100	0.041
4	*Monitor*							0.282	78			
5	**Network Surveillance System**									1	100	0.045
4	*Control*							0.238	66			
5	**Positioning System**									1	100	0.038
4	*Evaluate*							0.227	63			
5	**Status Report or Supporting Electronic Management System**									1	100	0.037
2	*Asset Maintenance*			0.497	79							
3	*Preventative*					0.571	80					
4	*Scheduled Logs*							1	100			
5	**Fulfilment**									1	100	0.091

		WITHIN FAMILY WEIGHT										
LEVEL	**PERFORMANCE-RELATED ASPECT**	**Weight Level 1**		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		**Weight Level 5**		**OUT OF FAMILY WEIGHT**
		(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	(Normal-ised)	(Raw Weight)	
3	*Corrective*					0.429	60					
4	*Defect Logs*							1	100			
5	**Tickets Logged**									0.400	50	0.027
5	**MTTR**									0.600	75	0.041

PROFIT

Refer to Table 98 and Table 99.

Table 98: Weight Elicitation - Economic Performance

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Economic Performance*	0.580	69							
2	*Economic Sustainability*			0.431	90					
3	*System Adaptability*					0.542	65			
4	**Scalability**							0.496	60	0.067
4	**Responsiveness**							0.504	61	0.068
3	*System Preservation*					0.458	55			
4	**Traveller Experience**							0.626	77	0.072
4	**Average Remaining Useful Life of Fleet**							0.374	46	0.043
2	*Economic Vitality*			0.292	61					
3	*Economic Development*					0.446	58			
4	**Jobs Created**							1	100	0.076
3	*Economic Growth*					0.554	72			
4	**Capacity Building and Infrastructure Development**							1	100	0.094
2	*Socio-Economic Prosperity*			0.278	58					

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
3	*(Social) Benefits*					1	100			
4	**Energy and Environment**							0.133	56	0.021
4	**Safety**							0.197	83	0.032
4	**Efficiency**							0.164	69	0.026
4	**Customer Satisfaction**							0.164	69	0.026
4	**Mobility**							0.176	74	0.028
4	**Productivity**							0.166	70	0.027

Table 99: Weight Elicitation - Financial Performance

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Financial Performance*	0.420	50							
2	*Financial Feasibility*			0.561	64					
3	*Non-recurring Costs*					0.209	53			
4	**Long-term Assets**							1	100	0.049
3	*Recurring Costs*					0.300	76			
4	**Selling Expenses**							0.478	55	0.034
4	**General and Administrative Expenses**							0.522	60	0.037
3	*Miscellaneous Costs*					0.198	50			
4	**Fines, Law Suits and Environmental Damage Costs**							1	100	0.047
3	*Social Costs*					0.292	74			
4	**Congestion, Accidents and Pollution**							1	100	0.069
2	*Investment Management*			0.439	50					
3	*Investment Performance*					1	100			
4	**ROI**							1	100	0.184

PEOPLE

Refer to Table 100 to Table 103.

Table 100: Weight Elicitation - Public Relations

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT: Weight Level 1 (Normalised)	Weight Level 1 (Raw Weight)	Weight Level 2 (Normalised)	Weight Level 2 (Raw Weight)	Weight Level 3 (Normalised)	Weight Level 3 (Raw Weight)	Weight Level 4 (Normalised)	Weight Level 4 (Raw Weight)	OUT OF FAMILY WEIGHT
1	*Public Relations*	0.217	50							
2	*Marketing*			0.479	69					
3	*Service Promotion*					1	100			
4	**Customer Satisfaction**							0.527	89	0.055
4	**Service Enhancements**							0.473	80	0.049
2	*Networking*			0.521	75					
3	*Service Interaction*					1	100			
4	**Social Media Attractiveness**							0.417	50	0.047
4	**Productive Relationships**							0.583	70	0.066

Table 101: Weight Elicitation - Customer Service

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Customer Service*	0.326	75							
2	*Traveller Information Provision*			0.587	71					
3	*Assist*					0.298	76			
4	**Trip Planning**							1	100	0.057
3	*Confirm*					0.255	65			
4	**Transit and Traffic Information**							1	100	0.049
3	*Notify*					0.231	59			
4	**Incident Notification**							1	100	0.044
3	*Advise*					0.216	55			
4	**Route Guidance**							1	100	0.041
2	*General Support Information*			0.413	50					
3	*Logging Attendance*					0.290	60			
4	**Reaction Time**							0.457	63	0.018
4	**Helpfulness**							0.543	75	0.021
3	*Inter-personal Interaction*					0.324	67			
4	**Personnel Performance**							1	100	0.044
3	*Self-service Systems*					0.386	80			

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
4	**Quality of Interaction Mediums**							1	100	0.052

Table 102: Weight Elicitation - Social Sustainability

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT Weight Level 1 (Normalised)	Weight Level 1 (Raw Weight)	Weight Level 2 (Normalised)	Weight Level 2 (Raw Weight)	Weight Level 3 (Normalised)	Weight Level 3 (Raw Weight)	Weight Level 4 (Normalised)	Weight Level 4 (Raw Weight)	OUT OF FAMILY WEIGHT
1	*Social Sustainability*	0.239	55							
2	*Sustainable Service Delivery*			0.549	73					
3	*Social Justice*					0.420	50			
4	**Transport Expenditure**							0.573	67	0.032
4	**Discounted Fares**							0.427	50	0.024
3	*Social Equality*					0.580	69			
4	**Degree of Urban Densification**							0.535	69	0.041
4	**Amenities for Disabled People**							0.465	60	0.035
2	*Sustainable Living*			0.451	60					
3	*Social Development*					1	100			
4	**Usability Study**							0.615	80	0.066
4	**Community Development Programs**							0.385	50	0.041

Table 103: Weight Elicitation - Human Resource Management

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Human Resource Management*	0.217	50							
2	*Employee Performance Management*			1	100					
3	*Employee Satisfaction*					0.249	63			
4	**Employee Contentment**							1	100	0.054
3	*Employee Commitment*					0.198	50			
4	**Absenteeism Scores**							1	100	0.043
3	*Employee Engagement*					0.273	69			
4	**Focus Groups**							0.500	50	0.030
4	**Trauma Counselling**							0.500	50	0.030
3	*Employee Development*					0.281	71			
4	**Training Services**							0.545	60	0.033
4	**Progress Evaluation**							0.455	50	0.028

PLANET

Refer to Table 104 to Table 107.

Table 104: Weight Elicitation - Air Quality Management

		WITHIN FAMILY WEIGHT								
LEVEL	**PERFORMANCE-RELATED ASPECT**	**Weight Level 1**		**Weight Level 2**		**Weight Level 3**		**Weight Level 4**		**OUT OF FAMILY WEIGHT**
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Air Quality Management*	0.291	76							
2	*Air Pollution Monitoring*			1	100					
3	*Mobile Source and GHG Emissions*					1	100			
4	**Priority Pollutants Governance**							0.281	57	0.082
4	**Pollution Mitigation**							0.433	88	0.126
4	**Emission Intensity**							0.286	58	0.083

Table 105: Weight Elicitation - Climate Change Management

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Climate Change Management*	0.192	50							
2	*Weather Monitoring*			1	100					
3	*Driving Behaviour*					1	100			
4	**Weather Conditions Governance**							0.371	66	0.071
4	**Impact Mitigation**							0.399	71	0.076
4	**Number of Weather-related Incidents**							0.230	41	0.044

Table 106: Weight Elicitation - Noise Management

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Noise Management*	0.257	67							
2	*Noise Exposure Monitoring*			1	100					
3	*Noise Sources and Receivers*					1	100			
4	**Noise Exposure Governance**							0.337	70	0.086
4	**Noise Exposure Mitigation**							0.380	79	0.097
4	**Sound Intensity**							0.284	59	0.073

Table 107: Weight Elicitation - Energy Management

LEVEL	PERFORMANCE-RELATED ASPECT	WITHIN FAMILY WEIGHT								OUT OF FAMILY WEIGHT
		Weight Level 1		Weight Level 2		Weight Level 3		Weight Level 4		
		(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	(Normalised)	(Raw Weight)	
1	*Energy Management*	0.261	68							
2	*Energy Use Monitoring*			1	100					
3	*Energy Efficiency*					1	100			
4	**Energy Consumption Governance**							0.330	64	0.086
4	**Energy Use Mitigation**							0.381	74	0.099
4	**Energy Intensity**							0.289	56	0.075

CONCLUDING REMARKS

All of the aforementioned tables, except those pertaining to the SBSC perspective: processes, have four weight levels. The tables pertaining to the SBSC perspective: processes have five weight levels. As mentioned previously, these weight levels correlate to the performance measurement levels. These levels were previously defined to account for five performance measurement levels.

In the case where only four weight levels were used, it was possible to concatenate two of the levels pertaining to the five performance measurement levels. However, due to the vastness of the SBSC perspective: processes and the complexity associated with its corresponding performance-related aspects, the concatenation of measurement levels could not be applied here as well.

INDEX ELICITATION

This section includes a discussion, per composite measure, on the (importance) weights associated with each of the index-related considerations. As mentioned previously, the percent weights were determined with the aid of Equation 16 (Alfares and Duffuaa 2008). Where applicable, these percent weights were computed separately for the private- and the public transport environment.

TRAVELLER EXPERIENCE INDEX

Refer to Table 108.

$$S_5 = 3.195 + \frac{37.758}{5} = 10.747$$

Table 108: Traveller Experience Index - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Safety and security	Freedom from danger, risk and/or doubt	100	25.476
2	Equipment	Functional equipment	89.253	22.738
3	Physical facilities	Convenience (e.g. time accessibility)	78.506	20.000
4	Communication materials	Applicable messages that are easy to understand	67.759	17.262
5	Technology	Up to date technology	57.012	14.524
			SUM	100

CUSTOMER SATISFACTION INDEX

Refer to Table 109 and Table 110.

$$S_9 = 3.195 + \frac{37.758}{9} = 7.390$$

Table 109: CSI Private Transport - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Timeliness	Travel time; considering the distance travelled	100	15.774
2	Safety and Security	Public travel- and personal safety: incident management	92.610	14.608
3	Accuracy	Accuracy of information (e.g. traffic images and expected service delays)	85.220	13.442
4	Respect for users	Availability of (personalised) information (e.g. shortest route options)	77.830	12.277

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
5	Physical facilities	Convenience (e.g. geographic accessibility)	70.440	11.111
6	Service appropriate for users' needs	Alternative route options where road restrictions exist (e.g. vehicle height and -weight)	63.050	9.945
7	Probity and confidentiality	Privacy of individual movement	55.660	8.780
8	Understanding the user	Door-to-door navigation (e.g. trip assistance)	48.270	7.614
9	Service appropriate for users' needs	Amenities for people with disabilities	40.880	6.448
			SUM	100

$$S_{15} = 3.195 + \frac{37.758}{15} = 5.712$$

Table 110: CSI Public Transport - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Accuracy	Accuracy of services (e.g. on-time departures)	100	11.108
2	Timeliness	Frequency of services (e.g. departures)	94.288	10.474
3	Consistency/ regularity	Availability of services (e.g. operational hours)	88.576	9.839
4	Safety and Security	Public travel- and personal safety: driver behaviour	82.864	9.205
5	Accuracy	Accuracy of information (e.g. expected service delays)	77.152	8.570
6	Respect for users	Availability of information (i.e. routes, stops/stations and timetables)	71.44	7.936
7	Respect for users	Ease of purchasing tickets	65.728	7.301
8	Physical facilities	Convenience (e.g. geographic- and transfer link accessibility)	60.016	6.667
9	Physical facilities	Comfort (e.g. shelter and seating)	54.304	6.032
10	Physical facilities	Cleanliness (e.g. stops/stations and transit vehicles)	48.592	5.398
11	Staff competence	Personnel access (e.g. appearance and knowledgeability)	42.88	4.763

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
12	Service appropriate for users' needs	Amenities for people with disabilities	37.168	4.129
13	Understanding the user	Door-to-door navigation (e.g. trip assistance)	31.456	3.494
14	Probity and confidentiality	Privacy of individual movement	25.744	2.860
15	Service appropriate for users' needs	Alternative route options where facility restrictions exist	20.032	2.225
			SUM	100

PRODUCTIVE RELATIONSHIPS INDEX

Refer to Table 111 and Table 112.

$$S_8 = 3.195 + \frac{37.758}{8} = 7.915$$

Table 111: Productive Relationships Index Private Transport - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Employees	Knowledge and courtesy	100	17.290
2	Access (to staff, services and information)	Approachability and ease of contact	92.085	15.921
3	Problem resolution and complaint handling	Fulfilling promises and obligations	84.170	14.553
4	Communication (clear, appropriate and timely)	Keeping customers informed in a language they can understand	76.255	13.184
5	Individualised attention	Making an effort to know customers and to understand their needs	68.340	11.816
6	Flexibility	Providing numerous interaction mediums	60.425	10.447
7	Provision of prompt services	Readily respond to concerns	52.510	9.079
8	Willingness to help	Listening to customers and acknowledging their comments	44.595	7.710
			SUM	100

$$S_8 = 3.195 + \frac{37.758}{8} = 7.915$$

Table 112: Productive Relationships Index Public Transport - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Employees	Knowledge and courtesy	100	17.290
2	Access (to staff, services and information)	Approachability and ease of contact	92.085	15.921
3	Individualised attention	Making an effort to know customers and to understand their needs	84.170	14.553
4	Problem resolution and complaint handling	Fulfilling promises and obligations	76.255	13.184
5	Provision of prompt services	Readily respond to concerns	68.340	11.816
6	Willingness to help	Listening to customers and acknowledging their comments	60.425	10.447
7	Communication (clear, appropriate and timely)	Keeping customers informed in a language they can understand	52.510	9.079
8	Flexibility	Providing numerous interaction mediums	44.595	7.710
			SUM	100

EMPLOYEE SATISFACTION INDEX

Refer to Table 113 and Table 114.

$$S_{20} = 3.195 + \frac{37.758}{20} = 5.083$$

Table 113: ESI Private Transport - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Access (to system and information)	Confidence instilled	100	9.669
2	Communication (clear, appropriate and timely)	Expectations clear	94.917	9.178
3	Problem resolution and complaint handling	Fulfilling promises and obligations	89.834	8.686
4	Communication materials	Appropriate communication channels	84.751	8.195
5	Consistency/regularity	System dependability (e.g. service provided at the promised time)	79.668	7.703

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
6	Accuracy	Records kept accurately and error-free	74.585	7.212
7	Safety and security	Feel safe and at ease with daily operations	69.502	6.720
8	Technology	Up to date technology	64.419	6.229
9	Provision of prompt services	Readily respond to concerns	59.336	5.737
10	Equipment	Easy to use equipment	54.253	5.246
11	Competence of co-workers	Level of knowledge	49.170	4.754
12	Willingness to help	Listening to employees and acknowledging their comments	44.087	4.263
13	Flexibility	Out-of-the-box thinking	39.004	3.771
14	Understanding the user	Best interests at heart (e.g. flexible operating hours)	33.921	3.280
15	Individualised attention	Interaction among co-workers encouraged	28.838	2.788
16	Credibility	Acknowledged for services	23.755	2.297
17	Probity and confidentiality	Personal information kept confidential	18.672	1.805
18	Respect for co-workers	Politeness towards each other	13.589	1.314
19	Physical facilities	Visually appealing and clean environment	8.506	0.822
20	Appearance of Co-workers	Well-dressed and neat in appearance	3.423	0.331
			SUM	100

$$S_{20} = 3.195 + \frac{37.758}{20} = 5.083$$

Table 114: ESI Public Transport - Weight Computation

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
1	Consistency/regularity	System dependability (e.g. service provided at the promised time)	100	9.669
2	Communication materials	Appropriate communication channels	94.917	9.178
3	Competence of co-workers	Level of knowledge	89.834	8.686

Rank	Quality Criteria	Parameter	Raw Weight	Normalised Weight
4	Safety and security	Feel safe and at ease with daily operations	84.751	8.195
5	Communication (clear, appropriate and timely)	Expectations clear	79.668	7.703
6	Provision of prompt services	Readily respond to concerns	74.585	7.212
7	Technology	Up to date technology	69.502	6.720
8	Understanding the user	Best interests at heart (e.g. flexible operating hours)	64.419	6.229
9	Willingness to help	Listening to employees and acknowledging their comments	59.336	5.737
10	Physical facilities	Visually appealing and clean environment	54.253	5.246
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12	Accuracy	Records kept accurately and error-free	44.087	4.263
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19	Probity and confidentiality	Personal information kept confidential	8.506	0.822
20	Appearance of Co-workers	Well-dressed and neat in appearance	3.423	0.331
			SUM	100

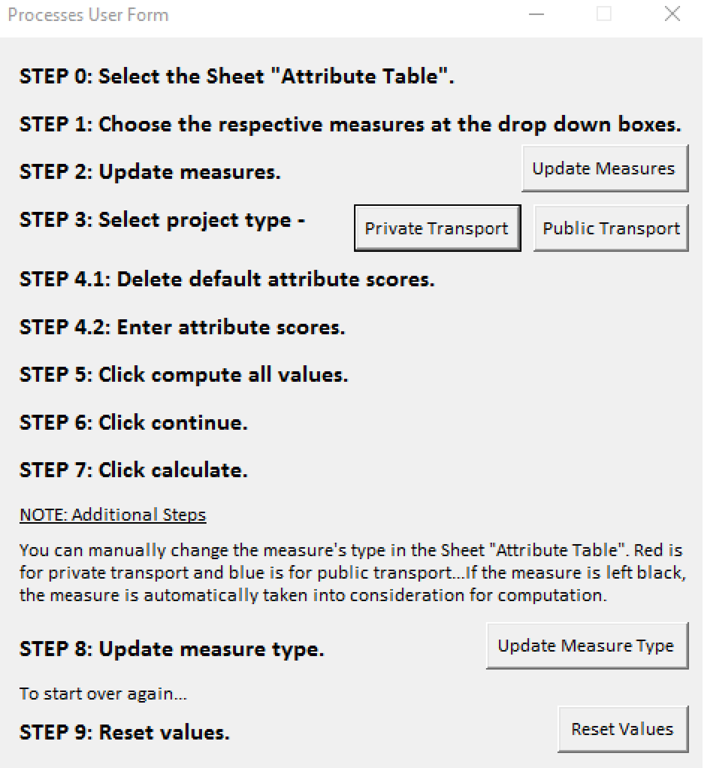
6.5.2 FRONT-END DESIGN

The five Microsoft Excel VBA models, as developed herein, can be viewed by referring to the attached CD. The content of this CD is listed in Appendix F. It needs to be noted, however, that these models can only be opened on the 32 bit version of Microsoft Office.

PROCESS MODEL

Since the reasoning behind all of the developed models is similar, only the model pertaining to the SBSC perspective: processes (which is the most exhaustive model) is considered in more detail here.

Upon opening this model, the user is presented with a user form. Refer to Figure 121. The code pertaining to this user form can be viewed in Appendix E.



STEP 0: Select the Sheet "Attribute Table".

STEP 1: Choose the respective measures at the drop down boxes.

STEP 2: Update measures.

STEP 3: Select project type -

STEP 4.1: Delete default attribute scores.

STEP 4.2: Enter attribute scores.

STEP 5: Click compute all values.

STEP 6: Click continue.

STEP 7: Click calculate.

NOTE: Additional Steps

You can manually change the measure's type in the Sheet "Attribute Table". Red is for private transport and blue is for public transport...If the measure is left black, the measure is automatically taken into consideration for computation.

STEP 8: Update measure type.

To start over again...

STEP 9: Reset values.

Figure 121: Processes User Form

As can be seen in Figure 121, there are nine steps to follow. While executing these steps, the user form needs to be minimised. If the user form is (accidently) closed, it can either be reopened from within VBA or by reopening the Microsoft Excel workbook.

For clarification purposes, a discussion of each of the ten sheets pertaining to the processes model follows.

SHEET 1: ATTRIBUTE TABLE

This sheet forms the basis for the entire model. It is at this sheet that the respective measures at the drop down boxes need to be chosen. For example, in this case, the user needs to select which alert time procedure he/she wishes to evaluate. The possible procedures are: VMS/ EMS, website/ application, SMS and email. Moreover, if it is desired to make alterations among the measure types, it needs to be made in this sheet. The phrasing measure type is used to distinguish among which measures are applicable to which transport environment.

As mentioned previously, a measure whose format is red represents a measure that is only applicable to the private transport environment. A measure whose format is blue represents a measure that is only applicable to the public transport environment. A measure whose format is black represents a measure that is applicable to both the private- and the public transport environment. If the user then, for example, choses to evaluate the performance of a private transport project, all of the blue measures will be left out of the computation.

It should however be mentioned that, even though it is possible to alter the measure types based on the user's (or project's) specific requirements, this alteration is not necessarily encouraged. The reason for this is that it was impossible for this author to test all possible alterations. Therefore, it could be that some alterations result in errors. Nevertheless, if alterations are made, the exact same colour type blue and/or red needs to be used. Moreover, the measures that are pre-set to red and blue should stay these colours since that is how they were defined.

After the respective measures at the drop down boxes have been chosen and after the measure types have been altered, the user needs to click the button 'Update Measures' as shown in the user form. (Note: the columns should never be collapsed when running the macros.)

SHEET 2: A - PRIVATE

This sheet is shown when the user clicks the button 'Private Transport' as shown in the user form. This sheet, in essence, filters the sheet 'Attribute Table' to only include the measures that were formatted either red or black.

At this sheet the user needs to input the before- and the after scores of each measure. The unit of each measure is shown in the column labelled 'Unit'. Refer to Figure 122.

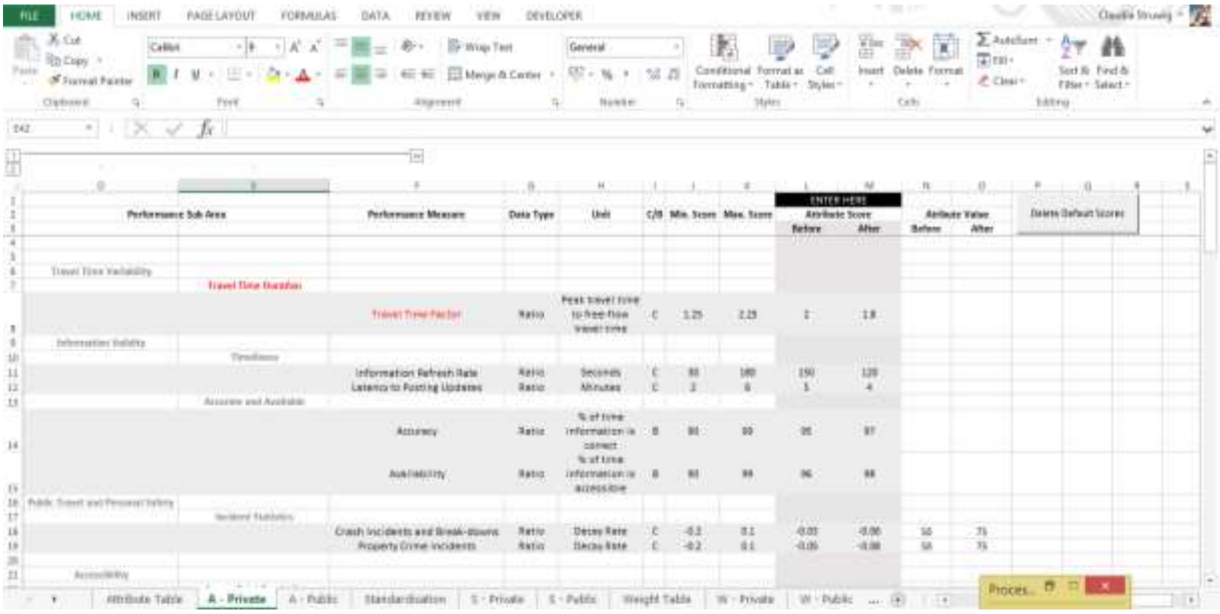


Figure 122: Sheet 2 - Screenshot

The user needs to (preferably) enter scores that fall within the minimum- and the maximum scores of the respective measure. For a benefit measure, if a number bigger than the maximum score is entered, the attribute value has been programmed to automatically equal 100. If a number smaller than the minimum score is entered, the attribute value has been programmed to automatically equal 0. For a cost measure, if a number bigger than the maximum score is entered, the attribute value has been programmed to automatically equal 0. If a number smaller than the minimum score is entered, the attribute value has been programmed to automatically equal 100.

For simplification reasons, default scores have been provided. These scores can be removed by clicking the button 'Delete Default Scores' at the top right part of this work sheet.

After the scores have been provided as input, the user first needs to click the button 'Compute All Values' and then click the button 'Continue'. These buttons are shown at the bottom of this work sheet. When the 'Continue' button is clicked, the user will be taken to the sheet 'MAVT'.

SHEET 3: A - PUBLIC

This sheet is shown when the user clicks the button 'Public Transport' as shown in the user form. This sheet, in essence, filters the sheet 'Attribute Table' to only include the measures that were formatted either blue or black.

At this sheet the user also needs to input the before- and the after scores of each measure (or use the default scores), then click the button 'Compute All Values' and then click the button 'Continue'. By clicking the latter mentioned button, which can be found at the bottom of this work sheet, the user will also be taken to the sheet ‘MAVT’.

SHEET 4: STANDARDISATION

This sheet includes the value functions of all the measures whose data was not obtained from the surveys. These include all the checklist measures, index measures, scorecard measures and increase-decrease measures. This sheet is always taken into consideration for computation. However, if a measure has been removed from the analysis due to its chosen measure type and the chosen transport evaluation environment, it is designated by the letters ‘N/A’. This then indicates that this measure was not taken into consideration for computation.

SHEET 5: S - PRIVATE

This sheet includes the value functions of all the possible private transport measures whose data was obtained from the surveys. This sheet is only taken into consideration for computation when the user has clicked the button ‘Private Transport’ as shown in the user form. However, if a measure has been omitted from the analysis due to the fact that only one option can be selected at the drop down box measures, it is designated by the letters ‘N/A’. This then indicates that this measure was not taken into consideration for computation.

SHEET 6: S - PUBLIC

This sheet includes the value functions of all the possible public transport measures whose data was obtained from the surveys. This sheet is only taken into consideration for computation when the user has clicked the button ‘Public Transport’ as shown in the user form. However, if a measure has been omitted from the analysis due to the fact that only one option can be selected at the drop down box measures, it is designated by the letters ‘N/A’. This then indicates that this measure was not taken into consideration for computation.

SHEET 7: WEIGHT TABLE

This sheet is linked to the sheet ‘Attribute Table’. That is, when either one of the buttons ‘Update Measures’ or ‘Update Measure Type’ as shown on the user form is clicked, the chosen measure type (i.e. the format of the measure) and the representative measures chosen at the drop down boxes are copied to this sheet from the sheet ‘Attribute Table’. (Note: the coding for both of these buttons are exactly the same. They were merely presented separately to prevent confusion.)

This sheet implements bottom-up hierarchical weighting and summarises the weights of all the performance measures, performance sub areas, performance areas and performance categories. The (raw) weights utilised here reflect the weights as obtained from the surveys that were sent out to the ITS experts.

SHEET 8: W - PRIVATE

This sheet filters the sheet 'Weight Table' to only include the measures that were formatted either red or black. It is at this sheet where altering the measure type (as done in the sheet 'Attribute Table') could result in errors. As mentioned previously, it was impossible for this author to test all possible alterations. And unfortunately, due to the principles underlining bottom-up hierarchical weighting, each within family (normalised) weight with the same parent node for each weight level needs to add up to one. This was easy to ensure when all of the measures were included in the analysis; as is the case in the sheet 'Weight Table'. However, when certain measures are omitted from the computation, it could be that additional unforeseen difficulties occur. Nevertheless, it is believed that the necessary steps have been taken to ensure that these errors do not surface.

SHEET 9: W - PUBLIC

This sheet filters the sheet 'Weight Table' to only include the measures that were formatted either blue or black. It is at this sheet where altering the measure type (as done in the sheet 'Attribute Table') could result in errors. As mentioned previously, it was impossible for this author to test all possible alterations. And unfortunately, due to the principles underlining bottom-up hierarchical weighting, each within family (normalised) weight with the same parent node for each weight level needs to add up to one. This was easy to ensure when all of the measures were included in the analysis; as is the case in the sheet 'Weight Table'. However, when certain measures are omitted from the computation, it could be that additional unforeseen difficulties occur. Nevertheless, it is believed that the necessary steps have been taken to ensure that these errors do not surface.

SHEET 10: MAVT

This sheet is also linked to the sheet 'Attribute Table'. That is, the chosen measure type (i.e. the format of the measure) and the representative measures chosen at the drop down boxes are copied to this sheet from the sheet 'Attribute Table'.

Moreover, the attribute values as computed in either one of the sheets 'A - Private' or 'A - Public' are copied to this sheet. The out of family weights as computed in either one the sheets 'W - Private' or

'W - Public' are also copied to this sheet. If the user is evaluating the performance of a private transport project, the values computed at the sheet 'A - Private' and the weights computed at the sheet 'W - Private' are used. The opposite is true when the user is evaluating the performance of a public transport project.

When the 'Calculate' button at the top of this sheet is clicked, the additive model integral to MAVT is implemented to determine the overall value for both the before- and the after scenarios. These overall values are automatically shown in a pop-up message box. Refer to Figure 123.

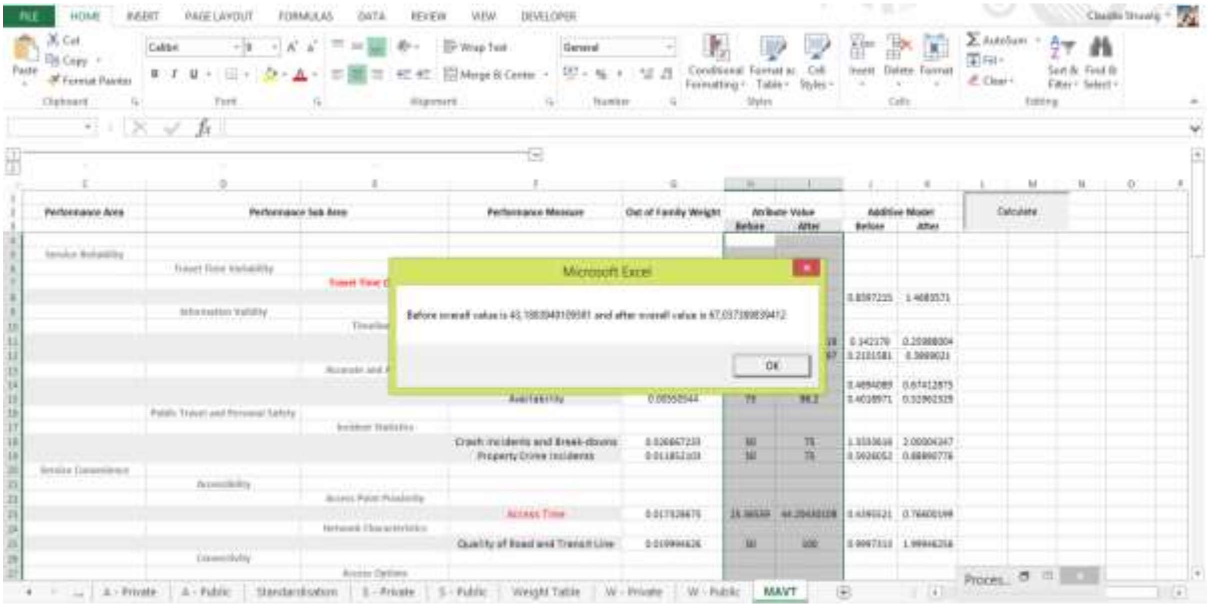
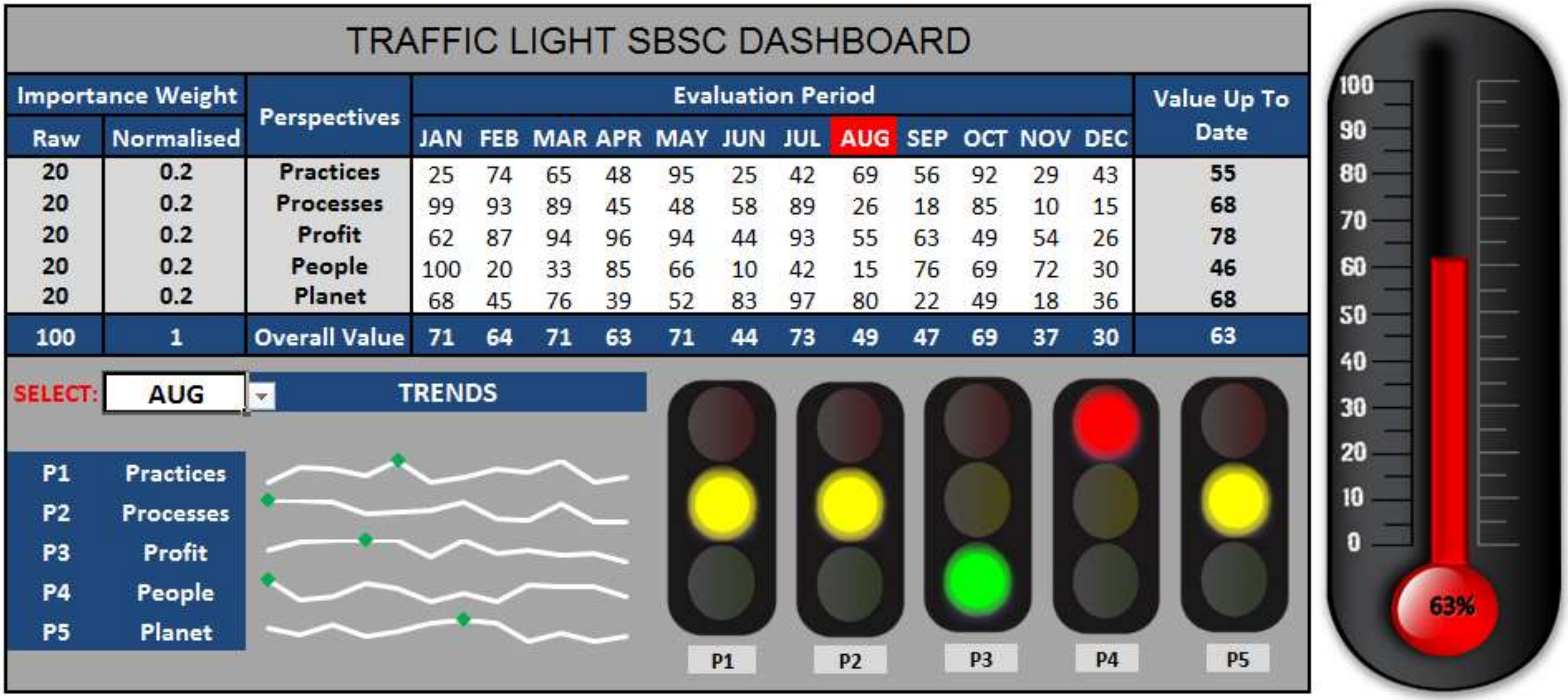


Figure 123: Sheet 10 - Screenshot

If the user wishes to restart the analysis, he/she can click the button 'Reset Values' as shown in the user form.

6.6 PERFORMANCE DASHBOARD

The performance dashboard, as developed herein, can be viewed by referring to the attached CD. The content of this CD is listed in Appendix F. A screenshot of this dashboard can be seen in Figure 124.



TRAFFIC LIGHT SBSC DASHBOARD

Importance Weight		Perspectives	Evaluation Period												Value Up To Date
Raw	Normalised		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
20	0.2	Practices	25	74	65	48	95	25	42	69	56	92	29	43	55
20	0.2	Processes	99	93	89	45	48	58	89	26	18	85	10	15	68
20	0.2	Profit	62	87	94	96	94	44	93	55	63	49	54	26	78
20	0.2	People	100	20	33	85	66	10	42	15	76	69	72	30	46
20	0.2	Planet	68	45	76	39	52	83	97	80	22	49	18	36	68
100	1	Overall Value	71	64	71	63	71	44	73	49	47	69	37	30	63

SELECT: AUG

TRENDS

P1	Practices
P2	Processes
P3	Profit
P4	People
P5	Planet

Figure 124: Traffic Light SBSC Dashboard

6.6.1 INPUT PARAMETERS

Unfortunately, due to time constraints, the dashboard was not designed to automatically sync with the five Microsoft Excel VBA models. That is, the user has to manually input the performance values of each perspective and for each month into this dashboard. These values are entered at the top middle part of Figure 124.

If desired, the user can alter the importance weight allocated to each perspective. If the user changes these raw weights at the top left part of Figure 124, the new normalised weights are automatically computed. However, the default scenario is to evaluate the weights of the perspectives with equal importance. In this sense, each perspective has an importance weight of 20%.

The user can also select the month up and until which he/she wishes to evaluate the project's overall performance. This can be chosen at the drop down box at the bottom left part of Figure 124. The specific month chosen will then automatically be highlighted red under the row labelled 'Evaluation Period' at the top middle part of Figure 124.

6.6.2 DEDUCTIONS

After entering the performance values of each perspective and for each month, any month's overall performance can be viewed in the row labelled 'Overall Value' at the middle part of Figure 124. This overall value is computed by using the additive model. That is, the sum of the product of each perspective's performance value and its importance weight.

In the column labelled 'Value Up To Date' at the top right part of Figure 124, the user can view the project's performance up and until the month he/she selected. The values in this column are computed by adding each month's value for each perspective, respectively, and then dividing the total value by the number of months up and until the date selected. For example: if the month June was selected, the total value would have been divided by six. The overall value under this column is computed analogously to the overall values of each month. This value is also depicted by the semi-detached thermometer positioned to the right of Figure 124. The content of this thermometer was programmed to move up and down based on the size of the overall value up to date.

At the bottom middle part of Figure 124, the project's performance trends for each perspective are depicted as sparklines. The green dots on these sparklines resemble the points (along the course of the year) at which the highest performance values were obtained.

At the bottom right part of Figure 124, five traffic lights are shown. These traffic lights depict the project's performance in each perspective up and until the month selected. In essence, the traffic lights are linked to the values in the column labelled 'Value Up To Date'. These lights were programmed to be red if the overall value up to date is below 50. If the overall value up to date is between 50 and 75, the traffic light is yellow. Any value up to date that is higher than 75 is shown as a green traffic light. A red light thus resembles a danger zone, a yellow light a vulnerable zone and a green light a safe zone. The ranges chosen for the traffic light signs can easily be altered to meet the needs of the user (or project) under consideration.

6.6.3 VALUE

In order to illustrate the developed dashboard's value and capability, default values were generated and provided as input to this dashboard. Based on this author's opinion, the deductions that can be made from the data in this graphical representation are extremely useful and provides a holistic view of a project's performance (health). In essence, this dashboard can facilitate implementing agencies and decision makers to easily and instantaneously obtain an impression of the project's performance in each sustainability perspective as well as its overall performance.

6.7 PERFORMANCE MANAGEMENT

6.7.1 INCENTIVISATION EXAMPLE APPLICATION

This section provides a private transport incentivisation example for the performance area: service reliability. Refer to Table 115.

Table 115: Service Reliability Incentivisation Example

No.	Performance Measure	Target Service Level (+10)	Top Score Band (-10)	Middle Score Band (-50)	Bottom Score Band (-500)	Performance Score
		Number of Days				
1	Travel Time Factor	18	5	4	3	-1570
2	Information Refresh Rate	23	6	1	0	120
3	Latency to Posting Updates	27	2	1	0	200
4	Accuracy	25	3	1	1	-330
5	Availability	24	3	2	1	-390
6	Crash Incidents and Break-downs	21	7	2	0	40
7	Property Crime Incidents	16	8	4	2	-1120
	Total (Performance Area) Performance Score					-3050
	Absolute Minimum Score					-117600
	Absolute Maximum Score					2100
	Standardised Performance Score					0.957
	Percentile Region					5
	Incentivisation Threshold					+10%

If the contractor (or the operator) is only being evaluated based on his/her performance in the performance area: service reliability and if the contractor's (or the operator's) agreed upon nominal service payment is R1 000 000, he/she will get paid R1 100 000. In essence, the contractor (or the operator) is rewarded with R100 000.

7. SUMMARY OF RESULTS

7.1 PERFORMANCE MEASUREMENT FRAMEWORK

An all-encompassing measurement framework that lays the groundwork for managing the performance of ITS deployments have been developed. An overview of the five sustainability perspectives and their relating performance categories, pertaining to the proposed SBSC measurement framework, is given in Figure 125.

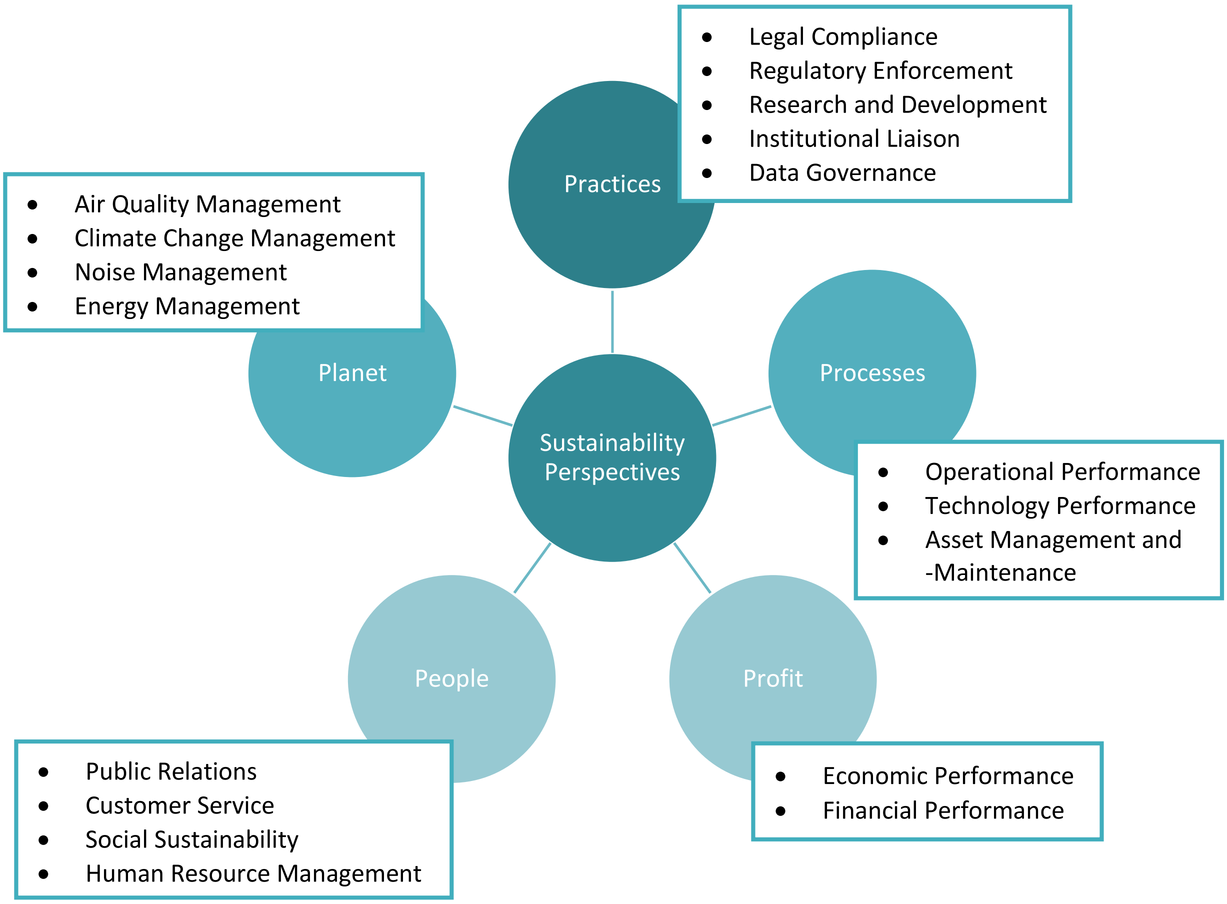


Figure 125: Sustainability Perspectives and Performance Categories

An overview of the performance areas pertaining to the identified performance categories, per sustainability perspective, is given in Table 116

Table 116: Performance Categories and Performance Areas

PRACTICES: GOVERNANCE, PLANNING AND DECISION MAKING
Legal Compliance: Legal Sources
Regulatory Enforcement: Regulators and Regulatory Documents
Research and Development: Research Support and Creativity Support

Institutional Liaison: Institutional Coordination and -Cooperation and Institutional Robustness Data Governance: Data Management
PROCESSES: OPERATIONS, SERVICES AND MAINTENANCE
Operational Performance: Service Reliability, Service Convenience, Operational Seamlessness and Operating Efficiency Technology Performance: System Health and System Performance Asset Management and -Maintenance: Asset Management and Asset Maintenance
PROFIT: MONEY MATTERS
Economic Performance: Economic Sustainability, Economic Vitality and Socio-Economic Prosperity Financial Performance: Financial Feasibility and Investment Management
PEOPLE: PEOPLE MATTERS
Public Relations: Marketing and Networking Customer Service: Traveller Information Provision and General Support Information Social Sustainability: Sustainable Service Delivery and Sustainable Living Human Resource Management: Employee Performance Management
PLANET: ENVIRONMENTAL MATTERS
Air Quality Management: Air Pollution Monitoring Climate Change Management: Weather Monitoring Noise Management: Noise Exposure Monitoring Energy Management: Energy Use Monitoring

An overview of the performance sub areas pertaining to the identified performance areas, per performance category and per sustainability perspective, is given in Table 117.

Table 117: Performance Areas and Performance Sub Areas

PRACTICES: GOVERNANCE, PLANNING AND DECISION MAKING
Legal Compliance
Legal Sources: Legislations and Acts (Transport, Environment, Labour, Safety, Security and Communications)
Regulatory Enforcement
Regulators: Governing Bodies Regulatory Documents: Regulations and Policies
Research and Development
Research Support: Research Development Creativity Support: Project Development
Institutional Liaison
Institutional Coordination and -Cooperation: Operational Alignment and Strategy Alignment Institutional Robustness: Business Continuity
Data Governance
Data Management: Information System Governance Procedures

PROCESSES: OPERATIONS, SERVICES AND MAINTENANCE
Operational Performance
Service Reliability: Travel Time Variability, Information Validity and Public Travel- and Personal Safety Service Convenience: Accessibility, Connectivity and Regularity Operational Seamlessness: Incident Management Operating Efficiency: Service Quality and Service Utilisation
Technology Performance
System Health: System Availability System Performance: Equipment Quality and Data Quality
Asset Management and -Maintenance
Asset Management: Operations Management (Record, Monitor, Control and Evaluate) Asset Maintenance: Preventative- and Corrective Maintenance
PROFIT: MONEY MATTERS
Economic Performance
Economic Sustainability: System Adaptability and System Preservation Economic Vitality: Economic Development and Economic Growth Socio-Economic Prosperity: Social Benefits (Energy and Environment, Safety, Efficiency, Customer Satisfaction, Mobility and Productivity)
Financial Performance
Financial Feasibility: Benefit-Cost Analysis (Non-recurring Costs, Recurring Costs, Miscellaneous Costs and Social Costs) Investment Management: Investment Performance (Capital Gain)
PEOPLE: PEOPLE MATTERS
Public Relations
Marketing: Service Promotion (Media) Networking: Service Interaction (Social Media)
Customer Service
Traveller Information Provision: Assist (Trip Planning), Confirm (Transit- and Traffic Information), Notify (Incident Notification), Advise (Route Guidance) General Support Information: Logging Attendance, Inter-personal Interaction and Self-service Systems
Social Sustainability
Sustainable Service Delivery: Social Justice and Social Equality Sustainable Living: Social Development
Human Resource Management
Employee Performance Management: Employee Satisfaction, Employee Commitment, Employee Engagement and Employee Development
PLANET: ENVIRONMENTAL MATTERS
Air Quality Management
Air Pollution Monitoring: Mobile Source and Greenhouse Gas Emissions
Climate Change Management
Weather Monitoring: Driving Behaviour (Impact)
Noise Management
Noise Exposure Monitoring: Noise Sources and -Receivers
Energy Management
Energy Use Monitoring: Energy Efficiency

The measurement fields relating to each of the aforementioned performance sub areas were also identified. Moreover, for each of the identified measurement fields, viable performance measures were stipulated. Due to the vast number of performance measures proposed, they are not listed here.

7.2 PERFORMANCE MEASURES

All of the KPIs needed for performance evaluation have been formalised. This entailed elaborating on each of the proposed measure's: measurement system, evaluation criterion, interested party, classification type, measurement technique, measurement time frame, measurement scale and data type as well as measurement feasibility.

7.3 PERFORMANCE MEASUREMENT

The performance score assessment of each of the proposed measures were established. This entailed developing checklists for all of the measures that have nominal data, indices for all of the measures that have ordinal data and that are influenced by separate empirical indicators, scorecards for all of the qualitative, low granularity measures that have ordinal data, value functions for all of the measures that have ratio data as well as score bands stipulating rates of change for all of the measures that permit comparisons to previous periods.

7.4 MEASUREMENT DATA

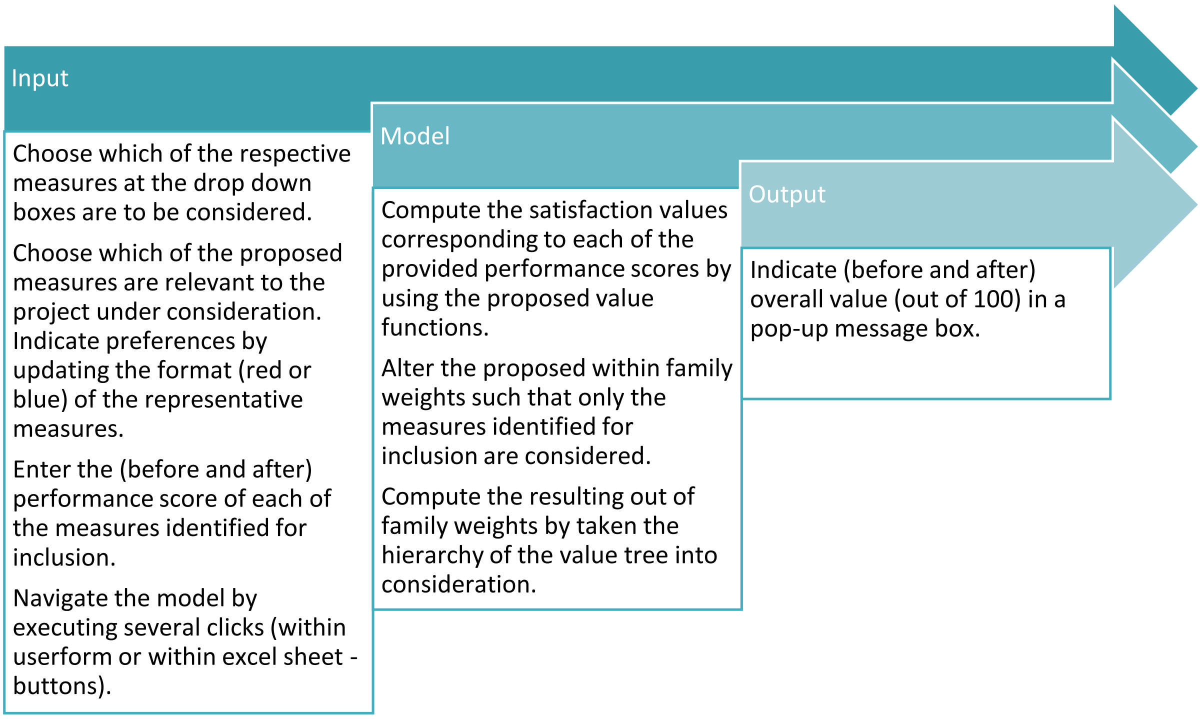
The importance weights of the separate empirical indicators needed for index development and the (satisfaction) values of the (pre-determined and user-specified) data points needed for value function development were obtained from the value elicitation surveys conducted herein. The data needed for the establishment of the scorecards and the score bands were, however, pre-determined without acquiring the input from the representative experts in the field of study. Based on the application required herein, this was deemed viable.

The importance (within and out of family) weights of each of the performance-related aspects were obtained from the weight elicitation surveys conducted herein. However, the importance weights corresponding to the five sustainability perspectives were not obtained. In the final analysis, where these values are required, they were taken to each be equally important.

7.5 MANAGEMENT TOOL

7.5.1 MEASUREMENT MODEL

Five Microsoft Excel VBA models, representing the project’s performance in each of the five sustainability perspectives, have been developed. These models are founded on value measurement theory and implement the Additive Model inherent to MAVT. An overview of these models is given in Figure 126. This figure provides specific reference to the input required, the modelling conducted and the output provided.



Choose which of the respective measures at the drop down boxes are to be considered.

Choose which of the proposed measures are relevant to the project under consideration. Indicate preferences by updating the format (red or blue) of the representative measures.

Enter the (before and after) performance score of each of the measures identified for inclusion.

Navigate the model by executing several clicks (within userform or within excel sheet - buttons).

Compute the satisfaction values corresponding to each of the provided performance scores by using the proposed value functions.

Alter the proposed within family weights such that only the measures identified for inclusion are considered.

Compute the resulting out of family weights by taken the hierarchy of the value tree into consideration.

Indicate (before and after) overall value (out of 100) in a pop-up message box.

Figure 126: Input, Model and Output - VBA Models

7.5.2 PERFORMANCE DASHBOARD

A Microsoft Excel performance dashboard that documents the results from all five of the Microsoft Excel VBA models, on a per month basis, over an evaluation period of a year, has also been developed. The proposed traffic light SBSC dashboard can be seen in Figure 124. The dashboard depicts a project’s performance in each of the five sustainability perspectives and as a whole (i.e. overall project health).

7.6 PERFORMANCE MANAGEMENT

In order to instigate performance management, an incentivisation structure that is based on activity-based payments and performance-related adjustments to the contractor’s (or the operator’s) nominal service payments have been developed. This entailed, among others, stipulating the performance appraisal period, the performance review cycle, the principles of performance assessment (i.e. target service level-, score band-, point allocation- and performance score development), the payment structure (i.e. incentivisation threshold development) and the payment period.

8. CONCLUSIONS

This research project has described a new method for realising a systematic approach to performance management through performance measurement. In this research project, a structure for evaluating the performance of, specifically, technology investments in the South African transport environment has been embraced. The advocated approach differs from the current measurement systems in place in that it utilises a holistic and generic measurement framework as the baseline for performance appraisal. This framework lays the groundwork for managing the performance, and contributes towards the sustainability, of the ITS deployments. The method put forth herein, in the form of the envisioned performance management tool, shows encouraging results towards ensuring the effective deployment and maintenance of the ITS applications.

This sections re-examines the results obtained by answering the unanswered questions posed in the preliminary part of this research project and by discussing the implications of the advocated approach. This section concludes with a discussion on the recommended way forward and some final remarks.

RESEARCH-RELATED QUESTIONS

SCIENTIFIC RESEARCH QUESTIONS

What are the key scientific issues that the research contributes to?

1. This research project facilitates the **integration of three diverse and unrelated research fields**. That is, the integration of all concepts pertaining to transport performance measurement, (conceptual) performance frameworks and the field of MCDM.
2. This research project advocates a **performance management approach** that is scalable and suitable to address the specific requirements as posed by a developing country and by the evolution of ITS technologies.
3. Through the identification of the five sustainability perspectives, this research project inherently ensures the effective development and maintenance of the ITS applications; thereby supporting **sustainable transport development**.
4. By providing a context for standard and/or target development, this research project stimulates consensus-oriented performance appraisal which, in itself, fosters the realisation of a (national) **performance management regime**.

What sets the research apart from other existing tools and evaluation methods?

1. Since the pursued performance management approach adheres to a **cyclical life-cycle approach**, the data capturing automatically allows for the continuous assessment and improvement of the ITS projects; thereby enabling strategic direction for the ITS projects.
2. The tool's **self-assessment nature** (i.e. measuring and generating results automatically) essentially creates for a quick and effortless assessment of the transport project's performance, per sustainability perspective or for the project as a whole, in the field of technology investments.
3. The management tool has the innate ability to present results **graphically and logically**. Such representation of results not only makes its interpretation easier, but also facilitates the user in strategically investigating the root causes and/or identifying the underperforming areas of interest.
4. The tool has been developed to be **comprehensive** such that it can be applied to both the private- and the public transport environment, **holistic** such that it considers and includes the opinions of all possible interested parties and **agile** such that it can accommodate any changes in the employer's (or the client's) needs and/or the specific project's desired outcomes.

What value is associated with the approach used?

1. The tool serves as **reference point** for ITS performance management. That is, it can facilitate transport role players in regularly and objectively assessing the effects of their specific applications with regard to the implementation of policies and technologies.
2. The management tool presents **guidelines** to widely accepted performance measures, captures **transferable methodologies** and utilises a **systematic approach** to performance management through performance measurement.
3. The management tool can prevent projects from diverging from their original objectives and can prioritise the contribution of various services to the overall success of the projects; thereby ensuring the **prosperity** of the current- and continuous investments in transport technology.
4. Since the tool is presented in a user-friendly GUI dashboard format, it can inherently allow for the **wider use and application** of a performance driven approach. In essence, the tool can aid ITS applications to meet the needs of (and be of beneficial use to) a wide spectrum of people.

RESEARCH PROPOSITION DRAWBACKS

How were the drawbacks solved?

The tool's possible drawback with regard to its broadness was counteracted by creating an "adjustable" tool. That is, the tool's interface has been designed to vary based on whether it is a private- or a public transport project that is being evaluated. Moreover, if desired, the user can also omit any performance-related aspect that he/she feels is not necessarily applicable to his/her specific circumstances. The tool then automatically takes the aforementioned into account and only uses the remaining applicable aspects when evaluating the performance of the project under consideration.

The tool's possible drawback with regard to the vastness of MCDM (and hence the difficulty with choosing among the many viable methods) was counteracted by conducting extensive research and by inquiring the insights of an expert in the field.

RESEARCH VALIDATION

How was the research validated?

The performance measurement framework, presented as a SBSC, was portrayed and explained in-depth on a website developed by this author. This website was used as the interaction medium to validate and verify the content of the framework. Feedback from personally selected practitioners (in the field of ITS, transport and performance measurement), worldwide, was obtained and the framework was augmented accordingly.

The data needed to develop the standards and/or targets for evaluating the performance of all the identified measures was obtained from six surveys. These surveys were developed to specifically assess and include the opinions of the identified (nationally located) interested parties. The data needed to establish the importance of the performance-related aspect was obtained from five surveys. These surveys were developed to specifically assess and include the opinions of the identified (internationally located) ITS experts.

Before commencing with the back-end design of the proposed tool, significant effort was exerted in acquiring in-depth knowledge of the MCDM field. This resulted in choosing the Additive Model inherent to MAVT. Based on the mathematical principles underlining this model, it was possible to ensure (as the coding was compiled) that the correct procedure was being followed.

In order to ascertain the effectiveness, validity and accuracy of the developed tool, default values were generated and provided as input to the model. Based on this author's opinion, the results obtained were not only deemed fitting and relevant, but also extremely useful.

THE IMPLICATIONS OF THE ADVOCATED APPROACH

The implications of utilising the developed management tool are shown in Table 118. This table compares the current practice with the advocated approach.

Table 118: Current Practice versus Advocated Approach

Current Practice	No.	Advocated Approach
The new areas for consideration, demanded by the ITS deployments, are not exclusively included in performance appraisal.	1	Scalable and suitable: addresses the specific requirements as posed by a developing country and by the evolution of ITS technologies.
Performance appraisal is limited to the employer's (or the client's) viewpoint.	2	Holistic: considers and includes the opinions of all possible interested parties.
Private- and public transport systems are measured in isolation.	3	Comprehensive: applies to both the private- and the public transport environment.
The current measures are likely incompetent for ensuring the sustainable deployment of the advanced transport systems.	4	Competent and concise: provides the necessary performance-related information by only measuring what counts.
Relatively inflexible service that is less responsive to changes.	5	Agile: accommodates any changes in the employer's needs and/or the specific project's desired outcomes.
Insufficient attention is given to the measuring and monitoring of the technology-related aspects of the ITS applications.	6	Smart: embraces a structure for evaluating performance in the field of technology investments.
Performance appraisal methods do not necessarily stimulate the achievement of a performance management regime.	7	Context: serves as the foundation for a (national) performance management regime and fosters the development of an ITS architecture.
Lack of emphasis on a consistent performance measurement approach.	8	Consistent: utilises pre-determined and pre-specified standards and/or targets.
Difficult (or even impossible) to attain an idea of the overall system health.	9	Objective: prioritise the contribution of various services to the overall success of the projects.
Measurement mostly executed on an ad-hoc basis.	10	Continuous: facilitates a cyclical life-cycle approach towards measuring performance.
Measurement not yet fully automated and requires manual efforts.	11	User-friendly: implements self-assessment (i.e. measures and generates results automatically).
Either management tools are absent or a disordered approach to performance appraisal is followed.	12	Systematic: facilitates the user in strategically investigating the root causes and/or identifying the underperforming areas of interest.
Complex and perhaps even tedious measurement systems.	13	Effective: allows for the wider use and application of a performance driven approach.
Inefficient measurement systems in that most have not yet attained full functionality.	14	Efficient: prevents projects from diverging from their original objectives and tracks performance.

Current Practice	No.	Advocated Approach
Concerns have been raised regarding the current practices that have created scepticism around the sustainability of the newly deployed advanced systems.	15	Viable: advocates sustainable transport development (i.e. measurement segmented among the five sustainability perspectives).

THE RECOMMENDED WAY FORWARD

This author recommends that SA continues to enforce its transport networks with ITS initiatives. However, the nation needs to exert effort towards ensuring the effective deployment and maintenance of the ITS applications. Therefore, since the management tool was developed as a South African solution that is not only locally sustainable, but also blazes the trail for the rest of sub-Saharan Africa, it is recommended that SA pursues the advocated performance management approach. However, in order to ease the changeover process, it is recommended that a phased implementation, per province and per implementing agency, be executed. Moreover, since the CoCT was taken as the representative transport environment herein, it is recommended that the implementation commences with the implementing agencies in the Western Province. It is believed that such a phased implementation will ultimately allow for nation-wide consensus-oriented performance appraisal. Therefore, when fully implemented, SA will have the necessary leverage to advocate a performance management regime. If such a regime is in place, the consistency of performance appraisal information and -data will inherently be ensured and hence the development of a national ITS architecture will be fostered.

CONCLUDING REMARKS

In conclusion, this author submits that, even though the concept of managing performance measurement is in its infancy, the need for a systematic approach to performance management through performance measurement and the believed positive outcomes that await those who embark on this path, are evident. The performance management approach advocated herein has proven to have sufficient capability, provide invaluable insights, add significant value to the transport environment as well as being multi-functional, consistent and all-encompassing. Once again, SA offers the entrepreneur many opportunities and subsequent riches as they are identified and developed.

9. RECOMMENDATIONS FOR FUTURE RESEARCH

The following main recommendations, as identified in Table 119, can be made for future research and development.

Table 119: Recommendations for Future Research

Performance Measures	Performance Measurement Framework	Measurement Data	Measurement Model	Performance Dashboard
Elaborate and/or augment current set of identified measures to include the future modifications recommended herein.	Distinguish among interested parties when evaluating performance (specifically in situations where a performance area contains two of more independent parties) by defining metrics that separate the performance of the parties.	Organise focus group sessions with the various survey respondents such that a general consensus on what is warranted from them and what is meant by the set of identified measures can be reached.	Investigate whether the preliminary conclusions are sensitive to changes in aspects of the developed model and/or if they are robust.	Design the performance dashboard to automatically sync with the measurement models.
		Rerun surveys with the aim of obtaining more responses. If necessary, either use a longer data capturing period and/or more aggressive marketing strategies.	Improve the developed model such that it is more agile and that is caters for all of the measures relating to the drop down boxes.	Expand the performance dashboard such that it provides for the three desired applications (i.e. monitor, analyse and manage) and the four layers of information.
	Alter framework to embrace the holistic computation of (social) benefit to cost ratios.		Validate the developed model with some available software package.	
	Consider the impact of operational boundaries on the performance measurement framework.	Acquire the input from the representative experts in the field of study regarding the pre-determined scorecards and score bands.	Use a prototype to assess the performance of a specific ITS project.	Incorporate performance incentivisation at the performance dashboard.
Conduct a financial analysis and an economic assessment on the proposition made herein.				

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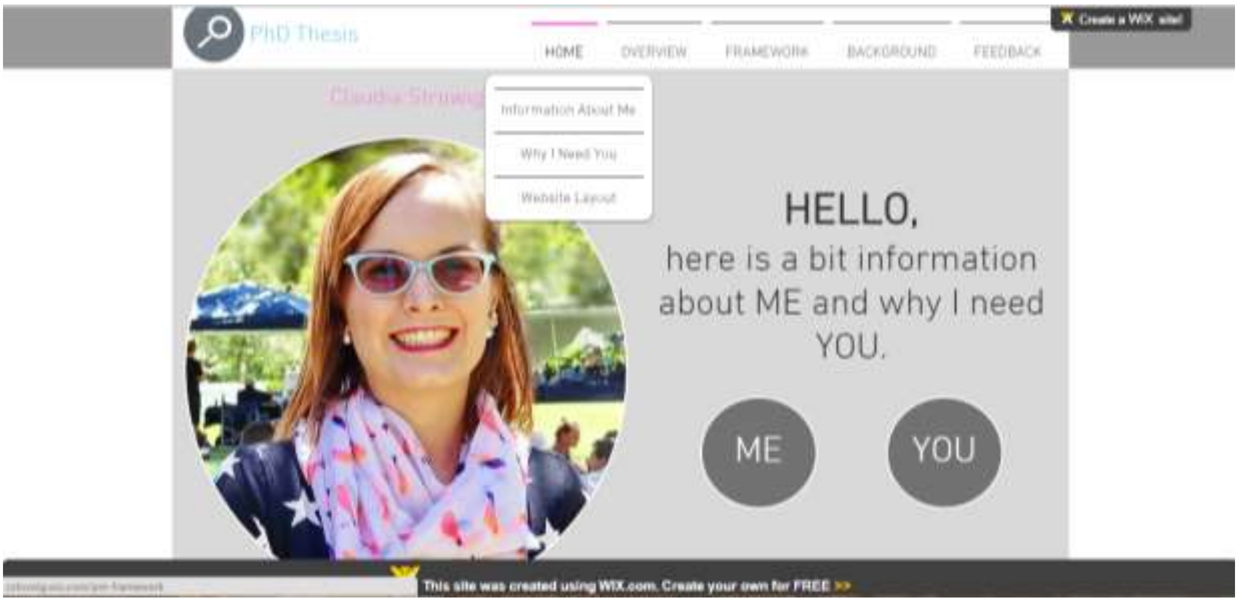
APPENDICES

A. DATA CAPTURING: FRAMEWORK VALIDATION AND VERIFICATION

WIX WEBSITE

Refer to Figure 127 to Figure 131.



HELLO,
here is a bit information about ME and why I need YOU.

This site was created using WIX.com. Create your own for FREE >>

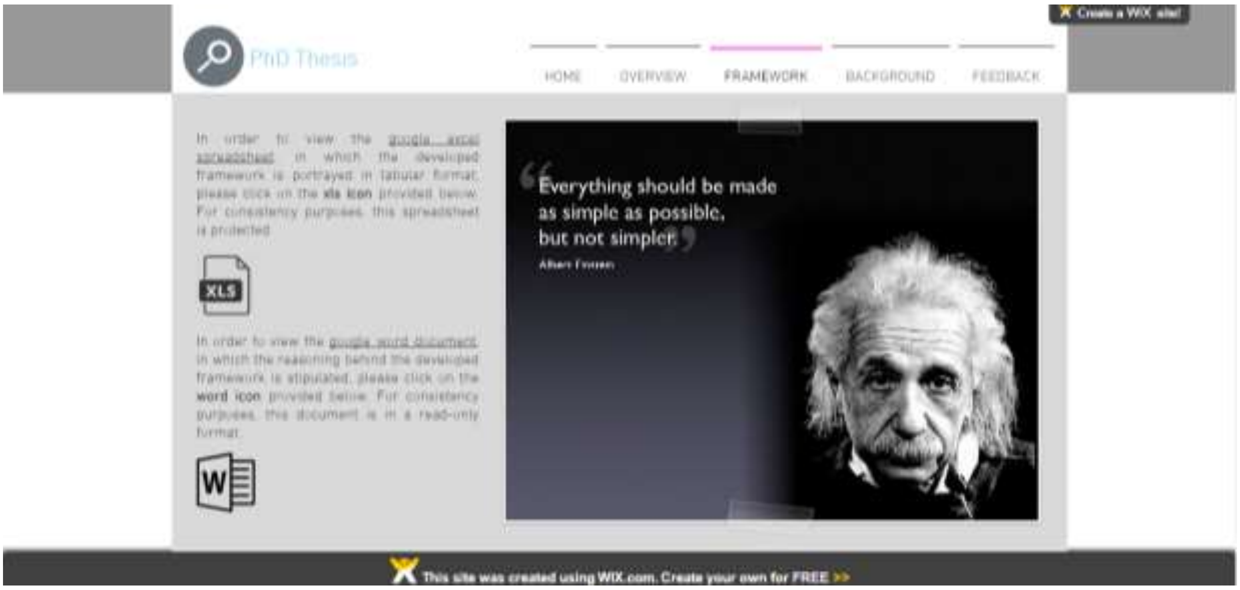
Figure 127: Home Screen

SUSTAINABILITY BALANCED SCORE

I have adopted a Sustainability Balanced Scoreca … sing the performance of ITS Projects.
In the following figure you can see the **perspecti** … **rmance categories** (i.e. boxes) that I
have chosen.

This site was created using WIX.com. Create your own for FREE >>

Figure 128: Overview Screen



In order to view the google excel spreadsheet in which the developed framework is portrayed in tabular format, please click on the **xls icon** provided below. For consistency purposes, this spreadsheet is protected.

In order to view the google word document in which the reasoning behind the developed framework is stipulated, please click on the **word icon** provided below. For consistency purposes, this document is in a read-only format.

"Everything should be made as simple as possible, but not simpler."
Albert Einstein

Figure 129: Framework Screen

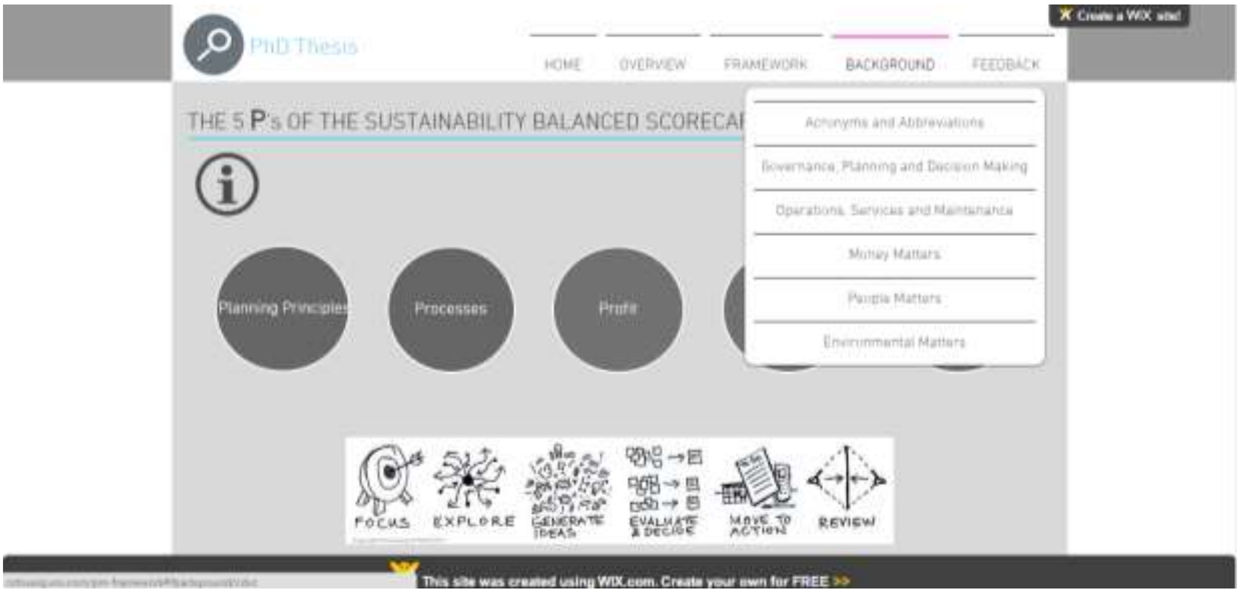
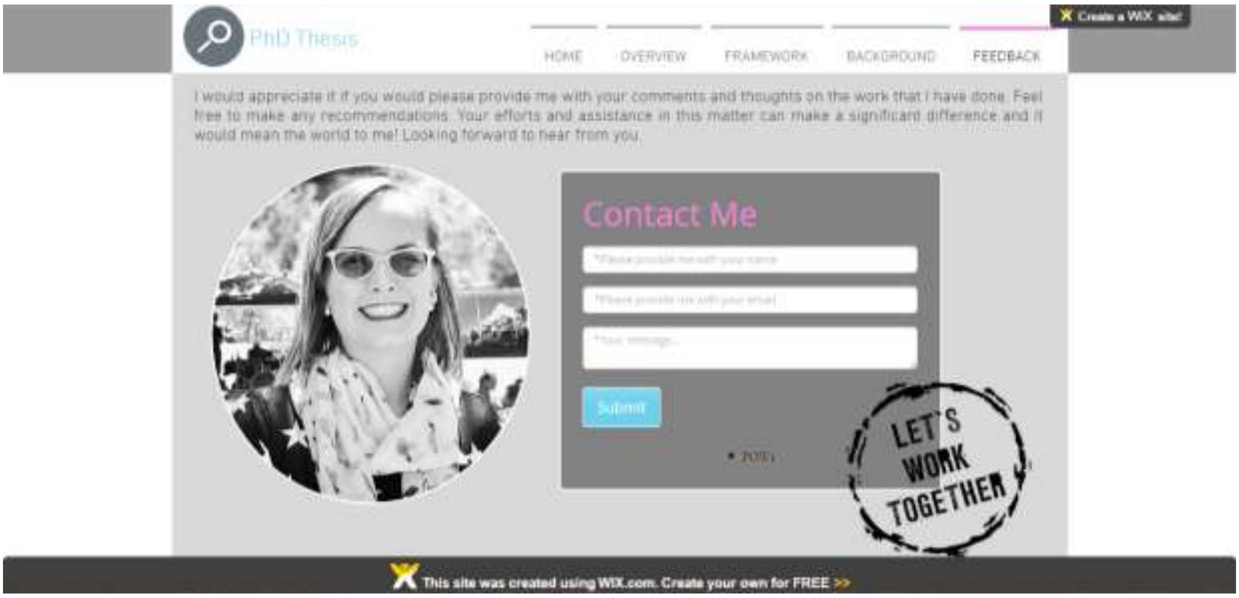


Figure 130: Background Screen



I would appreciate it if you would please provide me with your comments and thoughts on the work that I have done. Feel free to make any recommendations. Your efforts and assistance in this matter can make a significant difference and it would mean the world to me! Looking forward to hear from you.

Figure 131: Feedback Screen

B. DATA CAPTURING: VALUE ELICITATION

GENERAL PUBLIC: PRIVATE TRANSPORT USER

1. What would your satisfaction be if the following scenarios of congestion prevailed?

This refers to the average travel time during peak periods.

Satisfaction	Out of 100
If you drive 25 min instead of 20 min	50
If you drive 30 min instead of 20 min	50
If you drive 35 min instead of 20 min	50
If you drive 40 min instead of 20 min	50

2. With regard to the circumstances mentioned in Question 1, what is the longest driving time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

3. What would your satisfaction be if the following scenarios of information refresh rates prevailed?

This refers to the rate at which information is refreshed (e.g. updating traffic images) on the i-Traffic website to obtain or maintain real-time accuracy.

Satisfaction	Out of 100
Every 30 sec	50
Every 60 sec	50
Every 90 sec	50
Every 120 sec	50

4. What is the slowest refresh rate that you would tolerate/ deem to be satisfactory (after which you would associate anything slower with a satisfaction of 0)?

In seconds.

5. In the event of change (such as the occurrence of incidents), what would your satisfaction be if the following scenarios of latency to posting updates prevailed?

Updates include, among others, incident occurrence alerts made on the i-Traffic website or on the Variable Message Signs next to the freeways.

Satisfaction	Out of 100
Within 2 min after incident verification	50
Between 2 and 3 min after incident verification	50
Between 3 and 4 min after incident verification	50
Between 4 and 5 min after incident verification	50

6. What is the longest latency period that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

7. When travelling by private vehicle from your home to your everyday <u>recreational activities</u>, what would your satisfaction be if you could reach these activities in the following time periods?

Regardless of the time of day.

	Satisfaction Out of 100
Within 5 min	50
Between 5 and 10 min	50
Between 10 and 15 min	50
Between 15 and 20 min	50
Between 20 and 30 min	50

8. What is the longest time period that you would drive to access an everyday recreational activity (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

☐

9. What would your satisfaction be if you were faced with the following commuting times when traveling from <u>home to work or vice versa</u>?

This refers to the average <u>one-way commuting time</u>.

	Satisfaction Out of 100
Less than 20 min	50
Between 20 and 30 min	50
Between 30 and 45 min	50
Between 45 and 60 min	50

10. What is the longest commuting time from home to work or vice versa that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

One-way commuting time in minutes.

11. What would your satisfaction be if the following scenarios of mobility, while travelling on freeways, prevailed?

This refers to your average travel speeds in peak periods.

Satisfaction	Out of 100
If your average travel speed is between 50 and 60 km/h	50
If your average travel speed is between 40 and 50 km/h	50
If your average travel speed is between 30 and 40 km/h	50
If your average travel speed is between 20 and 30 km/h	50

12. What is the slowest travel speed that you would tolerate/ deem to be satisfactory (after which you would associate anything slower with a satisfaction of 0)?

In km/h.

13. What would your satisfaction be if the following scenarios of queuing times prevailed?

Queues could exist due to, for example, defective traffic signals, incidents and road works.

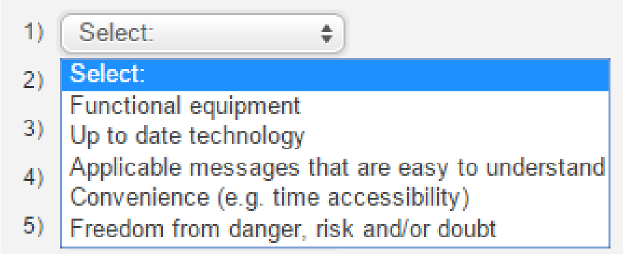
Satisfaction	Out of 100
If you queue for less than 2 min	50
If you queue for 2 to 5 min	50
If you queue for 5 to 10 min	50
If you queue for 10 to 15 min	50

14. What is the longest queuing time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

15. With regard to the status and the performance of the road network infrastructure, how important would you deem the following five attributes to be?

Rank the attributes from most important (i.e. 1) to least important (i.e. 5).

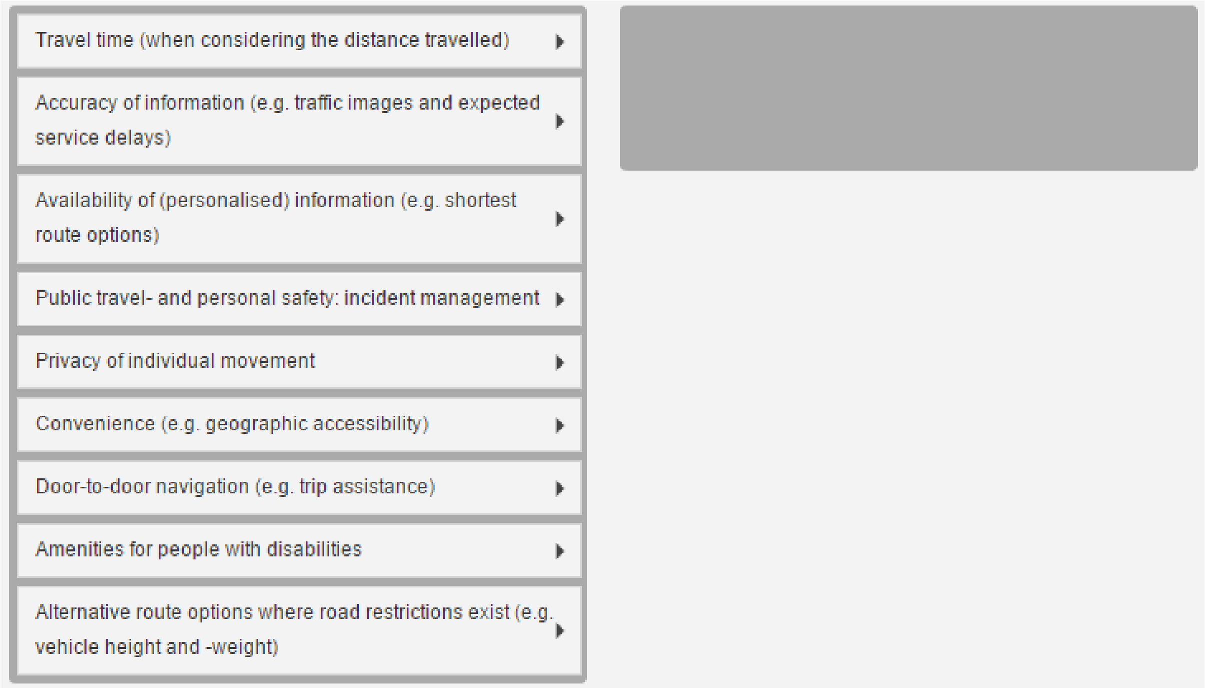


1) Select:
2)
3)
4)
5)

Select:
Functional equipment
Up to date technology
Applicable messages that are easy to understand
Convenience (e.g. time accessibility)
Freedom from danger, risk and/or doubt

16. With regard to the overall service delivery of private transport, how important would you deem the following nine attributes to be?

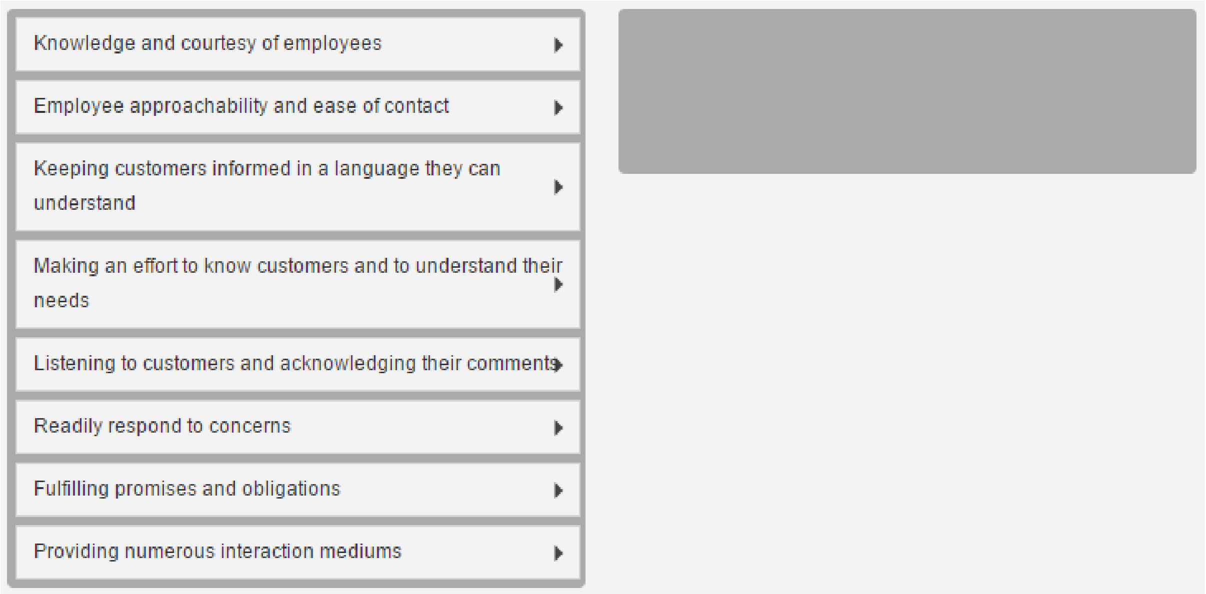
Reposition/ drag and drop the following attributes from most important (i.e. top) to least important (i.e. bottom).



Travel time (when considering the distance travelled)
Accuracy of information (e.g. traffic images and expected service delays)
Availability of (personalised) information (e.g. shortest route options)
Public travel- and personal safety: incident management
Privacy of individual movement
Convenience (e.g. geographic accessibility)
Door-to-door navigation (e.g. trip assistance)
Amenities for people with disabilities
Alternative route options where road restrictions exist (e.g. vehicle height and -weight)

17. With regard to the service interaction, how important would you deem the following eight attributes to be?

Reposition/ drag and drop the following attributes from most important (i.e. top) to least important (i.e. bottom).



Knowledge and courtesy of employees

Employee approachability and ease of contact

Keeping customers informed in a language they can understand

Making an effort to know customers and to understand their needs

Listening to customers and acknowledging their comments

Readily respond to concerns

Fulfilling promises and obligations

Providing numerous interaction mediums

GENERAL PUBLIC: PUBLIC TRANSPORT USER

1. What would your satisfaction be if the following general scenarios of on-time performance prevailed?

Satisfaction	Out of 100
If the transit vehicle arrives late 1 out of 20 times	50
If the transit vehicle arrives late 2 out of 20 times	50
If the transit vehicle arrives late 3 out of 20 times	50
If the transit vehicle arrives late 5 out of 20 times	50

2. With regard to the circumstances mentioned in Question 1, how many times of arriving late would you tolerate/ deem to be satisfactory (after which you would associate anything more with a satisfaction of 0)?

An integer smaller than 20.

3. What would your satisfaction be if the following scenarios of information refresh rates prevailed?

This refers to the rate at which information is refreshed (e.g. updating vehicle tracking images) on the representative service provider's website or application to obtain or maintain real-time accuracy.

Satisfaction	Out of 100
Every 30 sec	50
Every 60 sec	50
Every 90 sec	50
Every 120 sec	50

4. What is the slowest refresh rate that you would tolerate/ deem to be satisfactory (after which you would associate anything slower with a satisfaction of 0)?

In seconds.

5. In the event of change (such as a vehicle break-down), what would your satisfaction be if the following latency to posting updates prevailed?

Updates include, among others, interruption alerts and timetable corrections made on the representative service provider's website or application and/or on the electronic message signs at the stops or stations.

Satisfaction	Out of 100
Within 2 min after verifying the interruption	50
Between 2 and 3 min after verifying the interruption	50
Between 3 and 4 min after verifying the interruption	50
Between 4 and 5 min after verifying the interruption	50

6. What is the longest latency period that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

7. When travelling with public transport to your everyday <u>recreational activities</u>, what would your satisfaction be if you could reach transit facilities (i.e. stops and stations) within the following distances?

As measured from your home.

Satisfaction	Out of 100
Within 0.5 km	50
Between 0.5 and 1 km	50
Between 1 and 1.5 km	50
Between 1.5 and 2 km	50

8. What is the longest access distance to transit facilities that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In kilometres.

9. What would your satisfaction be if you were faced with the following average commuting times when travelling from <u>home to work or vice versa</u>?

This refers to the <u>one-way commuting time</u>.

Satisfaction	Out of 100
Less than 30 min	50
Between 30 and 45 min	50
Between 45 and 60 min	50
Between 60 and 90 min	50

10. What is the longest commuting time from home to work or vice versa that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

One-way commuting time in minutes.

11. What would your satisfaction be if you were faced with the following scenarios of transfer distances?

This refers to the distance travelled when changing modes of transport. For example: the distance between a bus stop and a train station.

Satisfaction	Out of 100
Less than 0.5 km	50
Between 0.5 and 1 km	50
Between 1 and 1.5 km	50
Between 1.5 and 2 km	50

12. What is the longest transfer distance that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In kilometres.

13. What would your satisfaction be if the following scenarios of service frequency, during peak periods, prevailed?

This refers to the rate at which transit vehicles arrives at stops/stations.

Satisfaction	Out of 100
Every 0 to 5 min	50
Every 5 to 10 min	50
Every 10 to 15 min	50
Every 15 to 20 min	50

14. What is the slowest peak period service frequency that you would tolerate/ deem to be satisfactory (after which you would associate anything slower with a satisfaction of 0)?

In minutes.

15. From when in the mornings would you like the transit service to be available?

In general.

16. Till when in the evenings would you like the transit service to be available?

In general.

17. What would your satisfaction be if the following scenarios of waiting times prevailed?

This refers to situations where the transit vehicle is delayed (i.e. running behind schedule).

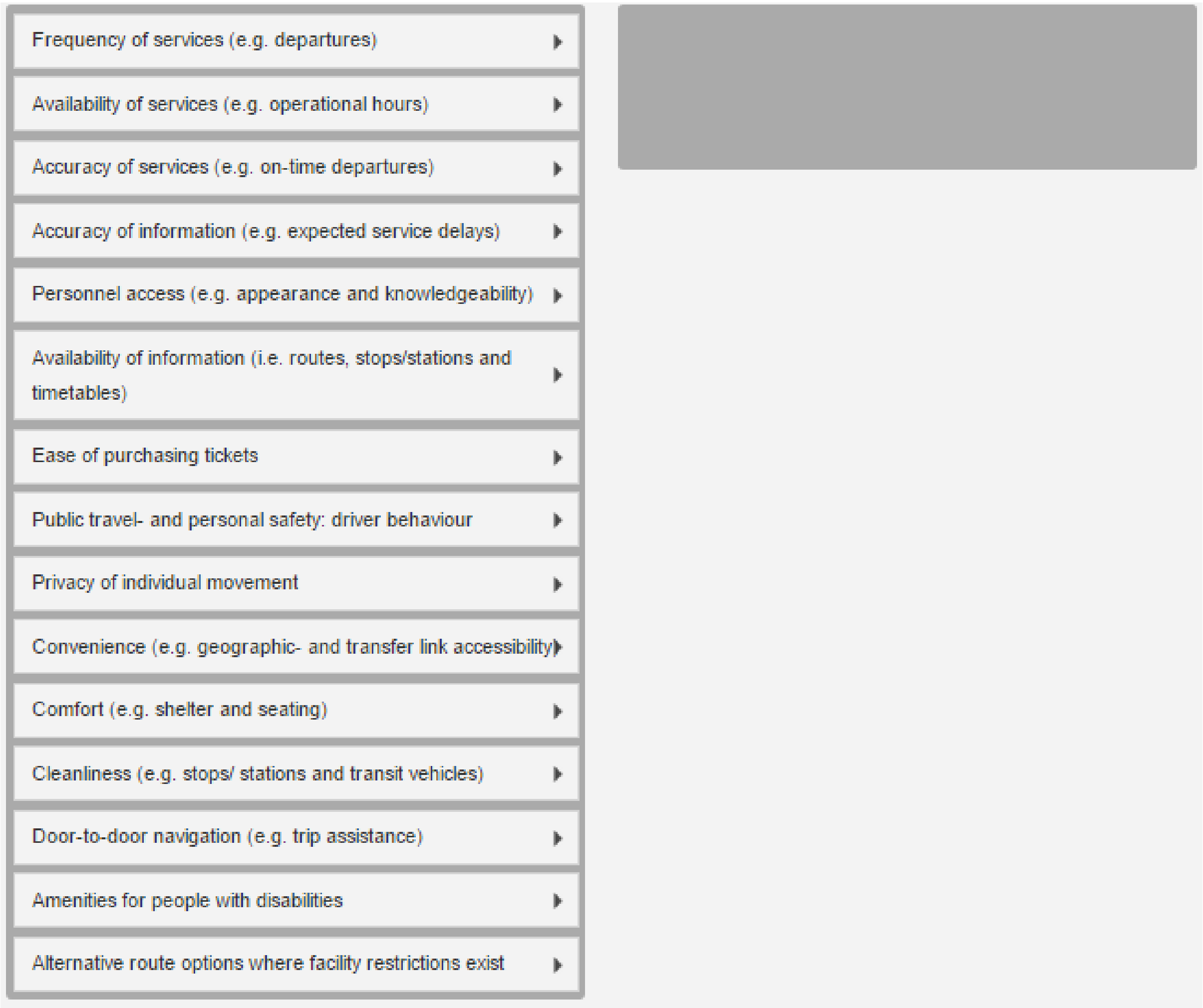
Satisfaction	Out of 100
If you wait less than 5 min	50
If you wait 5 to 10 min	50
If you wait 10 to 15 min	50
If you wait 15 to 20 min	50

18. What is the longest waiting time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

19. With regard to the overall service delivery of public transport, how important would you deem the following 15 attributes to be?

Reposition/ drag and drop the following attributes from most important (i.e. top) to least important (i.e. bottom).



Frequency of services (e.g. departures)

Availability of services (e.g. operational hours)

Accuracy of services (e.g. on-time departures)

Accuracy of information (e.g. expected service delays)

Personnel access (e.g. appearance and knowledgeability)

Availability of information (i.e. routes, stops/stations and timetables)

Ease of purchasing tickets

Public travel- and personal safety: driver behaviour

Privacy of individual movement

Convenience (e.g. geographic- and transfer link accessibility)

Comfort (e.g. shelter and seating)

Cleanliness (e.g. stops/ stations and transit vehicles)

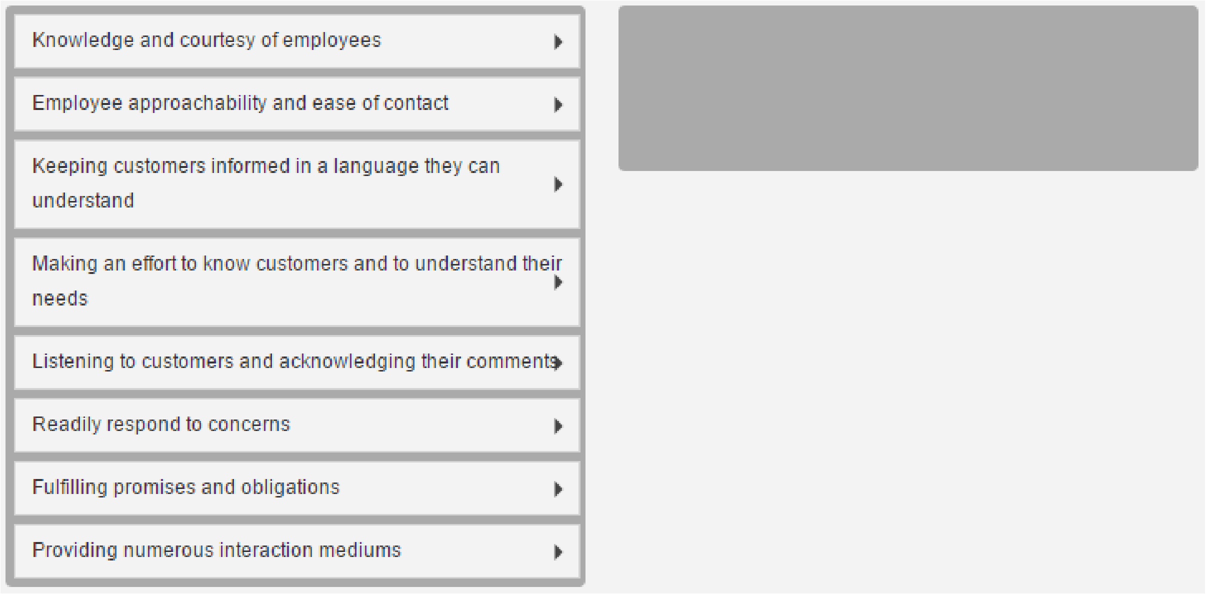
Door-to-door navigation (e.g. trip assistance)

Amenities for people with disabilities

Alternative route options where facility restrictions exist

20. With regard to the service interaction, how important would you deem the following eight attributes to be?

Reposition/ drag and drop the following attributes from most important (i.e. top) to least important (i.e. bottom).



- Knowledge and courtesy of employees
- Employee approachability and ease of contact
- Keeping customers informed in a language they can understand
- Making an effort to know customers and to understand their needs
- Listening to customers and acknowledging their comments
- Readily respond to concerns
- Fulfilling promises and obligations
- Providing numerous interaction mediums

OPERATOR OR CONTRACTOR: PRIVATE TRANSPORT

1. What would your satisfaction be if the following scenarios of information accuracy prevailed?

Information that is accurate means that the correct information is portrayed to the users.

Satisfaction	Out of 100
Accurate 96% of the time	50
Accurate 97% of the time	50
Accurate 98% of the time	50
Accurate 99% of the time	50

2. What is the worst information accuracy that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

3. What would your satisfaction be if the following scenarios of information availability prevailed?

Information that is available means that the information is accessible to the users.

	Satisfaction Out of 100
Available 96% of the time	50
Available 97% of the time	50
Available 98% of the time	50
Available 99% of the time	50

4. What is the worst information availability that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

5. What would your satisfaction be if the following scenarios of detection times prevailed?

This refers to the time it takes to detect an incident and is measured from incident occurrence time.

	Satisfaction Out of 100
Within 90 sec after incident occurrence	50
Between 90 and 120 sec after incident occurrence	50
Between 120 and 150 sec after incident occurrence	50
Between 150 and 180 sec after incident occurrence	50

6. What is the longest detection time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In seconds.

7. What would your satisfaction be if the following scenarios of verification times prevailed?

This refers to the time it takes to verify and classify an incident according to incident type and is measured from incident detection time.

Satisfaction	Out of 100
Within 30 sec after incident detection	50
Between 30 and 60 sec after incident detection	50
Between 60 and 90 sec after incident detection	50
Between 90 and 120 sec after incident detection	50

8. What is the longest verification time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In seconds.

9. What would your satisfaction be if the following scenarios of notification times prevailed?

This refers to the time it takes to no notify the partner authorities of the incident and is measured from incident verification time.

Satisfaction	Out of 100
Within 30 sec after incident verification	50
Between 30 and 60 sec after incident verification	50
Between 60 and 90 sec after incident verification	50
Between 90 and 120 sec after incident verification	50

10. What is the longest notification time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In seconds.

11. What would your satisfaction be if the following scenarios of response times prevailed?

This refers to the time it takes the authorities to reach the scene of the incident and is measured from incident verification time.

Satisfaction	Out of 100
Within 9 min after incident verification time	50
Between 9 and 12 min after incident verification time	50
Between 12 and 15 min after incident verification time	50
Between 15 and 18 min after incident verification time	50

12. What is the longest response time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

13. What would your satisfaction be if the following scenarios of alert times, per representative communication medium, prevailed?

This refers to the time it takes to notify the traveling public of the incident (i.e. information dissemination time) and is measured from incident verification time.

	Within 1 min	Between 1 and 2 min	Between 2 and 3 min	Between 3 and 4 min
VMS (Satisfaction %)				
Website or Application (Satisfaction %)				
SMS (Satisfaction %)				
E-mail (Satisfaction %)				

14. What is the longest alert time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

	VMS	Website or Application	SMS	E-mail
Alert Time (Longest)				

15. What would your satisfaction be if the following general scenarios of clearance times for crashes with <u>no injuries</u> prevailed?

This refers to the time it takes the authorities to clear the scene of the incident and is measured from incident verification time.

	Within 60 min	Between 60 and 70 min	Between 70 and 80 min	Between 80 and 90 min
Satisfaction (%)				

16. What is the longest clearance time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

	Crashes: No Injuries
Clearance Time (Longest)	

17. What would your satisfaction be if the following general scenarios of clearance times for crashes with <u>light to severe injuries</u> prevailed?

This refers to the time it takes the authorities to clear the scene of the incident and is measured from incident verification time.

	Within 70 min	Between 70 and 90 min	Between 90 and 110 min	Between 110 and 130 min
Satisfaction (%)				

18. What is the longest clearance time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

	Crashes: Light to Severe
Clearance Time (Longest)	

19. What would your satisfaction be if the following general scenarios of clearance times for crashes with <u>fatal injuries</u> prevailed?

This refers to the time it takes the authorities to clear the scene of the incident and is measured from incident verification time.

	Within 120 min	Between 120 and 150 min	Between 150 and 180 min	Between 180 and 210 min
Satisfaction (%)				

20. What is the longest clearance time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

	Crashes: Fatal
Clearance Time (Longest)	

21. What would your satisfaction be if the following scenarios of system uptime prevailed?

This refers to the percentage of time the system is operable (i.e. in working condition).

Satisfaction	Out of 100
Operable 96% of the time	50
Operable 97% of the time	50
Operable 98% of the time	50
Operable 99% of the time	50

22. What is the worst system uptime that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

23. What would your satisfaction be if the following general scenarios of Mean Time Between Failures (MTBF) prevailed?

This refers to the elapsed time between inherent failures of a system during operation. Examples of ITS equipment include: Variable Message Signs (VMS), detectors, cameras and signal controllers.

	Between 2 and 3 years	Between 3 and 4 years	Between 4 and 5 years	Between 5 and 6 years
Satisfaction (%)				

24. What is the shortest MTBF that you would tolerate/ deem to be satisfactory (after which you would associate anything shorter with a satisfaction of 0)?

In years (or months if necessary).

*Please specify your chosen unit.

25. What would your satisfaction be if the following scenarios of error rates prevailed?

This refers to erroneous data occurrences.

Satisfaction	Out of 100
Less than 1% erroneous occurrences	50
Between 1 and 2% erroneous occurrences	50
Between 2 and 3% erroneous occurrences	50
Between 3 and 4% erroneous occurrences	50

26. What is the worst error rate that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

27. If 20 assets were identified to undergo inspection, what would your satisfaction be if only the following numbers of assets underwent inspection?

This refers to the number of tickets fulfilled, in time.

Satisfaction	Out of 100
Only 19 tickets fulfilled	50

Only 18 tickets fulfilled	50
Only 17 tickets fulfilled	50
Only 16 tickets fulfilled	50

28. With regard to the circumstances mentioned in Question 27, what would the lowest number of assets undergoing inspection be that you would tolerate/ deem to be satisfactory (after which you would associate anything lower with a satisfaction of 0)?

An integer smaller than 20.

29. What would your satisfaction be if the following general scenarios of Mean Time To Repair (MTTR) prevailed?

This refers to the average time required to repair a failed asset.

	Less than 24 hours	Between 24 and 48 hours	Between 48 and 72 hours	Between 72 and 96 hours
Satisfaction (%)				

30. What is the longest MTTR that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In days (or hours if necessary).

*Please specify your chosen unit.

31. What would your satisfaction be if the following scenarios of reaction times, per representative communication medium, prevailed?

This refers to the average time taken to react to inquiries, queries, complaints and compliments; measured from log time.

	Within 12 hours	Between 12 and 24 hours	Between 24 and 36 hours	Between 36 and 48 hours
Call Centre (Satisfaction %)				
Website or Application (Satisfaction %)				

32. What is the longest reaction time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In hours.

	Call Centre	Website or Application
Reaction Time (Longest)		

OPERATOR OR CONTRACTOR: PUBLIC TRANSPORT

1. What would your satisfaction be if the following scenarios of information accuracy prevailed?

Information that is accurate means that the correct information is portrayed to the users.

Satisfaction	Out of 100
Accurate 96% of the time	50
Accurate 97% of the time	50
Accurate 98% of the time	50
Accurate 99% of the time	50

2. What is the worst information accuracy that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

3. What would your satisfaction be if the following scenarios of information availability prevailed?

Information that is available means that the information is accessible to the users.

Satisfaction	Out of 100
Available 96% of the time	50
Available 97% of the time	50

Available 98% of the time	50
Available 99% of the time	50

4. What is the worst information availability that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

5. What would your satisfaction be if the following scenarios of alert times, per representative communication medium, prevailed?

This refers to the time it takes to notify the traveling public of the incident (i.e. information dissemination time) and is measured from incident verification time.

	Within 1 min	Between 1 and 2 min	Between 2 and 3 min	Between 3 and 4 min
Electronic Message Signs (Satisfaction %)				
Website or Application (Satisfaction %)				
SMS (Satisfaction %)				
E-mail (Satisfaction %)				

6. What is the longest alert time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In minutes.

	Electronic Message Signs	Website or Application	SMS	E-mail
Alert Time (Longest)				

7. What would your satisfaction be if the following scenarios of system uptime prevailed?

This refers to the percentage of time the system is operable (i.e. in working condition).

	Satisfaction Out of 100
Operable 96% of the time	50
Operable 97% of the time	50
Operable 98% of the time	50
Operable 99% of the time	50

8. What is the worst system uptime that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

9. What would your satisfaction be if the following general scenarios of Mean Time Between Failures (MTBF), per representative ITS equipment group, prevailed?

This refers to the elapsed time between inherent failures of a system during operation.

*Fleet management (APTS-related) equipment. For example: electronic message signs, detectors, cameras, signal controllers and vehicle trackers.

*Fare management (AFC-related) equipment. For example: turnstiles, smart card readers and passenger counters.

	Between 2 and 3 years	Between 3 and 4 years	Between 4 and 5 years	Between 5 and 6 years
Fleet Management Equipment (Satisfaction %)				
Fare Management Equipment (Satisfaction %)				

10. What is the shortest MTBF that you would tolerate/ deem to be satisfactory (after which you would associate anything shorter with a satisfaction of 0)?

In years (or months if necessary).

*Please specify your chosen unit.

	Fleet Management Equipment	Fare Management Equipment
MTBF (Shortest)		

11. What would your satisfaction be if the following scenarios of error rates, per representative ITS equipment group, prevailed?

This refers to erroneous data occurrences.

	Less than 1% erroneous data occurrences	Between 1 and 2 % erroneous data occurrences	Between 2 and 3 % erroneous data occurrences	Between 3 and 4 % erroneous data occurrences
Fleet Management Equipment (Satisfaction %)				
Fare Management Equipment (Satisfaction %)				

12. What is the worst error rate that you would tolerate/ deem to be satisfactory (after which you would associate anything worse with a satisfaction of 0)?

In percentage.

	Fleet Management Equipment	Fare Management Equipment
Error Rate (Worst)		

13. If 20 assets were identified to undergo inspection, what would your satisfaction be if only the following numbers of assets underwent inspection?

This refers to the number of tickets fulfilled, in time.

Satisfaction	Out of 100
Only 19 tickets fulfilled	50
Only 18 tickets fulfilled	50
Only 17 tickets fulfilled	50
Only 16 tickets fulfilled	50

14. With regard to the circumstances mentioned in Question 13, what would the lowest number of assets undergoing inspection be that you would tolerate/ deem to be satisfactory (after which you would associate anything lower with a satisfaction of 0)?

An integer smaller than 20.

15. What would your satisfaction be if the following general scenarios of Mean Time To Repair (MTTR), per representative ITS equipment group, prevailed?

This refers to the average time required to repair a failed asset.

	Less than 24 hours	Between 24 and 48 hours	Between 48 and 72 hours	Between 72 and 96 hours
Fleet Management Equipment (Satisfaction %)				
Fare Management Equipment (Satisfaction %)				

16. What is the longest MTTR that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In days (or hours if necessary).

*Please specify your chosen unit.

	Fleet Management Equipment	Fare Management Equipment
MTTR (Longest)		

17. What would your satisfaction be if the following scenarios of reaction times, per representative communication medium, prevailed?

This refers to the average time taken to react to inquiries, queries, complaints and compliments; measured from log time.

	Within 12 hours	Between 12 and 24 hours	Between 24 and 36 hours	Between 36 and 48 hours
Call Centre (Satisfaction %)				
Website or Application (Satisfaction %)				

18. What is the longest reaction time that you would tolerate/ deem to be satisfactory (after which you would associate anything longer with a satisfaction of 0)?

In hours.

	Call Centre	Website or Application
Reaction Time (Longest)		

EMPLOYER OR CLIENT: PRIVATE TRANSPORT

1. What would your satisfaction be if the following scenarios of Level of Service (LOS), for peak periods, prevailed?

This refers to the percentage of major road segments assigned with a <u>LOS of C or better</u>.

Satisfaction	Out of 100
Between 55 and 65 % of all major roads	50
Between 65 and 75 % of all major roads	50
Between 75 and 85 % of all major roads	50
Between 85 and 95 % of all major roads	50

2. With regard to the circumstances mentioned in Question 1, what is the lowest percentage that you would tolerate/ deem to be satisfactory (after which you would associate anything lower with a satisfaction of 0)?

A percentage.

☐

3. What would your satisfaction be if the following scenarios of saturation proportions, in peak periods, prevailed?

This refers to the proportion of the network's demand (i.e. volume: v) to its supply (i.e. capacity: c). Specifically, major roads and freeways.

Satisfaction	Out of 100
v/c proportion of 1	50
v/c proportion between 0.8 and 1	50
v/c proportion between 0.6 and 0.8	50

v/c proportion between 0.4 and 0.6	50
v/c proportion less than 0.4	50

4. What would your satisfaction be if the following scenarios of helpfulness ratios prevailed?

This refers to the total number of compliments compared to the total number of complaints.

Satisfaction	Out of 100
If you get 20 or more compliments for every 10 complaints	50
If you get between 15 and 20 compliments for every 10 complaints	50
If you get between 10 and 15 compliments for every 10 complaints	50
If you get between 5 and 10 compliments for every 10 complaints	50
If you get less than 5 compliments for every 10 complaints	50

5. With regard to service affordability, what would your satisfaction be if the following scenarios of transport expenditure prevailed?

This refers to the percentage of a household's monthly income that goes towards their transport expenditure.

Satisfaction	Out of 100
Less than 10 %	50
Between 10 and 20 %	50
Between 20 and 30 %	50
Between 30 and 40 %	50

6. What is the largest percentage of transport expenditure that you would tolerate/ deem to be satisfactory (after which you would associate anything larger with a satisfaction of 0)?

A percentage.

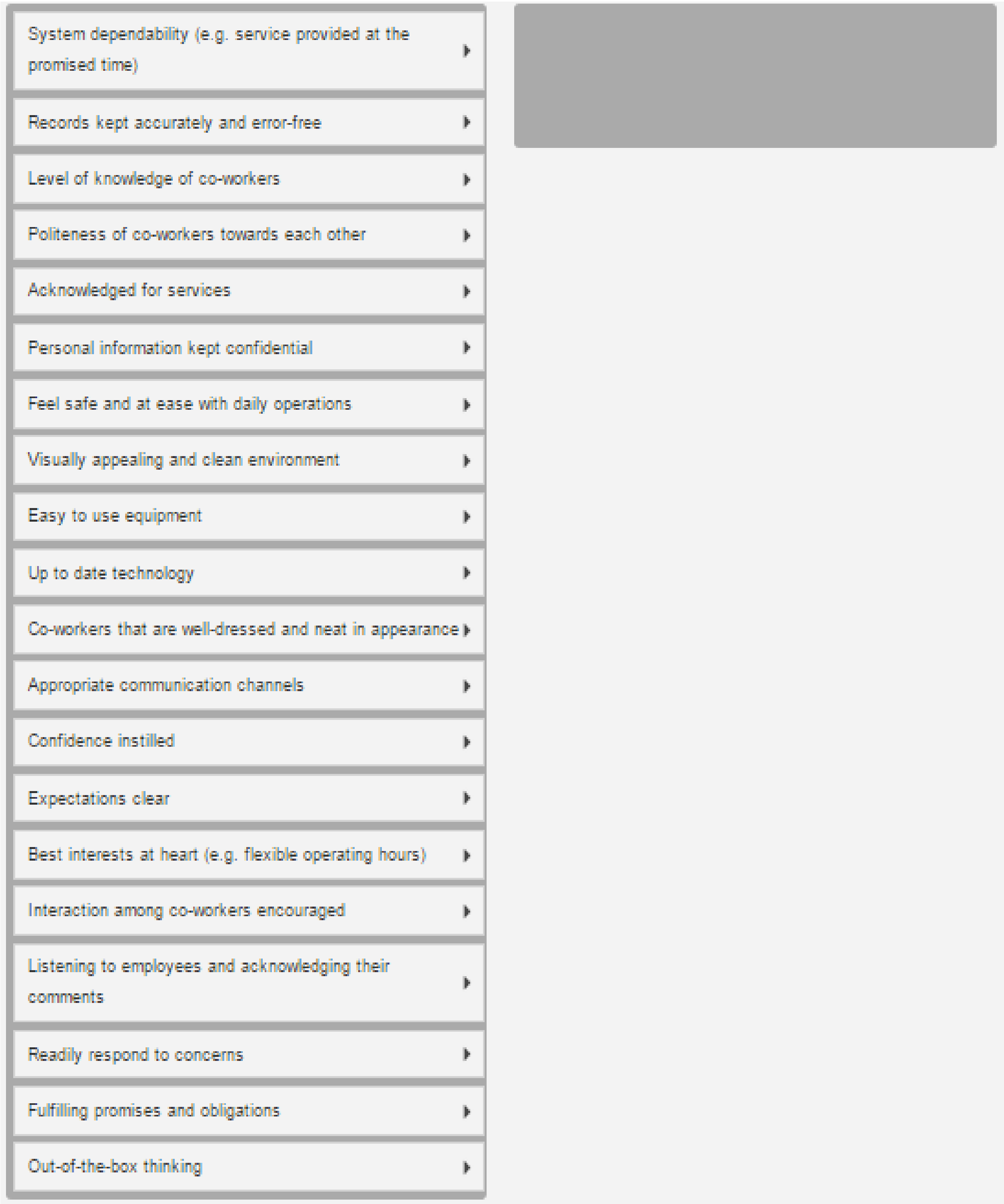
7. With regard to social inclusion, what would your satisfaction be (as the road authority) if the following scenarios of urban densification prevailed?

This refers to the percentage of the urban population that can conveniently access major roads and freeways.

Satisfaction	Out of 100
Less than 20 %	50
Between 20 and 40 %	50
Between 40 and 60 %	50
Between 60 and 80 %	50
Between 80 and 100 %	50

8. When evaluating employees' satisfaction with regard to their job- and operating environment conditions, how important would you reckon your employees deem the following 20 attributes?

Reposition/ drag and drop the following attributes from most important (i.e. top) to least important (i.e. bottom).



System dependability (e.g. service provided at the promised time)
Records kept accurately and error-free
Level of knowledge of co-workers
Politeness of co-workers towards each other
Acknowledged for services
Personal information kept confidential
Feel safe and at ease with daily operations
Visually appealing and clean environment
Easy to use equipment
Up to date technology
Co-workers that are well-dressed and neat in appearance
Appropriate communication channels
Confidence instilled
Expectations clear
Best interests at heart (e.g. flexible operating hours)
Interaction among co-workers encouraged
Listening to employees and acknowledging their comments
Readily respond to concerns
Fulfilling promises and obligations
Out-of-the-box thinking

EMPLOYER OR CLIENT: PUBLIC TRANSPORT

1. What would your satisfaction be if the following scenarios of load factors, for peak periods, prevailed?

This refers to the proportion of the average transit vehicle load to its capacity.

*For example: a load factor of 1 means that every seat on the transit vehicle is occupied; a load factor of 1.25 means that every seat on the transit vehicle is occupied and the number of standees equals 25% of the number of seats on the transit vehicle.

Satisfaction	Out of 100
Load factor exceeding 1.2	50
Load factor between 1 and 1.2	50
Load factor between 0.8 and 1	50
Load factor between 0.6 and 0.8	50
Load factor between 0.4 and 0.6	50
Load factor less than 0.4	50

2. What would your satisfaction be if the following scenarios of standing densities, for peak periods, prevailed?

This refers to the average number of pedestrians per square meter of the facility's platform.

*Note:
Level of Service (LOS) A = average pedestrian area of more than 1.2 square meter per person
LOS B = average pedestrian area of between 0.9 and 1.2 square meter per person
LOS C = average pedestrian area of between 0.7 and 0.9 square meter per person
LOS D = average pedestrian area of between 0.3 and 0.7 square meter per person
LOS E = average pedestrian area of between 0.2 and 0.3 square meter per person
LOS F = average pedestrian area of less than 0.2 square meter per person

Satisfaction	Out of 100
1 pedestrian per square meter	50
2 pedestrians per square meter	50
3 pedestrians per square meter	50
4 pedestrians per square meter	50

5 pedestrians per square meter	50

3. What would your satisfaction be if the following scenarios of saturation proportions, in peak periods, prevailed?

This refers to the proportion of the transit line's demand (i.e. volume: v) to its supply (i.e. capacity: c).

Satisfaction	Out of 100
v/c proportion of 1	50
v/c proportion between 0.8 and 1	50
v/c proportion between 0.6 and 0.8	50
v/c proportion between 0.4 and 0.6	50
v/c proportion less than 0.4	50

4. What would your satisfaction be if the following scenarios of helpfulness ratios prevailed?

This refers to the total number of compliments compared to the total number of complaints.

Satisfaction	Out of 100
If you get 20 or more compliments for every 10 complaints	50
If you get between 15 and 20 compliments for every 10 complaints	50
If you get between 10 and 15 compliments for every 10 complaints	50
If you get between 5 and 10 compliments for every 10 complaints	50
If you get less than 5 compliments for every 10 complaints	50

5. With regard to service affordability, what would your satisfaction be if the following scenarios of transport expenditure prevailed?

This refers to the percentage of a household's monthly income that goes towards their transport expenditure.

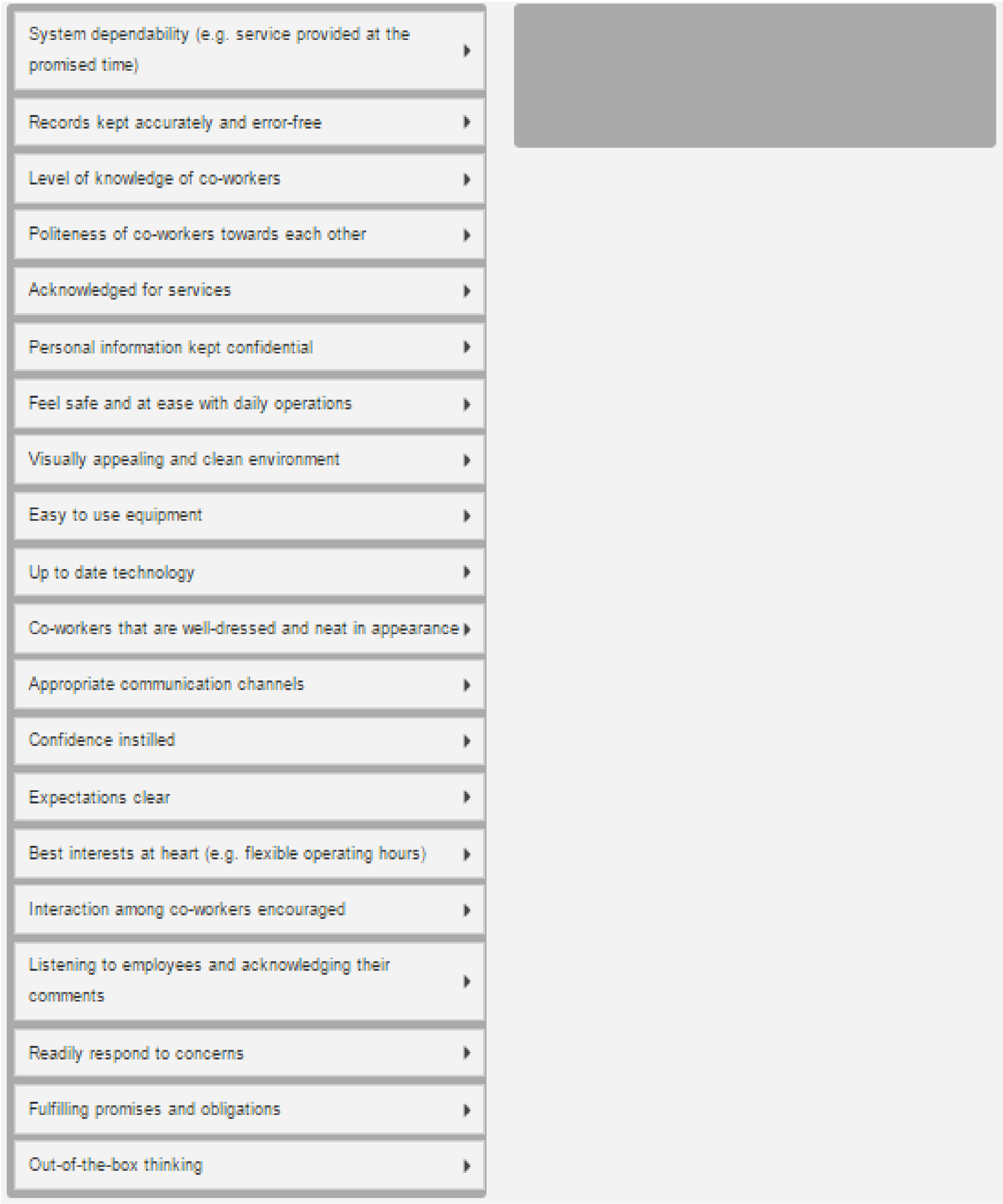
Satisfaction	Out of 100
Less than 10 %	50
Between 10 and 20 %	50
Between 20 and 30 %	50
Between 30 and 40 %	50

6. What is the largest percentage of transport expenditure that you would tolerate/ deem to be satisfactory (after which you would associate anything larger with a satisfaction of 0)?

A percentage.

7. When evaluating employees' satisfaction with regard to their job- and operating environment conditions, how important would you reckon your employees deem the following 20 attributes?

Reposition/ drag and drop the following attributes from most important (i.e. top) to least important (i.e. bottom).



System dependability (e.g. service provided at the promised time) ▸
Records kept accurately and error-free ▸
Level of knowledge of co-workers ▸
Politeness of co-workers towards each other ▸
Acknowledged for services ▸
Personal information kept confidential ▸
Feel safe and at ease with daily operations ▸
Visually appealing and clean environment ▸
Easy to use equipment ▸
Up to date technology ▸
Co-workers that are well-dressed and neat in appearance ▸
Appropriate communication channels ▸
Confidence instilled ▸
Expectations clear ▸
Best interests at heart (e.g. flexible operating hours) ▸
Interaction among co-workers encouraged ▸
Listening to employees and acknowledging their comments ▸
Readily respond to concerns ▸
Fulfilling promises and obligations ▸
Out-of-the-box thinking ▸

C. DATA CAPTURING: WEIGHT ELICITATION

ITS EXPERT: PRACTICES

GOVERNANCE, PLANNING AND DECISION MAKING

This perspective consists of five performance categories. These are: 1) Legal Compliance, 2) Regulatory Enforcement, 3) Research and Development, 4) Institutional Liaison and 5) Data Governance.

Legal Compliance consists of only one performance area; namely Legal Sources. **Regulatory Enforcement** consists of two performance areas. These are: 1) Regulators and 2) Regulatory Documents. **Research and Development** consists of two performance areas. These are: 1) Research Support and 2) Creativity Support. **Institutional Liaison** consists of two performance areas. These are: 1) Institutional Coordination and Cooperation and 2) Institutional Robustness. **Data Governance** consists of only one performance area; namely Data Management. The associated value tree can be viewed at: Value Tree Governance Planning and Decision Making.pdf

This survey consists of four parts: A to D. The data obtained from this survey will be used for the weight elicitation step of Multi Criteria Decision Analysis.

Part A

This part of the survey gathers data on the attributes at level 4 (i.e. performance measures) of the value tree.

LEGAL COMPLIANCE

Legal Sources

Legal sources relate to legislations and acts. Legislation refers to the enactment of laws through legally binding acts. An act is a bill which has passed through the various required legislative steps and which has hence become law.

1. Weigh the following five attributes based on their importance with regard to Legislations and Acts.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Transport: Laws and Bylaws For example: the National Road Traffic Act, the National Land Transport Act, the National Road Safety Act, the South African National Roads Agency Limited (SANRAL) and National Roads Act as well as the Road Traffic Management Corporation Act	50

Environment: Laws and Bylaws	
For example: the National Environmental Management Act and the Environment Conservation Act	50
Labour: Laws and Bylaws	
For example: the Labour Relations Act, the Basic Conditions of Employment Act, the Employment Equity Act, the Occupational Health and Safety Act as well as the Skills Development Act	50
Safety and Security: Laws and Bylaws	
For example: the Disaster Management Act and the South African Police Service Act	50
Communications: Laws and Bylaws	
For example: the Promotion of Access to Information Act and the Electronic Communications and Transactions Act	50

REGULATORY ENFORCEMENT

Regulators

Note: No weight elicitation is needed for governing bodies, since there is only one performance measure identified for this performance sub-area.

Regulatory Documents

Regulatory documents relate to any governing document that regulates a project's execution. The most prominent being regulations and policies. A regulation refers to any rule or directive made and maintained by an authority. A policy refers to a course or principle of action adopted or proposed by an organisation or individual.

2. Weigh the following four attributes based on their importance with regard to Regulations and Policies.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Standards	
For example: the South African National Standards (SANS) as well as the South African Bureau of Standards (SABS) and its Technical Committees (TC) for standards development	50
Manuals	

For example: the South African Road Traffic Signs Manual, the Road Safety Audit Manual and the Routine Road Maintenance Manual	50

Guidelines and Instructions

For example: the Urban Transport Guidelines (UTG); the Technical Methods for Highways (TMH); COLTO's Incident Management (IM) guidelines; the Guidelines for Human Settlement, Planning and Design (also known as the "red book"); the specifications relating to the Europay, MasterCard and Visa (EMV) card; and the data structures for Automated Fare Collection (AFC)	50

Statements, Plans and Frameworks

For example: the White Paper on National Transport Policy, the Moving South Africa (SA) Action Agenda, the National Development Plan 2030 and the National Transport Master Plan 2050	50

RESEARCH AND DEVELOPMENT

Research Support

Note: No weight elicitation is needed for research development, since there is only one performance measure identified for this performance sub-area.

Creativity Support

Creativity support refers to the in-house support processes provided by the project for creativity stimulation. Such support processes help to ensure that project requirements do not hinder or prevent innovation. Rather, they aid in improving products, services and/or processes such that the performance of the project(s) can be enhanced. This is accomplished through facilitating the identification of and response to internal- and external opportunities. Project development is thus identified as the performance sub area for creativity support.

3. Weigh the following two attributes based on their importance with regard to <u>Project Development</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Innovation Management: Ideation	
Ideation is the process of generating, developing and communicating new ideas. An example of an ideation process is the activity of brainstorming	50
Continuous Improvement: Competitive Analysis	
Competitive analysis in the form of, for example, benchmarking provides for a critical assessment of the project's strengths, weaknesses, opportunities and threats (SWOT)	50

INSTITUTIONAL LIAISON

Institutional Coordination and Cooperation

The concept of institutional coordination and cooperation is based on achieving mutually beneficial relationships through partnership development. Close coordination and cooperation can be attained if the institutions' strategies and operations are synchronised. Operational- and strategy alignment are thus identified as the performance sub areas.

4. Weigh the following two attributes based on their importance with regard to <u>Operational Alignment</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Activity Integration		
Agreements on planning- and design practices		50
Technical Compatibility		
Agreements on operating protocols and technical matters		50

Note: No weight elicitation is needed for strategy alignment, since there is only one performance measure identified for this performance sub-area.

Institutional Robustness

Note: No weight elicitation is needed for business continuity, since there is only one performance measure identified for this performance sub-area.

DATA GOVERNANCE

Data Management

Data management refers to the overall management of the availability, usability, integrity and security of the data employed in the system. Effective data management is grounded on sound information system governance procedures.

5. Weigh the following seven attributes based on their importance with regard to <u>Information System Governance Procedures</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Data Collection		
Data source and -acquisition protocols. For example: adhering to the required data log frequency	50	
Data Accuracy		
Data accuracy protocols. For example: are the data values stored for an object the correct values (i.e. the right value in right format)	50	
Data Retention		
Data archival protocols. For example: adhering to the required data backup period	50	
Data Security		
CIA (Confidentiality, Integrity and Availability) protocols	50	
Data Quality		
Quality checking protocols. For example: complying with the decided data standards and the data dictionaries of the databases	50	
Data Fusion		
Data filtering, -cleaning and -presentation protocols	50	
Data Accessibility		
Data accessibility protocols. For example: regulating how data is transmitted between computing devices and over networks	50	

Part B

This part of the survey gathers data on the attributes at level 3 (i.e. performance sub-areas) of the value tree.

LEGAL COMPLIANCE

Note: No weight elicitation is needed for legal sources, since there is only one performance sub-area identified for this performance area.

REGULATORY ENFORCEMENT

Note: No weight elicitation is needed for both regulators and regulatory documents, since there is only one performance sub-area identified for these performance areas.

RESEARCH AND DEVELOPMENT

Note: No weight elicitation is needed for both research- and creativity support, since there is only one performance sub-area identified for these performance areas.

INSTITUTIONAL LIAISON

6. Weigh the following two attributes based on their importance with regard to <u>Institutional Coordination and Cooperation</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Operational Alignment		
Activity integration and technical compatibility: Agreements towards standardised procedures		50
Strategy Alignment		
Collaborative relationships: Commitments to sharing resources and information		50

Note: No weight elicitation is needed for institutional robustness, since there is only one performance sub-area identified for this performance area.

DATA GOVERNANCE

Note: No weight elicitation is needed for data management, since there is only one performance sub-area identified for this performance area.

Part C

This part of the survey gathers data on the attributes at level 2 (i.e. performance areas) of the value tree.

Note: No weight elicitation is needed for legal compliance, since there is only one performance area identified for this performance category.

7. Weigh the following two attributes based on their importance with regard to <u>Regulatory Enforcement</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Regulators	
Governing bodies: Industry role players	50
Regulatory Documents	
Regulations and policies: Standards, manuals, guidelines, instructions, statements, plans and frameworks	50

8. Weigh the following two attributes based on their importance with regard to <u>Research and Development</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Research Support	
Research development: Project-based learning	50
Creativity Support	
Project development: Innovation management and continuous improvement	50

9. Weigh the following two attributes based on their importance with regard to <u>Institutional Liaison</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Institutional Coordination and Cooperation	
Operational- and strategy alignment: Activity integration, technical compatibility and collaborative relationships	50
Institutional Robustness	
Business continuity: Risk management	50

Note: No weight elicitation is needed for data governance, since there is only one performance area identified for this performance category.

Part D

This part of the survey gathers data on the attributes at level 1 (i.e. performance categories) of the value tree.

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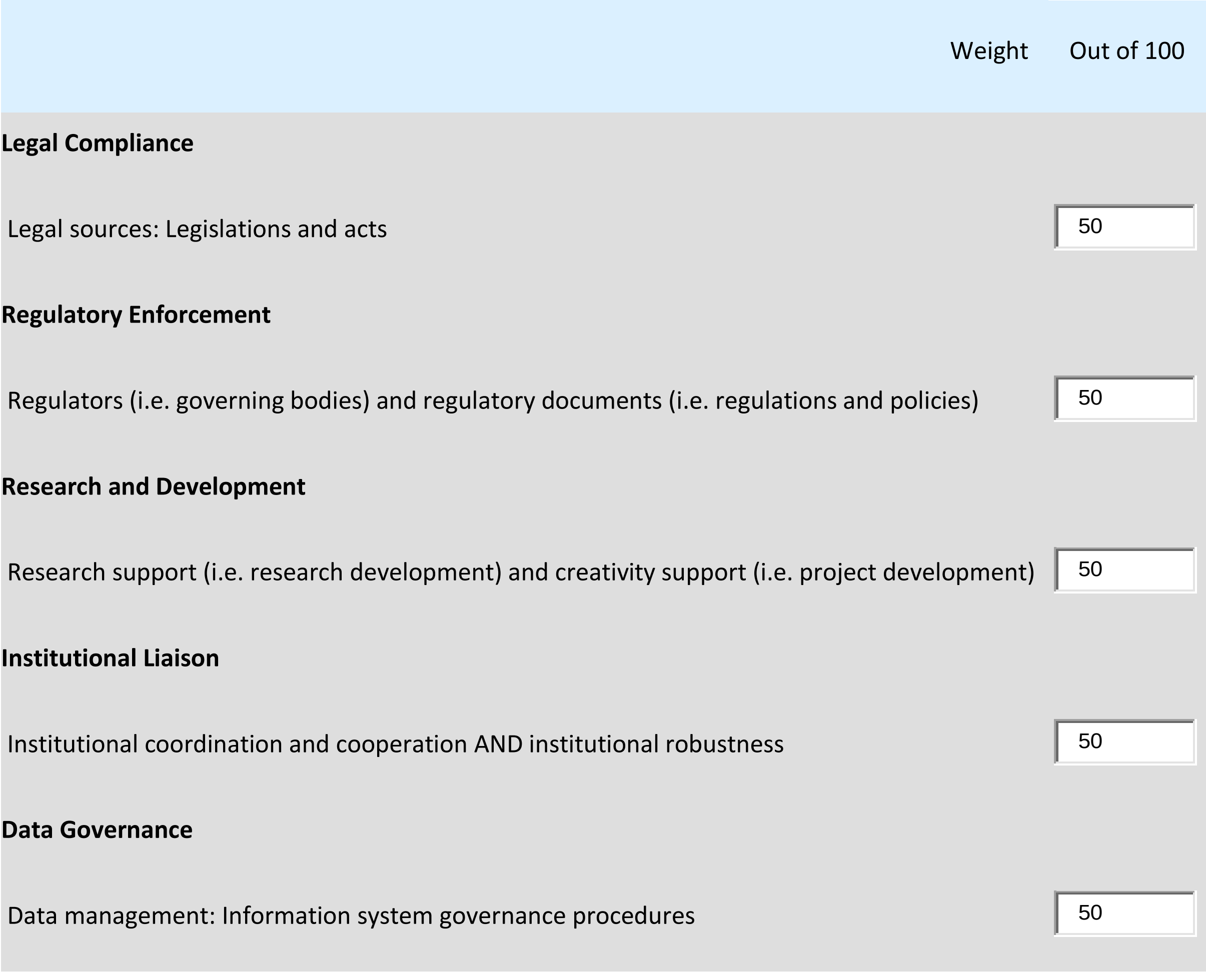
10. Weigh the following five attributes based on their importance with regard to <u>Governance, Planning and Decision Making</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.



	Weight Out of 100
Legal Compliance	
Legal sources: Legislations and acts	50
Regulatory Enforcement	
Regulators (i.e. governing bodies) and regulatory documents (i.e. regulations and policies)	50
Research and Development	
Research support (i.e. research development) and creativity support (i.e. project development)	50
Institutional Liaison	
Institutional coordination and cooperation AND institutional robustness	50
Data Governance	
Data management: Information system governance procedures	50

OPERATIONS, SERVICES AND MAINTENANCE

This perspective consists of three performance categories. These are: 1) Operational Performance, 2) Technology Reliability and 3) Asset Management and Maintenance.

Operational Performance consists of four performance areas. These are: 1) Service Reliability, 2) Service Convenience, 3) Operational Seamlessness and 4) Operating Efficiency. **Technology Reliability** consists of two performance areas. These are: 1) System Health and 2) System Performance. **Asset Management and Maintenance** consists of two performance areas. These are: 1) Asset Management and 2) Asset Maintenance. The associated value tree can be viewed at: Value Tree Operations Services and Maintenance.pdf

This survey consists of four parts: A to D. The data obtained from this survey will be used for the weight elicitation step of Multi Criteria Decision Analysis.

Part A

This part of the survey gathers data on the attributes at level 4 (i.e. performance measures) of the value tree.

OPERATIONAL PERFORMANCE

Service Reliability

A service, whether public- or private transport, is deemed to be reliable if three conditions are met. These are: 1) if travel time variability is managed to be as low as possible, 2) if the information given to the users is valid and 3) if using the service is safe.

1. Weigh the following two attributes based on their importance with regard to Travel Time Variability.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Travel Time Duration: Travel Time Factor The ratio of the average peak period travel time to the free flow travel time		50
Schedule Adherence: On-time Performance The percentage of time the transit vehicles arrives at times as stipulated in their timetables		50

2. Weigh the following two attributes based on their importance with regard to <u>Information Validity</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Timeliness	
Portraying information in a timely manner	50
Accuracy and Availability	
Portraying information that is applicable: accurate and available when needed	50

3. Weigh the following two attributes based on their importance with regard to <u>Timeliness</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Information Refresh Rate	
The rate at which information is refreshed (e.g. updating images) to obtain or maintain real-time accuracy	50
Latency to Posting Updates	
The time it takes to update and/or correct information (e.g. incident occurrence updates and timetable corrections) in the event of change	50

4. Weigh the following two attributes based on their importance with regard to <u>Accuracy and Availability</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Accuracy	
The percentage of time the information portrayed to the public is accurate (i.e. correct)	50
Availability	

The percentage of time the information portrayed to the public is available (i.e. accessible)	50

5. Weigh the following two attributes based on their importance with regard to Safety.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Public Travel Safety: Incident Statistics	
The number of crash incident and vehicle break-down occurrences	50
Personal Safety: Incident Statistics	
The number of property crime incident occurrences (e.g. theft and vehicle hijacking)	50

Service Convenience

The convenience of the service is dependent on three conditions. These are: 1) if the service is accessible, 2) if the service offers sufficient connectivity and 3) if the service provided is regular and being used regularly.

6. Weigh the following two attributes based on their importance with regard to Accessibility.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Access Point Proximity	
The closeness (time or distance) of points of interest (whether work or recreational points of interest) and transit facilities	50
Network Characteristics	
The quality of the road and transit line wrt the user's accessibility, when considering the constraints imposed on certain routes, to access points (e.g. road-, vehicle- and facility restrictions)	50

7. Weigh the following two attributes based on their importance with regard to Access Point Proximity.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Access Time		
The average access time to the access points (while travelling with private transport)		50
Access Distance		
The average access distance to the access points (while travelling with public transport)		50

8. Weigh the following two attributes based on their importance with regard to <u>Connectivity</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Access Options: Commuting Time		
The average' citizen's commuting time as a proportion of their (working) day		50
Access Options: Transfer Distance		
The percentage of transfers between modes to be under "x" metres		50

9. Weigh the following two attributes based on their importance with regard to <u>Regularity</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Mode Preference: Modal Split		
The proportion of mode share within overall transport demand		50
Periodicity: Service Frequency		
The rate at which transit vehicles arrives at stops/stations		50

Operational Seamlessness

In order for a service to operate seamlessly, any incidents that could impede the operation of the service need to be managed in a timely manner. Examples include, among others, crashes, stationary vehicles blocking a lane of traffic, special events and adverse weather conditions.

10. Weigh the following two attributes based on their importance with regard to Incident Management (IM).

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Measures concerning Time		
Detection, verification, notification, response, alert and clearance		50
Measures concerning (staff) Safety		
Adverse health conditions and secondary incidents		50

11. Weigh the following six attributes based on their importance with regard to the IM: time conscious measures.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Detection Time		
The time it takes to detect an incident after its occurrence		50
Verification Time		
The time it takes to verify and classify the incident according to the incident type; measured from incident detection time		50
Notification Time		
The time it takes to notify the partner authorities of the incident; measured from incident verification time		50
Response Time		
The time it takes for the authorities to reach the scene of the incident; measured from incident verification time		50
Alert Time		

The time it takes to notify the travelling public of the incident (i.e. information dissemination time); measured from incident verification time	50
Clearance Time	
The time it takes the authorities to clear the incident scene; measured from incident verification time (as one does not always exactly know when the incident occurred)	50

12. Weigh the following two attributes based on their importance with regard to the IM: (staff) safety measures.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Adverse Health Conditions		
The number of adverse health condition occurrences (as a result of attending the scene of the incident)	50	
Secondary Incidents		
The number of secondary incident occurrences	50	

Operating Efficiency

The operating efficiency of a service is determined by two conditions. These are: 1) the quality of the service provided and 2) the utilisation of the service.

13. Weigh the following two attributes based on their importance with regard to Service Quality.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Density and Congestion		
Level of Service (LOS), load factor and standing density	50	
Mobility		
Network travel speeds, queue length/time and waiting time	50	

14. Weigh the following three attributes based on their importance with regard to Density and Congestion.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
LOS		
The percentage of road segments assigned with a LOS of C or better		50
Load Factor		
The proportion of the average transit vehicle load (i.e. passengers on-board) to the total transit vehicle capacity		50
Standing Density		
The average number of passengers per square meter of the facility's platform		50

15. Weigh the following four attributes based on their importance with regard to Mobility.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Network Travel Speeds		
The average travel speed on freeways		50
Queue Length		
The average length of queues (in vehicles) at major road segments or major intersections		50
Queue Time		
The average queuing times at major road segments or major intersections		50
Waiting Time		
The average time spend waiting for transit vehicles to arrive at stops/stations		50

Note: No weight elicitation is needed for service utilisation, since there is only one performance measure identified for this performance sub-area.

TECHNOLOGY RELIABILITY

Note: No weight elicitation is needed for system availability, equipment quality and data quality, since there is only one performance measure identified for each of these performance sub-areas.

ASSET MANAGEMENT AND MAINTENANCE

Asset Management

The aim of asset management is to manage the operational performance of the assets. This refers to maintaining assets that are fit for their purpose and it may or may not require procurement, lifecycle management or rehabilitation.

16. Weigh the following four attributes based on their importance with regard to <u>Operations Management</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Record		
Asset Register: Record all asset-related information over an asset's whole lifecycle		50
Monitor		
Network Surveillance Systems: Verify accuracy and quality of the assets in the field		50
Control		
Positioning Systems: Manage the public transport fleet by tracking and/or navigating the transit vehicles		50
Evaluate		
Status Report: Document the condition and the (financial book) value of all the assets in the field		50

Asset Maintenance

Asset maintenance is about preserving the asset's condition or operable state during its useful life. Asset maintenance is executed with the aid of two actions. These are: 1) preventative maintenance and 2) corrective maintenance.

Note: No weight elicitation is needed for preventative maintenance, since there is only one performance measure identified for this performance sub-area.

17. Weigh the following two attributes based on their importance with regard to Corrective Maintenance.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Defect Logs		
The number of tickets logged (i.e. the number of assets that require rectification)		50
Mean Time To Repair		
The average time to repair a failed asset; measured from asset log time		50

Part B

This part of the survey gathers data on the attributes at level 3 (i.e. performance sub-areas) of the value tree.

OPERATIONAL PERFORMANCE

18. Weigh the following three attributes based on their importance with regard to Service Reliability.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Travel Time Variability		
Travel time duration and schedule adherence		50
Information Validity		
Information: timeliness, accuracy and availability		50
Safety		
Incident statistics: Public travel- and personal safety		50

19. Weigh the following three attributes based on their importance with regard to <u>Service Convenience</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Accessibility		
Access point proximity and network characteristics		50
Connectivity		
Access options: The availability of route and mode options wrt commuting and transfer time		50
Regularity		
Mode preference (service used regularly) and periodicity (service provided regular)		50

Note: No weight elicitation is needed for operational seamlessness, since there is only one performance sub-area identified for this performance area.

20. Weigh the following two attributes based on their importance with regard to <u>Operating Efficiency</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Service Quality		
Traffic density (LOS), passenger density (load factor and standing density) and mobility		50
Service Utilisation		
Network's degree of saturation: Demand (throughput) to supply (capacity)		50

TECHNOLOGY RELIABILITY

Note: No weight elicitation is needed for system health, since there is only one performance sub-area identified for this performance area.

21. Weigh the following two attributes based on their importance with regard to <u>System Performance</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Equipment Quality		
Value evaluation: Mean time between failures		50
Data Quality		
Data verification and validation: Error rates		50

ASSET MANAGEMENT AND MAINTENANCE

Note: No weight elicitation is needed for asset management, since there is only one performance sub-area identified for this performance area.

22. Weigh the following two attributes based on their importance with regard to <u>Asset Maintenance</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Preventative Maintenance		
Inspecting all identified assets (scheduled logs): Fulfilment ratio		50
Corrective Maintenance		
Rehabilitating identified assets: No. of defect logs and mean time to repair		50

Part C

This part of the survey gathers data on the attributes at level 2 (i.e. performance areas) of the value tree.

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23. Weigh the following four attributes based on their importance with regard to <u>Operational Performance</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Service Reliability	
Travel time variability, information validity as well as public travel- and personal safety	50
Service Convenience	
Accessibility, connectivity and regularity	50
Operational Seamlessness	
Incident management	50
Operating Efficiency	
Service quality and -utilisation	50

24. Weigh the following two attributes based on their importance with regard to Technology Reliability.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
System Health	
System availability: System functionality	50
System Performance	
Equipment- and data quality: Evaluation, verification and validation	50

25. Weigh the following two attributes based on their importance with regard to Asset Management and Maintenance.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Asset Management	
Operations management: Record, monitor, control and evaluate	50
Asset Maintenance	
Preventative- and corrective maintenance: Scheduled- and defect logs	50

Part D

This part of the survey gathers data on the attributes at level 1 (i.e. performance categories) of the value tree.

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26. Weigh the following three attributes based on their importance with regard to <u>Operations, Services and Maintenance</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Operational Performance	
Service reliability, service convenience, operational seamlessness and operating efficiency	50
Technology Reliability	
System health and -performance	50
Asset Management and Maintenance	
Operations management as well as preventative- and corrective maintenance	50

ITS EXPERT: PROFIT

MONEY MATTERS

This perspective consists of two performance categories. These are: 1) Economic Performance and 2) Financial Performance.

Economic Performance consists of three performance areas. These are: 1) Economic Sustainability, 2) Economic Vitality and 3) Socio-Economic Prosperity. **Financial Performance** consists of two performance areas. These are: 1) Financial Feasibility and 2) Investment Management. The associated value tree can be viewed at: Value Tree Money Matters.pdf

This survey consists of four parts: A to D. The data obtained from this survey will be used for the weight elicitation step of Multi Criteria Decision Analysis.

Part A

This part of the survey gathers data on the attributes at level 4 (i.e. performance measures) of the value tree.

ECONOMIC PERFORMANCE

Economic Sustainability

Economic sustainability involves the identification of various strategies to promote using the available resources to their best advantage. This entails that the resources be used such that the system continues to function over a number of years, while consistently returning or generating a profit. A system is thus deemed to have economic sustainability if two conditions are met. These are: 1) if the system is able to adapt over time and 2) if the system is preserved over time.

1. Weigh the following two attributes based on their importance with regard to System Adaptability.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Operational Resilience: Scalability	
Scalability is the ability of a system to change its scale in order to meet changing volumes of demand; without compromising its performance	50
Operational Resilience: Responsiveness	
Responsiveness is the ability of the system to meet traveller needs and to respond to market changes, within a reasonable time period, such that competitive advantage can be established	50

2. Weigh the following two attributes based on their importance with regard to System Preservation.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Project Infrastructure Status: Traveller Experience		
The users' opinion on the overall condition and the quality of the road network. For example: their satisfaction with regard to the transport-related equipment such as VMS and traffic lights		50
Project Infrastructure Status: Age Distribution of Fleet		
The average remaining useful life for each representative transit vehicle type		50

Economic Vitality

Note: No weight elicitation is needed for both economic development and -growth, since there is only one performance measure identified for each of these performance sub-areas.

Socio-Economic Prosperity

Socio-economic prosperity is achieved when the project caters for an environment in which both the society and economy can flourish. Prosperous circumstances relate to thriving conditions (especially in, but not limited to, financial respects) that enhance the socio-economic standard of the country. The well-known ITS project goals can result in (social) benefits.

3. Weigh the following six attributes based on their importance with regard to the <u>(Social) Benefits</u> associated with ITS projects.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Energy and Environment		
Managing traffic flow conditions and transport mode shares		50
Safety		
Managing primary- and secondary incident occurrences		50
Efficiency		
Managing network throughput		50
Customer Satisfaction		

Managing the community's confidence in and perception of the service 50

Mobility

Managing travellers' ease of movement 50

Productivity

Managing the effectiveness of the system 50

FINANCIAL PERFORMANCE

Financial Feasibility

In order to determine the financial feasibility of the ITS project(s) deployed, a benefit-cost analysis needs to be conducted. The costs associated with ITS projects can be categorised into four groups. These are: 1) non-recurring costs, 2) recurring costs, 3) miscellaneous costs and 4) social costs.

4. Weigh the following two attributes based on their importance with regard to the Recurring Costs associated with ITS projects.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Recurring Costs: Operating Expenditure	
Selling expenses: Costs pertaining to activities related to marketing the service (e.g. advertising- and promotional material cost)	50
General- and administrative expenses: Costs pertaining to activities related to the day-to-day operations needed to provide the service (e.g. cost of workers, facility expenses and cost of maintenance and repairs)	50

Note: No weight elicitation is needed for non-recurring-, miscellaneous- and social costs, since there is only one performance measure identified for each of these performance sub-areas.

Investment Management

Note: No weight elicitation is needed for investment performance, since there is only one performance measure identified for this performance sub-area.

Part B

This part of the survey gathers data on the attributes at level 3 (i.e. performance sub-areas) of the value tree.

ECONOMIC PERFORMANCE

5. Weigh the following two attributes based on their importance with regard to <u>Economic Sustainability</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
System Adaptability		
Operational resilience: Scalability and responsiveness		50
System Preservation		
Project infrastructure status evaluation: Traveller experience and age distribution of fleet		50

6. Weigh the following two attributes based on their importance with regard to <u>Economic Vitality</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Economic Development		
Business opportunities: Jobs created		50
Economic Growth		
Service expansion: Capacity building and infrastructure development		50

Note: No weight elicitation is needed for socio-economic prosperity, since there is only one performance sub-area identified for this performance area.

FINANCIAL PERFORMANCE

7. Weigh the following four attributes based on their importance with regard to the <u>Financial Feasibility</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Non-recurring Costs	
Capital expenditure: Long-term assets	50
Recurring Costs	
Operating expenditure: Selling expenses as well as general- and administrative expenses	50
Miscellaneous Costs	
Unforeseen expenditure. For example: fines, law suits and environmental damage costs	50
Social Costs	
Negative transport externalities (i.e. congestion, accidents and pollution)	50

Note: No weight elicitation is needed for investment management, since there is only one performance sub-area identified for this performance area.

Part C

This part of the survey gathers data on the attributes at level 2 (i.e. performance areas) of the value tree.

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8. Weigh the following three attributes based on their importance with regard to the Economic Performance.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Economic Sustainability	
System adaptability and -preservation	50
Economic Vitality	

Economic development and -growth	50
Socio-Economic Prosperity	
(Social) Benefits associated with ITS projects	50

9. Weigh the following two attributes based on their importance with regard to <u>Financial Performance</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Financial Feasibility	
Costs: Non-recurring, recurring, miscellaneous and social - as used in Benefit-Cost Analysis	50
Investment Management	
Investment performance: Capital gain (Return On Investment)	50

Part D

This part of the survey gathers data on the attributes at level 1 (i.e. performance categories) of the value tree.

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10. Weigh the following two attributes based on their importance with regard to <u>Money Matters</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Economic Performance	
Economic sustainability, economic vitality and socio-economic prosperity	50
Financial Performance	

Financial feasibility and investment management	50

ITS EXPERT: PEOPLE

PEOPLE MATTERS

This perspective consists of four performance categories. These are: 1) Public Relations, 2) Customer Service, 3) Social Sustainability and 4) Human Resource Management.

Public Relations consists of two performance areas. These are: 1) Marketing and 2) Networking. **Customer Service** consists of two performance areas. These are: 1) Traveller Information Provision and 2) General Support Information. **Social Sustainability** consists of two performance areas. These are: 1) Sustainable Service Delivery and 2) Sustainable Living. **Human Resource Management** consists of only one performance area; namely Employee Performance Management. The associated value tree can be viewed at: Value Tree People Matters.pdf

This survey consists of four parts: A to D. The data obtained from this survey will be used for the weight elicitation step of Multi Criteria Decision Analysis.

Part A

This part of the survey gathers data on the attributes at level 4 (i.e. performance measures) of the value tree.

PUBLIC RELATIONS

Marketing

Marketing is the action of promoting services (or selling products), including market research and advertising. A service can be promoted with the aid of marketing campaigns and -modules.

1. Weigh the following three attributes based on their importance with regard to Service Promotion.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Raising Awareness	
The use of marketing campaigns to promote the service (e.g. traffic and road safety campaigns)	50
Developing Understanding	

The use of publicity modules to enhance the reputation of the service among the target audience through manipulation	50
Securing Acceptance	
The use of public information modules to maintain the image of the service (e.g. press releases, newsletters and brochures)	50

Networking

Networking is the action of interacting with individuals or groups by exchanging information on social media platforms.

2. Weigh the following two attributes based on their importance with regard to <u>Service Interaction</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Attractiveness and Exposure		
The rate of growth in social media attractiveness	50	
Productive Relationships		
The users' thoughts on the overall service delivery	50	

CUSTOMER SERVICE

Traveller Information Provision

Note: No weight elicitation is needed for traveller information provision, since there is only one performance measure identified for each performance sub-area.

General Support Information

General support information refers to the range of services provided to help customers in using the service. These support services take on different forms for a variety of means. These are to provide: 1) logging attendance, 2) inter-personal interaction and 3) self-service systems.

3. Weigh the following two attributes based on their importance with regard to <u>Logging Attendance</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Inquiries, Queries, Complaints and Compliments	
The time it takes to react to the user's log(s)	50
The helpfulness of the replies made to the user's log(s). That is, are the replies on par with what the customer requested	50

Note: No weight elicitation is needed for both inter-personal interaction and self-service systems, since there is only one performance measure identified for each of these performance sub-areas.

SOCIAL SUSTAINABILITY

Sustainable Service Delivery

Sustainable service delivery refers to the community’s ability to provide services that not only meet the needs of its current members, but also support future generations in realising and maintaining a healthy community. The community’s proceedings in delivering a sustainable service can be represented by two conditions. These are: 1) social justice and 2) social equality.

4. Weigh the following two attributes based on their importance with regard to Social Justice.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Service Affordability	
The percentage of a household's monthly income that goes towards their transport expenditure	50
The extent of the support provided by the government in the form of subsidies (e.g. discounted fare options)	50

5. Weigh the following two attributes based on their importance with regard to Social Equality.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Social Inclusion	
The degree of urban densification in the vicinity of the major roads (e.g. the percentage of the population living in urban areas)	50

The presence of amenities for people with disabilities (e.g. wheelchair ramps at transit facilities, audio signals at pedestrian crossings and clear notice boards)	50

Sustainable Living

Sustainable living refers to a state of flourishing, thriving, good fortune and successful social status. In order to pursue such a state of living and hence enhance the overall social status of the community, the project needs to foster social development.

6. Weigh the following two attributes based on their importance with regard to Social Development.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Public-Service Alignment	
Usability study: to ensure that the services provided benefit the public	50
Community development programs: to shape human capital development	50

HUMAN RESOURCE MANAGEMENT

Employee Performance Management

Employee performance management is about aligning the organisational objectives with the employees' agreed measures, skills, competency requirements, development plans and the delivery of results. In order to create a high performance workforce, the following conditions thus need to be evaluated. These are: 1) employee satisfaction, 2) employee commitment, 3) employee engagement and 4) employee development.

Note: No weight elicitation is needed for both employee satisfaction and employee commitment, since there is only one performance measure identified for each of these performance sub-areas.

7. Weigh the following two attributes based on their importance with regard to Employee Engagement.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Organisational Structure (Communication Channels)	
Focus groups: to facilitate horizontal- and vertical communication	50

Trauma counselling: to ensure the general morale and well-being of the employees	50

8. Weigh the following two attributes based on their importance with regard to <u>Employee Development</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Advancing Skillsets		
Regular training services (e.g. in-service training and staff development programs)		50
Improvement Tracking		
Progress evaluation: to determine their ability to assume greater responsibility in higher positions		50

Part B

This part of the survey gathers data on the attributes at level 3 (i.e. performance sub-areas) of the value tree.

PUBLIC RELATIONS

Note: No weight elicitation is needed for both marketing and networking, since there is only one performance sub-area identified for each of these performance areas.

CUSTOMER SERVICE

9. Weigh the following four attributes based on their importance with regard to <u>Traveller Information Provision</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Assist		
Trip planning: Door-to-door routing services		50

Confirm	
Transit- and traffic information: Information confirmation wrt travel times, fares and schedules	50
Notify	
Incident notification: Notifying travellers of crashes, adverse weather conditions, delays and strikes	50
Advise	
Route guidance: Advisory information provision (e.g. detour/alternative route options)	50

10. Weigh the following three attributes based on their importance with regard to <u>General Support Information</u>.

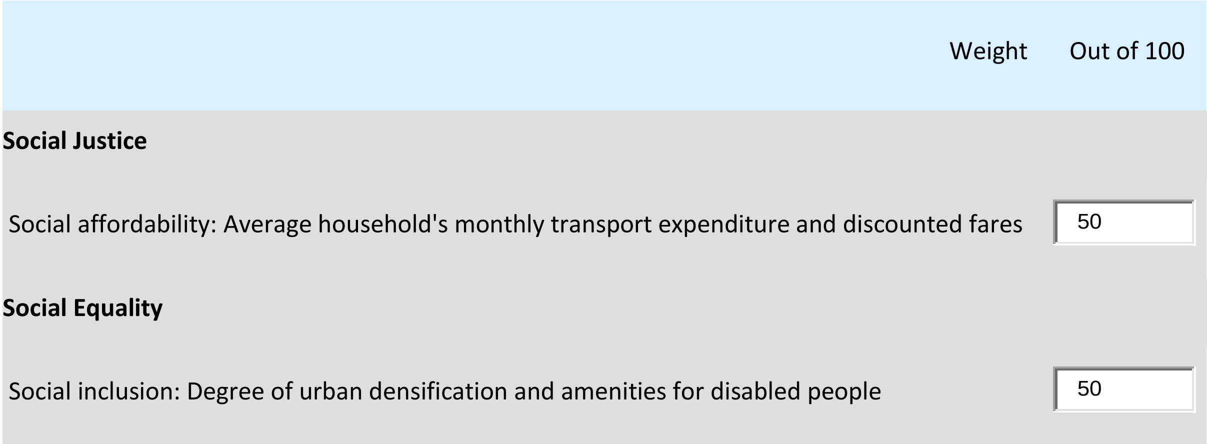
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight Out of 100
Logging Attendance	
Inquiries, queries, complaints and compliments: Reaction time and helpfulness	50
Inter-personal Interaction	
Workforce: Personnel performance (e.g. courtesy, appearance and knowledgeability)	50
Self-service Systems	
Service inventory and technology: Quality of interaction mediums (e.g. simple to use and easy to understand)	50

SOCIAL SUSTAINABILITY

11. Weigh the following two attributes based on their importance with regard to <u>Sustainable Service Delivery</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.



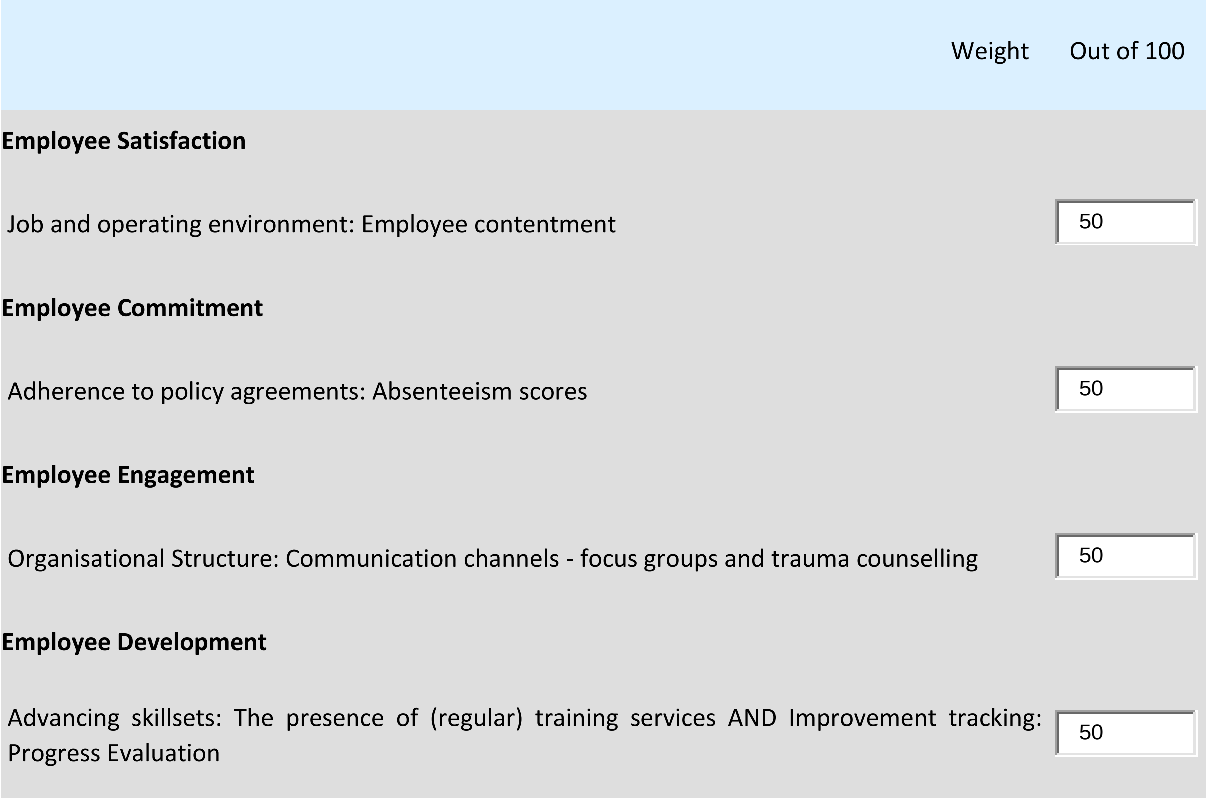
	Weight	Out of 100
Social Justice		
Social affordability: Average household's monthly transport expenditure and discounted fares		50
Social Equality		
Social inclusion: Degree of urban densification and amenities for disabled people		50

Note: No weight elicitation is needed for sustainable living, since there is only one performance sub-area identified for this performance area.

HUMAN RESOURCE MANAGEMENT

12. Weigh the following four attributes based on their importance with regard to Employee Performance Management.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.



	Weight	Out of 100
Employee Satisfaction		
Job and operating environment: Employee contentment		50
Employee Commitment		
Adherence to policy agreements: Absenteeism scores		50
Employee Engagement		
Organisational Structure: Communication channels - focus groups and trauma counselling		50
Employee Development		
Advancing skillsets: The presence of (regular) training services AND Improvement tracking: Progress Evaluation		50

Part C

This part of the survey gathers data on the attributes at level 2 (i.e. performance areas) of the value tree.

---

13. Weigh the following two attributes based on their importance with regard to <u>Public Relations</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Marketing		
Service promotion (media)		50
Networking		
Service interaction (social media)		50

14. Weigh the following two attributes based on their importance with regard to <u>Customer Service</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Traveller Information Provision		
Assist, confirm, notify and advise		50
General Support Information		
Logging attendance, inter-personal interaction and self-service systems		50

15. Weigh the following two attributes based on their importance with regard to <u>Social Sustainability</u>.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Sustainable Service Delivery		
Social justice and social equality		50
Sustainable Living		
Social development		50

Note: No weight elicitation is needed for human resource management, since there is only one performance area identified for this performance category.

Part D

This part of the survey gathers data on the attributes at level 1 (i.e. performance categories) of the value tree.

---

16. Weigh the following four attributes based on their importance with regard to People Matters.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do no need to add up to 100.

	Weight	Out of 100
Public Relations		
Marketing and networking		50
Customer Service		
Traveller information provision and general support information		50
Social Sustainability		
Sustainable service delivery and sustainable living		50
Human Resource Management		
Employee performance management		50

ITS EXPERTS: PLANET

ENVIRONMENTAL MATTERS

This perspective consists of four performance categories. These are: 1) Air Quality Management, 2) Climate Change Management, 3) Noise Management and 4) Energy Management.

Air Quality Management consists of only one performance area; namely Air Pollution Monitoring. **Climate Change Management** consists of only one performance area; namely Weather Monitoring. **Noise Management** consists of only one performance area; namely Noise Exposure Monitoring. **Energy Management** consists of only one performance area; namely Energy Use Monitoring. The associated value tree can be viewed at: Value Tree Environmental Matters.pdf

This survey consists of four parts: A to D. The data obtained from this survey will be used for the weight elicitation step of Multi Criteria Decision Analysis.

Part A

This part of the survey gathers data on the attributes at level 4 (i.e. performance measures) of the value tree.

AIR QUALITY MANAGEMENT

Air Quality Monitoring

In order to monitor air pollution and hence the quality of the air we breathe, both the emissions from mobile sources and greenhouse gas (GHG) emissions need to be considered. While mobile source emissions refer to the emissions from vehicles, trucks and buses; GHG emissions refer to the emissions from burning fossil fuel to operate these transport modes. The priority pollutants from vehicle emissions are: Particulate Matter, Sulphur Dioxide, Nitrogen Dioxide, Ozone, Carbon Monoxide and Hydrogen Sulphide. The priority pollutants from GHG emissions are: Carbon Dioxide, Nitrous Oxide and Methane.

1. Weigh the following three attributes based on their importance with regard to Mobile Source and GHG Emissions.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Priority Pollutants: Governance		
Regulate priority pollutants. For example: manufacturer declarations and roadside air quality tests		50
Pollution: Mitigation Strategies		

Emission control technologies and reducing activities. For example: hybrid vehicles and clean fuel initiatives	50
Pollution: Trend Evaluation	
Change in air quality and/or emissions intensity	50

CLIMATE CHANGE MANAGEMENT

Weather Monitoring

Weather monitoring relates to the action of managing the effects of adverse weather conditions. Adverse weather conditions prevail when there is a severe presence of: wind, temperature, sunshine, rain, hail and fog. Such conditions can influence the road condition and can also impair human senses. For example: excessive rain can cause a slippery road surface and excessive sunshine can impair human sight. Both of the aforementioned situations influence driving behaviour.

2. Weigh the following three attributes based on their importance with regard to Driving Behaviour.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

Weight	Out of 100
Weather Conditions: Governance	
Manage weather conditions with the aid of an environmental sensor station	50
Weather Conditions: Impact Mitigation Strategies	
Weather control technologies and activities. For example: street lights, electric cat eyes, reflective paint and variable speed limit signs	50
Weather Conditions: Trend Evaluation	
Change in number of weather-related incidents	50

NOISE MANAGEMENT

Noise Exposure Monitoring

Noise can be defined as an unwanted sound or an audible acoustic energy that adversely affects the physiological and/or psychological well-being of people or that disturbs or impairs the convenience or peace of any person. When monitoring noise exposure, both the noise source and the -receiver need to be considered. The noise source generates the noise. Examples of noise sources are vehicles and infrastructure. The generated noise is then transmitted or reflected via a variety of paths to the receiver. The receiver refers to the person (i.e. traveller - driver or passenger) that is exposed to the noise.

3. Weigh the following three attributes based on their importance with regard to Noise Sources and Receivers.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Noise Exposure: Governance	
Regulate noise exposure levels and time exposed. For example: manufacturer declarations and in-field tests	50
Nosie Exposure: Mitigation Strategies	
Noise screening at source and noise protection at receiver. For example: noise barriers and soundproof windows	50
Noise Exposure: Trend Evaluation	
Change in noise exposure levels and time exposed	50

ENERGY MANAGEMENT

Energy Use Monitoring

Energy use monitoring refers to the action of managing the efficient consumption of energy. Efficient energy use, also called energy efficiency, is about reducing the amount of energy that is required to provide the service (or product). Energy efficiency is thus identified as the performance sub area for energy use monitoring.

4. Weigh the following three attributes based on their importance with regard to Energy Efficiency.
* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight Out of 100
Energy Consumption: Governance	
Regulate energy consumption levels and rates. For example: manufacturer declarations	50
Energy Consumption: Mitigation Strategies	

Efficiency programs. For example: renewable energy programs (e.g. wind turbines and solar energy) and waste management programs (e.g. recycling)	50
Energy Consumption: Trend Evaluation	
Change in energy consumption/ energy intensity and efficiency score	50

Part B

This part of the survey gathers data on the attributes at level 3 (i.e. performance sub-areas) of the value tree.

Note: No weight elicitation is needed at this level, since there is only one performance sub-area identified for each of the performance areas.

Part C

This part of the survey gathers data on the attributes at level 2 (i.e. performance areas) of the value tree.

Note: No weight elicitation is needed at this level, since there is only one performance area identified for each of the performance categories.

Part D

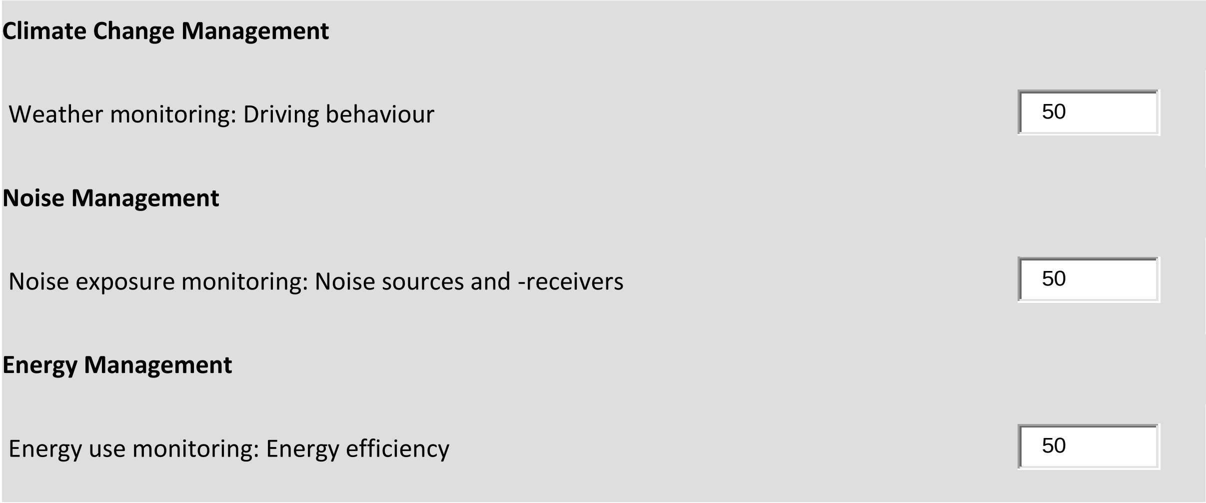
This part of the survey gathers data on the attributes at level 1 (i.e. performance categories) of the value tree.

---

5. Weigh the following four attributes based on their importance with regard to <u>Environmental Matters</u>.

* If some of the attributes are equally important, they need to be given the same weight.
* Note: the weights do not need to add up to 100.

	Weight	Out of 100
Air Quality Management		
Air pollution monitoring: Mobile source and GHG emissions	50	



Climate Change Management

Weather monitoring: Driving behaviour	50

Noise Management

Noise exposure monitoring: Noise sources and -receivers	50

Energy Management

Energy use monitoring: Energy efficiency	50

D. CAPE TALK 567 ARTICLE

PHD STUDENT HELL-BENT ON EASING TRAFFIC USING INTELLIGENT TRANSPORT SYSTEMS

23 September 2015, 8:51 AM

The electronic information signboards system across Cape Town's highways exist to improve the experience of motorists when commuting. However, many commuters would say that the traffic management system could be made even more effective.

One such person is Claudia Struwig, a final year PhD Civil engineering student at the University of Stellenbosch. Struwig's studies are focused on evaluating the Intelligent Transport System use on our roads and the experiences of all road-users.

> *“Intelligent Transport Systems are any system that uses technology to improve the transport environment as experienced by the user.”* - Claudia Struwig, PhD Student at Stellenbosch University

She is looking into the effectiveness of the system and, in order to see how it can be better implemented, requires public feedback.

Share your experiences and participate in the PhD survey.

E. MICROSOFT EXCEL MODELS: VBA CODE

PROCESSES USER FORM

PRIVATE SUB RESET VALUES

```
Private Sub ResetValues_Click()
```

```
Sheets("A - Private").Activate
Range("A4:O103").Select
Selection.Delete
Sheets("A - Public").Activate
Range("A4:O103").Select
Selection.Delete
Sheets("Standardisation").Activate
Range("B6:B11").Select
Selection.ClearContents
Range("D6:D11").Select
Selection.ClearContents
Range("B12:E17").Select
Selection.ClearContents
Sheets("S - Private").Activate
Range("B3:B29").Select
Selection.ClearContents
Range("D3:D29").Select
Selection.ClearContents
Sheets("S - Public").Activate
Range("B3:B27").Select
Selection.ClearContents
Range("D3:D27").Select
Selection.ClearContents
Sheets("W - Private").Activate
Range("A5:T103").Select
Selection.Delete
Sheets("W - Public").Activate
Range("A5:T103").Select
Selection.Delete
Sheets("MAVT").Activate
```

```
    Range("A4:K105").Select
    Selection.Delete
    Sheets("Attribute Table").Select
End Sub
```

PRIVATE SUB RUN ALL PRIVATE TRANSPORT MACROS

```
Private Sub RunAllPrivateTransportMacros_Click()
   Call Convert_Private
   Call Hide_Private
   Call Copy_Visible_Private
   Call Unhide_Private
   Call Delete_Private
   Call Range_Private
   Call Go_To_Private
End Sub
Sub Convert_Private()
    Dim MyRange1 As Range
    Dim MyRange2 As Range
    Dim MyCell As Range
    Sheets("Attribute Table").Activate
    Set MyRange1 = Range("F4:F103")
    Set MyRange2 = MyRange1.SpecialCells(xlCellTypeAllFormatConditions)
    For Each MyCell In MyRange2
        If MyCell.Text = "MTBF" Or MyCell.Text = "Error Rate" Or MyCell.Text = "MTTR" Then
            MyCell.Font.ColorIndex = 3  'red
        End If
    Next MyCell
End Sub
Sub Hide_Private()
    Dim MyRange As Range
    Dim MyCell As Range
```

```
    Sheets("Attribute Table").Activate
    Set MyRange = ActiveSheet.Range("E4:F103")
    For Each MyCell In MyRange
        If Not IsEmpty(MyCell) Then
            If MyCell.Font.ColorIndex = 23 Then 'blue
            MyCell.EntireRow.Hidden = True
            End If
        End If
    Next MyCell
End Sub
 Sub Copy_Visible_Private()
    Dim MyRange1 As Range
    Dim MyRange2 As Range
    Dim MyRange3 As Range
    Sheets("Attribute Table").Activate
    Set MyRange1 = Range("A4:K103")
    MyRange1.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("A - Private").Activate
    Cells(4, 1).PasteSpecial Paste:=xlPasteFormats
    Cells(4, 1).PasteSpecial Paste:=xlPasteValues
    Sheets("A - Private").Activate
    Range("A4:A103").Select
    With Selection
        Selection.NumberFormat = "General"
        .Value = .Value
    End With
    Sheets("Attribute Table").Activate
    Set MyRange2 = Range("L4:M103")
    MyRange2.SpecialCells(xlCellTypeVisible).Select
```

```
    Selection.Copy
    Sheets("A - Private").Activate
    Cells(4, 12).Activate
    ActiveSheet.Paste
    Sheets("Attribute Table").Activate
    Set MyRange3 = Range("N4:O103")
    MyRange3.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("A - Private").Activate
    Cells(4, 14).PasteSpecial Paste:=xlPasteFormulas
End Sub
Sub Unhide_Private()
    Sheets("Attribute Table").Activate
    ActiveSheet.Cells.EntireRow.Hidden = False
End Sub
Sub Delete_Private()
    Dim MyRange As Range
    Dim MyCell As Range
    Dim LastRowE As Integer
    Sheets("Weight Table").Select
    Range("A5:T103").Select
    Selection.Copy
    Sheets("W - Private").Activate
    Cells(5, 1).Activate
    Selection.PasteSpecial xlPasteAll
    Set MyRange = Sheets("W - Private").Range("E5:F103")
    For Each MyCell In MyRange
        If Not IsEmpty(MyCell) Then
            If MyCell.Font.ColorIndex = 23 Then 'blue
            MyCell.EntireRow.Hidden = True
```

```
        End If
      End If
    Next MyCell
    Sheets("W - Private").Activate
    LastRowE = Range("A" & Rows.Count).End(xlUp).Row
    For i = 5 To LastRowE
      If Cells(i, 6).EntireRow.Hidden = True Then
        Cells(i, 6).EntireRow.Delete
        i = i - 1
      End If
    Next i
End Sub
Sub Range_Private()
    Dim LookFor As Range
    Dim Lookup_Range As Range
    Dim Min As Double
    Dim Max As Double
    Dim ws1 As Worksheet
    Dim ws2 As Worksheet
    Set ws1 = ThisWorkbook.Sheets("A - Private")
    Set ws2 = ThisWorkbook.Sheets("S - Private")
    ws1.Activate
    ws1.Range("I4:I103").Select
    For i = 4 To 103
      If Not IsEmpty(Cells(i, 9)) And IsEmpty(Cells(i, 10)) Then
        Set LookFor = ws1.Cells(i, 1)
        Set Lookup_Range = ws2.Range("A33:E59")
        Min = Application.VLookup(LookFor, Lookup_Range, 4, False)
        Max = Application.VLookup(LookFor, Lookup_Range, 5, False)
        Cells(i, 10).Value = Min    'column J
```

```
            Cells(i, 11).Value = Max    'column K
        End If
    Next i
End Sub
Sub Go_To_Private()
    Sheets("A - Private").Select
End Sub
```

PRIVATE SUB RUN ALL PUBLIC TRANSPORT MACROS

```
Private Sub RunAllPublicTransportMacros_Click()
   Call Convert_Public
   Call Hide_Public
   Call Copy_Visible_Public
   Call Unhide_Public
   Call Delete_Public
   Call Range_Public
    Call Go_To_Public
End Sub
Sub Convert_Public()
    Dim MyRange1 As Range
    Dim MyRange2 As Range
    Dim MyCell As Range
    Sheets("Attribute Table").Activate
    Set MyRange1 = Range("F4:F103")
    Set MyRange2 = MyRange1.SpecialCells(xlCellTypeAllFormatConditions)
    For Each MyCell In MyRange2
                If MyCell.Text = "MTBF: Fleet" Or MyCell.Text = "MTBF: Fare" Or MyCell.Text = "Error Rate: Fleet" Or
                MyCell.Text = "Error Rate: Fare" Or MyCell.Text = "MTTR: Fleet" Or MyCell.Text = "MTTR: Fare" Then
                MyCell.Font.ColorIndex = 23 'blue
        End If
    Next MyCell
End Sub
```

```
Sub Hide_Public()
   Dim MyRange As Range
   Dim MyCell As Range
   Sheets("Attribute Table").Activate
   Set MyRange = ActiveSheet.Range("E4:F103")
   For Each MyCell In MyRange
      If Not IsEmpty(MyCell) Then
         If MyCell.Font.ColorIndex = 3 Then 'red
            MyCell.EntireRow.Hidden = True
         End If
      End If
   Next MyCell
End Sub
Sub Copy_Visible_Public()
   Dim MyRange1 As Range
   Dim MyRange2 As Range
   Dim MyRange3 As Range
   Sheets("Attribute Table").Activate
   Set MyRange1 = Range("A4:K103")
   MyRange1.SpecialCells(xlCellTypeVisible).Select
   Selection.Copy
   Sheets("A - Public").Activate
   Cells(4, 1).PasteSpecial Paste:=xlPasteFormats
   Cells(4, 1).PasteSpecial Paste:=xlPasteValues
   Sheets("A - Public").Activate
   Range("A4:A103").Select
   With Selection
      Selection.NumberFormat = "General"
      .Value = .Value
   End With
```

```
  Sheets("Attribute Table").Activate
  Set MyRange2 = Range("L4:M103")
  MyRange2.SpecialCells(xlCellTypeVisible).Select
  Selection.Copy
  Sheets("A - Public").Activate
  Cells(4, 12).Activate
  ActiveSheet.Paste
  Sheets("Attribute Table").Activate
  Set MyRange3 = Range("N4:O103")
  MyRange3.SpecialCells(xlCellTypeVisible).Select
  Selection.Copy
  Sheets("A - Public").Activate
  Cells(4, 14).PasteSpecial Paste:=xlPasteFormulas
End Sub
Sub Unhide_Public()
  Sheets("Attribute Table").Activate
  ActiveSheet.Cells.EntireRow.Hidden = False
End Sub
Sub Delete_Public()
  Dim MyRange As Range
  Dim MyCell As Range
  Dim LastRowE As Integer
  Sheets("Weight Table").Select
  Range("A5:T103").Select
  Selection.Copy
  Sheets("W - Public").Activate
  Cells(5, 1).Activate
  Selection.PasteSpecial xlPasteAll
  Set MyRange = Sheets("W - Public").Range("E5:F103")
  For Each MyCell In MyRange
```

```
      If Not IsEmpty(MyCell) Then
         If MyCell.Font.ColorIndex = 3 Then 'red
            MyCell.EntireRow.Hidden = True
         End If
      End If
   Next MyCell
   Sheets("W - Public").Activate
   LastRowE = Range("A" & Rows.Count).End(xlUp).Row
   For i = 5 To LastRowE
      If Cells(i, 6).EntireRow.Hidden = True Then
         Cells(i, 6).EntireRow.Delete
         i = i - 1
      End If
   Next i
End Sub
Sub Range_Public()
   Dim LookFor As Range
   Dim Lookup_Range As Range
   Dim Min As Double
   Dim Max As Double
   Dim ws1 As Worksheet
   Dim ws2 As Worksheet
   Set ws1 = ThisWorkbook.Sheets("A - Public")
   Set ws2 = ThisWorkbook.Sheets("S - Public")
   ws1.Activate
   ws1.Range("I4:I103").Select
   For i = 4 To 103
      If Not IsEmpty(Cells(i, 9)) And IsEmpty(Cells(i, 10)) Then
         Set LookFor = ws1.Cells(i, 1)
         Set Lookup_Range = ws2.Range("A31:E55")
```

```
        Min = Application.VLookup(LookFor, Lookup_Range, 4, False)

        Max = Application.VLookup(LookFor, Lookup_Range, 5, False)

        Cells(i, 10).Value = Min    'column J

        Cells(i, 11).Value = Max    'column K

      End If

    Next i

End Sub

Sub Go_To_Public()

    Sheets("A - Public").Select

End Sub
```

PRIVATE SUB UPDATE MEASURES

```
Private Sub UpdateMeasures_Click()

    Dim MyRange1 As Range

    Dim MyRange2 As Range

    Dim MyRange3 As Range

    Dim MyCell As Range

    Sheets("Attribute Table").Activate

    Set MyRange1 = Range("F4:F103")

    Set MyRange2 = MyRange1.SpecialCells(xlCellTypeAllFormatConditions)

    For Each MyCell In MyRange2

            If MyCell.Text = "MTBF" Or MyCell.Text = "Error Rate" Or MyCell.Text = "MTTR" Then
            MyCell.Font.ColorIndex = 3  'red

            End If

            If MyCell.Text = "MTBF: Fleet" Or MyCell.Text = "MTBF: Fare" Or MyCell.Text = "Error Rate: Fleet" Or
            MyCell.Text = "Error Rate: Fare" Or MyCell.Text = "MTTR: Fleet" Or MyCell.Text = "MTTR: Fare" Then
            MyCell.Font.ColorIndex = 23 'blue

            End If

    Next MyCell

    Sheets("Attribute Table").Activate

    Set MyRange3 = Range("A4:F103")

    MyRange3.Select
```

```
    Selection.Copy
    Sheets("Weight Table").Activate
    Cells(5, 1).PasteSpecial Paste:=xlPasteFormats
    Cells(5, 1).PasteSpecial Paste:=xlPasteValues
    Sheets("Weight Table").Activate
    Range("A5:A103").Select
    With Selection
        Selection.NumberFormat = "General"
        .Value = .Value
    End With
    Sheets("Attribute Table").Select
End Sub
```

MODULE PRIVATE

```
Sub Button_Private_Reset()
    Sheets("A - Private").Activate
    ActiveSheet.Range("L4:M103").ClearContents
End Sub
Sub Button_Private_Values()
    Dim LookFor As Range
    Dim Lookup_Range As Range
    Dim Slope As Double
    Dim Intercept As Double
    Dim Value1 As Double
    Dim Value2 As Double
    Dim Answer1 As Double
    Dim Answer2 As Double
    Dim ws1 As Worksheet
    Dim ws2 As Worksheet
    Set ws1 = ThisWorkbook.Sheets("A - Private")
    Set ws2 = ThisWorkbook.Sheets("S - Private")
```

```
ws1.Range("N4:O103").Select

For i = 4 To 103

  If Cells(i, 14).HasFormula() = False Then

    If Not IsEmpty(Cells(i, 11)) Then

      Set LookFor = ws1.Cells(i, 1)

      Set Lookup_Range = ws2.Range("A33:E59")

      Slope = Application.VLookup(LookFor, Lookup_Range, 2, False)

      Intercept = Application.VLookup(LookFor, Lookup_Range, 3, False)

      Value1 = Cells(i, 12).Value ' as is value

      Answer1 = Slope * Value1 + Intercept

      If Value1 < Cells(i, 10).Value And Cells(i, 9).Text = "B" Then

        Answer1 = 0

      End If

      If Value1 > Cells(i, 11).Value And Cells(i, 9).Text = "B" Then

        Answer1 = 100

      End If

      If Value1 < Cells(i, 10).Value And Cells(i, 9).Text = "C" Then

        Answer1 = 100

      End If

      If Value1 > Cells(i, 11).Value And Cells(i, 9).Text = "C" Then

        Answer1 = 0

      End If

      Cells(i, 14).Value = Answer1    'column N

      Value2 = Cells(i, 13).Value 'after value

      Answer2 = Slope * Value2 + Intercept

      If Value2 < Cells(i, 10).Value And Cells(i, 9).Text = "B" Then

        Answer2 = 0

      End If

      If Value2 > Cells(i, 11).Value And Cells(i, 9).Text = "B" Then

        Answer2 = 100
```

```
            End If
            If Value2 < Cells(i, 10).Value And Cells(i, 9).Text = "C" Then
              Answer2 = 100
            End If
            If Value2 > Cells(i, 11).Value And Cells(i, 9).Text = "C" Then
              Answer2 = 0
            End If
            Cells(i, 15).Value = Answer2    'column O
            If Answer1 > 100 Then
              Answer1 = 100
              Cells(i, 14).Value = Answer1
            End If
            If Answer2 > 100 Then
              Answer2 = 100
              Cells(i, 15).Value = Answer2
            End If
            If Answer1 < 0 Then
              Answer1 = 0
              Cells(i, 14).Value = Answer1
            End If
            If Answer2 < 0 Then
              Answer2 = 0
              Cells(i, 15).Value = Answer2
            End If
          End If
        End If
  Next i
End Sub
Sub Button_Private_Compute()
  Call Standard_Private
```

```
    Call S_Private
    Call MAVT_Private
End Sub
Sub Standard_Private()
    Dim LookFor As Range
    Dim Lookup_Range As Range
    Dim ws1 As Worksheet
    Dim ws2 As Worksheet
    Set ws1 = ThisWorkbook.Sheets("Standardisation")
    Set ws2 = ThisWorkbook.Sheets("A - Private")
    ws1.Select
    Set LookFor = ws1.Cells(6, 1)  'binary
    Set Lookup_Range = ws2.Range("A4:O103")
    LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)
        If IsError(LookFor.Offset(0, 1).Value) Then
            ws1.Cells(6, 2).Value = "N/A"
        End If
    LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
        If IsError(LookFor.Offset(0, 3).Value) Then
            ws1.Cells(6, 4).Value = "N/A"
        End If
    For i = 7 To 10 'scores
        Set LookFor = ws1.Cells(i, 1)
        Set Lookup_Range = ws2.Range("A4:O103")
        LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)
        If IsError(LookFor.Offset(0, 1).Value) Then
            ws1.Cells(i, 2).Value = "N/A"
        End If
        LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
        If IsError(LookFor.Offset(0, 3).Value) Then
```

```
        ws1.Cells(i, 4).Value = "N/A"
    End If
Next i
Set LookFor = ws1.Cells(11, 1)  'special case
Set Lookup_Range = ws2.Range("A4:O103")
LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(11, 2).Value = "N/A"
    End If
LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
    If IsError(LookFor.Offset(0, 3).Value) Then
        ws1.Cells(11, 4).Value = "N/A"
    End If
For i = 12 To 17   'decay rate
    Set LookFor = ws1.Cells(i, 1)
    Set Lookup_Range = ws2.Range("A4:O103")
    LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)  'column B and N
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(i, 2).Value = "N/A"
    End If
    LookFor.Offset(0, 2).Value = Application.VLookup(LookFor, Lookup_Range, 12, False)
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(i, 3).Value = "N/A"
    End If
    LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False
    If IsError(LookFor.Offset(0, 3).Value) Then
        ws1.Cells(i, 4).Value = "N/A"
    End If
    LookFor.Offset(0, 4).Value = Application.VLookup(LookFor, Lookup_Range, 13, False)
    If IsError(LookFor.Offset(0, 1).Value) Then
```

```
    ws1.Cells(i, 5).Value = "N/A"
  End If
Next i
End Sub
Sub S_Private()
  Dim LookFor As Range
  Dim Lookup_Range As Range
  Dim ws1 As Worksheet
  Dim ws2 As Worksheet
  Set ws1 = ThisWorkbook.Sheets("S - Private")
  Set ws2 = ThisWorkbook.Sheets("A - Private")
  ws1.Select
  For i = 3 To 29
    Set LookFor = ws1.Cells(i, 1)
    Set Lookup_Range = ws2.Range("A4:O103")
    LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 12, False)
    If IsError(LookFor.Offset(0, 1).Value) Then
      ws1.Cells(i, 2).Value = "N/A"
    End If
    LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 13, False)
    If IsError(LookFor.Offset(0, 3).Value) Then
      ws1.Cells(i, 4).Value = "N/A"
    End If
  Next i
End Sub
Sub MAVT_Private()
  Dim MyRange1 As Range
  Dim MyRange2 As Range
  Dim MyRange3 As Range
  Sheets("A - Private").Activate
```

```
    Set MyRange1 = Range("A4:F103")
    MyRange1.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("MAVT").Activate
    Sheets("MAVT").Cells(4, 1).Select
    ActiveSheet.Paste
    Sheets("W - Private").Activate
    Set MyRange2 = Range("T5:T103")
    MyRange2.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("MAVT").Activate
    Sheets("MAVT").Cells(4, 7).PasteSpecial xlPasteValues
    Sheets("A - Private").Activate
    Set MyRange3 = Range("N4:O103")
    MyRange3.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("MAVT").Activate
    Sheets("MAVT").Range("H4:I103").PasteSpecial xlPasteValues
End Sub
```

MODULE PUBLIC

```
Sub Button_Public_Reset()
    Sheets("A - Public").Activate
      ActiveSheet.Range("L4:M103").ClearContents
End Sub
Sub Button_Public_Values()
    Dim LookFor As Range
    Dim Lookup_Range As Range
    Dim Slope As Double
    Dim Intercept As Double
    Dim Value1 As Double
```

```
Dim Value2 As Double

Dim Answer1 As Double

Dim Answer2 As Double

Dim ws1 As Worksheet

Dim ws2 As Worksheet

Set ws1 = ThisWorkbook.Sheets("A - Public")

Set ws2 = ThisWorkbook.Sheets("S - Public")

ws1.Range("N4:O103").Select

For i = 4 To 103

    If Cells(i, 14).HasFormula() = False Then

        If Not IsEmpty(Cells(i, 11)) Then

            Set LookFor = ws1.Cells(i, 1)

            Set Lookup_Range = ws2.Range("A31:E55")

            Slope = Application.VLookup(LookFor, Lookup_Range, 2, False)

            Intercept = Application.VLookup(LookFor, Lookup_Range, 3, False)

            Value1 = Cells(i, 12).Value ' as is value

            Answer1 = Slope * Value1 + Intercept

            If Value1 < Cells(i, 10).Value And Cells(i, 9).Text = "B" Then

                Answer1 = 0

            End If

            If Value1 > Cells(i, 11).Value And Cells(i, 9).Text = "B" Then

                Answer1 = 100

            End If

            If Value1 < Cells(i, 10).Value And Cells(i, 9).Text = "C" Then

                Answer1 = 100

            End If

            If Value1 > Cells(i, 11).Value And Cells(i, 9).Text = "C" Then

                Answer1 = 0

            End If

            Cells(i, 14).Value = Answer1    'column N
```

```
Value2 = Cells(i, 13).Value 'after value

Answer2 = Slope * Value2 + Intercept

If Value2 < Cells(i, 10).Value And Cells(i, 9).Text = "B" Then

   Answer2 = 0

End If

If Value2 > Cells(i, 11).Value And Cells(i, 9).Text = "B" Then

   Answer2 = 100

End If

If Value2 < Cells(i, 10).Value And Cells(i, 9).Text = "C" Then

   Answer2 = 100

End If

If Value2 > Cells(i, 11).Value And Cells(i, 9).Text = "C" Then

   Answer2 = 0

End If

Cells(i, 15).Value = Answer2    'column O

If Answer1 > 100 Then

   Answer1 = 100

   Cells(i, 14).Value = Answer1

End If

If Answer2 > 100 Then

   Answer2 = 100

   Cells(i, 15).Value = Answer2

End If

If Answer1 < 0 Then

   Answer1 = 0

   Cells(i, 14).Value = Answer1

End If

If Answer2 < 0 Then

   Answer2 = 0

   Cells(i, 15).Value = Answer2
```

```
            End If
          End If
        End If
      Next i
    End Sub
    Sub Button_Public_Compute()
     Call Standard_Public
     Call S_Public
     Call MAVT_Public
    End Sub
    Sub Standard_Public()
      Dim LookFor As Range
      Dim Lookup_Range As Range
      Dim ws1 As Worksheet
      Dim ws2 As Worksheet
      Set ws1 = ThisWorkbook.Sheets("Standardisation")
      Set ws2 = ThisWorkbook.Sheets("A - Public")
      ws1.Select
      Set LookFor = ws1.Cells(6, 1)  'binary
      Set Lookup_Range = ws2.Range("A4:O103")
      LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)
        If IsError(LookFor.Offset(0, 1).Value) Then
          ws1.Cells(6, 2).Value = "N/A"
        End If
      LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
        If IsError(LookFor.Offset(0, 3).Value) Then
          ws1.Cells(6, 4).Value = "N/A"
        End If
      For i = 7 To 10 'scores
        Set LookFor = ws1.Cells(i, 1)
```

```
    Set Lookup_Range = ws2.Range("A4:O103")
    LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(i, 2).Value = "N/A"
    End If
    LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
    If IsError(LookFor.Offset(0, 3).Value) Then
        ws1.Cells(i, 4).Value = "N/A"
    End If
Next i
Set LookFor = ws1.Cells(11, 1)  'special case
Set Lookup_Range = ws2.Range("A4:O103")
LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False)
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(11, 2).Value = "N/A"
    End If
LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
    If IsError(LookFor.Offset(0, 3).Value) Then
        ws1.Cells(11, 4).Value = "N/A"
    End If
For i = 12 To 17   'decay rate
    Set LookFor = ws1.Cells(i, 1)
    Set Lookup_Range = ws2.Range("A4:O103")
    LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 14, False
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(i, 2).Value = "N/A"
    End If
    LookFor.Offset(0, 2).Value = Application.VLookup(LookFor, Lookup_Range, 12, False
    If IsError(LookFor.Offset(0, 1).Value) Then
        ws1.Cells(i, 3).Value = "N/A"
```

```
        End If
        LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 15, False)
        If IsError(LookFor.Offset(0, 3).Value) Then
            ws1.Cells(i, 4).Value = "N/A"
        End If
        LookFor.Offset(0, 4).Value = Application.VLookup(LookFor, Lookup_Range, 13, False
        If IsError(LookFor.Offset(0, 1).Value) Then
            ws1.Cells(i, 5).Value = "N/A"
        End If
    Next i
End Sub
Sub S_Public()
    Dim LookFor As Range
    Dim Lookup_Range As Range
    Dim ws1 As Worksheet
    Dim ws2 As Worksheet
    Set ws1 = ThisWorkbook.Sheets("S - Public")
    Set ws2 = ThisWorkbook.Sheets("A - Public")
    ws1.Select
    For i = 3 To 27
        Set LookFor = ws1.Cells(i, 1)
        Set Lookup_Range = ws2.Range("A4:O103")
        LookFor.Offset(0, 1).Value = Application.VLookup(LookFor, Lookup_Range, 12, False)
        If IsError(LookFor.Offset(0, 1).Value) Then
            ws1.Cells(i, 2).Value = "N/A"
        End If
        LookFor.Offset(0, 3).Value = Application.VLookup(LookFor, Lookup_Range, 13, False)
        If IsError(LookFor.Offset(0, 3).Value) Then
            ws1.Cells(i, 4).Value = "N/A"
        End If
```

```
    Next i
End Sub
Sub MAVT_Public()
    Dim MyRange1 As Range
    Dim MyRange2 As Range
    Dim MyRange3 As Range
    Sheets("A - Public").Activate
    Set MyRange1 = Range("A4:F103")
    MyRange1.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("MAVT").Activate
    Sheets("MAVT").Cells(4, 1).Select
    ActiveSheet.Paste
    Sheets("W - Public").Activate
    Set MyRange2 = Range("T5:T103")
    MyRange2.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("MAVT").Activate
    Sheets("MAVT").Cells(4, 7).PasteSpecial xlPasteValues
    Sheets("A - Public").Activate
    Set MyRange3 = Range("N4:O103")
    MyRange3.SpecialCells(xlCellTypeVisible).Select
    Selection.Copy
    Sheets("MAVT").Activate
    Sheets("MAVT").Range("H4:I103").PasteSpecial xlPasteValues
End Sub
```

MODULE MAVT

```
Sub MAVT_Button2_Click()
    Dim MyCell As Range
    Dim MyRange As Range
```

```
 Dim asis As Double
 Dim after As Double
 Sheets("MAVT").Activate
 Set MyRange = ActiveSheet.Range("I4:I103")
     For Each MyCell In MyRange
         If Not IsEmpty(MyCell) Then
             MyCell.Offset(0, 1) = MyCell.Offset(0, -2) * MyCell.Offset(0, -1)
             MyCell.Offset(0, 2) = MyCell.Offset(0, -2) * MyCell
         End If
     Next MyCell
 Range("J105").Formula = "=Sum(J4:J103)"
 Range("K105").Formula = "=Sum(K4:K103)"
MsgBox "Before overall value is " & Range("J105").Value & " and after overall value is " & Range("K105").Value
End Sub
```

F. CONTENT OF ATTACHED CD

The attached CD contains the following files:

- raw survey data (i.e. value- and weight elicitation),
- STATISTICA program installation files and output data,

  Note: any person with a Stellenbosch University email address can install STATISTICA.
- five Microsoft Excel VBA models (i.e. practices, processes, profit, people and planet), and
- Microsoft Excel performance dashboard.