Performance Measurement Trends in the implementation of Intelligent Transportation Systems (ITS) within the South African Transportation Environment

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Abstract – **Over the past decade, the South African transportation environment has actively started to adapt a technology-driven setting. Intelligent Transportation Systems (ITS) applications such as Advanced Traffic Management Systems (ATMS) and Advanced Public Transportation Systems (APTS) have since been promoted and developed. These ITS deployments have brought about 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 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 conceptualization- and planning phase of ITS projects. 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 industry to objectively assess the effects of their specific applications with regard to the implementation of policies and technologies. The aim of this paper is thus to define a common evaluation framework for the monitoring and managing of the newly developed systems and to present guidelines as to its application. The aforementioned is accomplished by elucidating the need for managing performance measurement and by providing a review on the current ITS measurement trends and movements in the South African transportation environment. Ultimately, a major evolution in the nation's transportation environment - in the form of an ITS performance management regime - may be stimulated.**

I. Foreword

This paper is of an investigative nature and is the first in a series of publications emanating from a research project on ITS performance management. The specific application environment addressed is that of a developing country such as South Africa (SA). In this paper, the need for managing performance measurement is elucidated and a review on the current ITS measurement trends is provided. The recommended way forward and the future directions are also discussed.

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II. Background

In 2007 the South African Government introduced the National Land Transportation Act (NLTA) in which the minimum requirements for the nation's Integrated Transportation Plans (ITPs) are stipulated [6]. The provision of the NLTA has given rise to a significant increase in implementation mandates; especially with regard to the deployment of ITS applications such as ATMS and APTS. In general, SA has started to adapt a technology-driven setting where mobility for all, system interoperability and seamless traveling are fostered.

III. Introduction

A. *Problem Formulation*

Since ATMS and APTS are examples of ITS applications, the critical role that technology plays in their realization and operation is evident. For example, the implementation of Freeway Management Systems (FMS) is dependent on technology such as traffic control devises and the implementation of Integrated Rapid Transportation (IRT) systems is dependent on technology such as electronic payment devices. These inherent technology-related aspects of the ITS applications need to be managed.

These aspects are currently, to varying degrees, being measured and monitored. However, little thought is given to ITS performance management in the conceptualization- and planning phase of ITS projects. As a result, the monitoring is mostly done by a modular- and possibly inconsistent performance measurement approach. Moreover, the resulting required multi-facet deployment associated with implementing such technology-oriented systems renders the ease of their management. Consequently, 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.

This current state of affairs creates skepticism 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. This likelihood of degradation is also further exacerbated by the ever changing world of technology we find ourselves in.

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B. *Proposition and Motivation*

In order to ensure the sustainable deployment of ITS applications, their technology-related aspects need to be managed in a pre-defined, continuous and holistic manner. In essence, the local 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. This gives rise to the adoption of a performance management regime. However, for such a regime to be employed, a performance measurement framework first needs to be developed. This framework will serve as the reference point for ITS performance management by presenting guidelines to widely accepted performance measures and by capturing transferable methodologies. If such a framework is in place, implementing agencies will be able to obtain the necessary knowledge to easily make day-to-day informed decisions regarding the overall performance of their respective systems and decision makers will be provided with a useful evaluation tool to aid in the continuous assessment of their investment in transportation technology.

C. *Focus of Paper*

The emphasis of a performance measurement framework is to act as a management tool for assessing the effective development and maintenance of ITS applications. The aim of this paper is thus to define an evaluation framework for the monitoring and managing of the technology-related aspects inherent to ATMS and APTS. The aforementioned is accomplished by elucidating the need for managing performance measurement and by providing a review on the current ITS measurement trends and movements with regard to technology deployments. Through the analysis of the status quo, various shortages are identified. These shortages assist in filling the identified gaps and aid in identifying measurement guidelines which then contribute towards the establishment of the performance measurement framework.

IV. Managing Performance Measurement

In order to comprehend the concept of managing performance measurement, firstly an understanding of performance **measurement** and then, secondly, an understanding of performance **management** are needed.

A. *Performance Measurement*

According to [3], performance measurement is defined as the assessment of an organization's output as a product of the management of its internal resources (e.g. money, people, vehicles and facilities) and the environment in which it operates. Therefore, in general terms, performance measurement refers to any evaluation- or comparison measure. These measures can either be a quantitative- or a qualitative characterization of performance; with each measure having certain indicators that are used to signify the performance of the system under consideration.

As can be seen in Fig. 1, the performance measurement process can be disassembled into a systematic top-down approach.

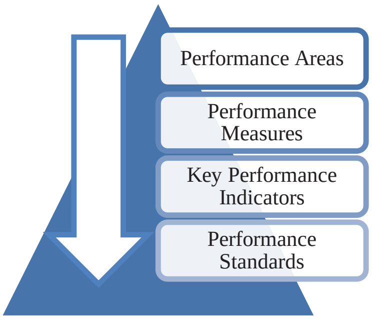

Figure 1. A Systematic (top-down) Approach towards Performance Measurement

B. *Performance Management*

As stated in [1], performance-based management is a systematic approach to performance improvement through an ongoing process of establishing strategic performance objectives; measuring performance; collecting, analyzing, reviewing and reporting performance data; and using that data to drive performance improvement. In essence, performance measurement is thus a critical component and predecessor of performance-based management.

The performance management process can be subdivided into six main sub-processes. These are [1]:

1. Establish a performance-based management program.
2. Establish an integrated performance measurement system.
3. Establish accountability for performance.
4. Collect data to assess performance.
5. Analyze, review and report performance data.
6. Use performance information to drive improvement.

V. Status Quo

As mentioned previously, no consistent or holistic performance management approach for measuring the technology-related aspects of the ITS deployments in the South African transportation environment is currently available. In order to investigate and elucidate the need for the provision of a performance management approach, a typical transportation environment that reflects the status of the current technology implementation with regard to the nation's ITS applications should be considered. An example of such a representative transportation environment is the City of Cape Town (CoCT).

As a point of reference, the CoCT's current transit- and traffic operations, including background to the extensive recent implementation of technology systems in this transportation environment, are considered. A discussion of these systems and their relating ITS-aspects follows in the next sub-sections.

A. *Technological Developments and Applications*

With the evolvement of information technology, immense scope for growth in the utilization of information systems has been created. Several initiatives within the transportation

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industry serve as testimony of this fact. A discussion of some of the evident emerging technology developments and their applications follows.

1) *The Transportation Management Center*

In May 2010, the CoCT officially opened its Transportation Management Center (TMC). The TMC is the City's operations' facility, with resultant transportation data repository, that is regarded as one of the finest state-of-the art multi-functional facilities in the world [2]. Since the realization of this center, extensive deployment of technology and the relating supporting ITS devices have been implemented. The TMC has five main functional areas, namely: 1) FMS, 2) Arterial Management System: AMS/ Urban Traffic Control: UTC, 3) Integrated Incident Management: IIM, 4) IRT and 5) Transportation Information Center: TIC [3].

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

2) *A Shift towards a Technology-oriented Approach*

a) Advanced Traffic Management Systems

ATMS utilize 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 in order to connect traffic sensors and roadside equipment, vehicle probes, Closed Circuit Television (CCTV) cameras, Electronic Vehicle Identification (EVI) and other devices together to create an integrated view of traffic flow and to detect accidents, dangerous weather events or other roadway hazards [4]. The information retrieved from the real time traffic monitoring is portrayed to drivers on output devices such as Variable Message Signs (VMS).

These ATMS procedures are currently managed by the CoCT's TMC and assist with FMS, AMS, UTC and IIM. Drivers are presently informed about the 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.

b) Advanced Public Transportation Systems

APTS utilize 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 in order to connect Global Positioning Systems (GPS) and Automated Vehicle Location (AVL), Electronic Fare Payment (EFP) and other devices together to create a real time view of the status of all the assets and the movement of the commuters in the public transportation system [4].

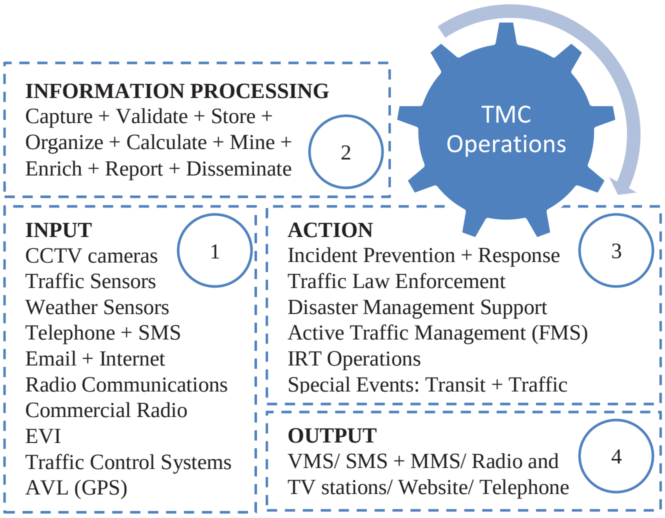

Figure 2. TMC Operations

The information retrieved from the real time monitoring is portrayed to the commuters on output devices such as Passenger Information Display Systems (PIDS) at stations and Advanced Traffic Information Systems (ATIS).

These APTS procedures facilitate IRT and are also currently managed by the CoCT's TMC. Commuters are presently informed about the arrival- and departure status (and overall timeliness) of buses and trains. Moreover, the CoCT's IRT network (referred to as MyCiti) implements Automated Fare Collection (AFC) by using an EFP system in conjunction with a smart card interoperable fare media type.

B. Performance Measurement and -Management

1) *Private Transportation Environment*

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.

a) SANRAL's Contract Performance Measurement

SANRAL has pursued a Key Performance Indicator (KPI) approach towards establishing the performance of the FMS in Gauteng, Kwazulu-Natal and the Western Cape [7]. Their primary objective is to deliver both regionally- and nationally integrated ITS functions at a consistent high level of quality. The developed performance measurement system encapsulates the following components: 1) employer's requirements, 2) principles of governance, 3) performance measurement and 4) payment mechanism. For the purpose required herein, only component three will be considered in more detail.

The concept of SANRAL's KPI approach towards performance measurement can, essentially, be represented through Fig. 3. This figure is adapted from the work in [7]. As can be seen in Fig. 3, SANRAL's measurement framework inherently caters for strategic alignment. They aim to align, from the beginning to the end of the

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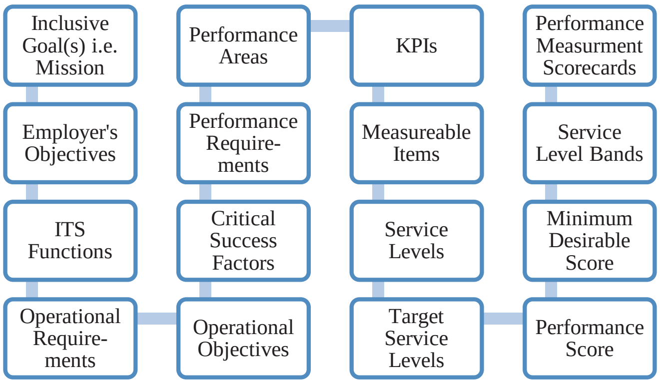

Figure 3. SANRALs Contract Performance Measurement

performance measurement contract, the operations of the main contractor with their objectives.

Unfortunately, since full functionality has not yet been deployed in the Western Cape, only certain KPIs in some of the identified performance areas are being measured. These areas include: 1) system availability, 2) incident responsiveness and information dissemination and 3) contract performance management. Moreover, the measurement is 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 transportation role-players as being too complex and perhaps even tedious.

2) *Public Transportation Environment*

In the Western Cape, two approaches are currently available to assist in managing the performance of the public transportation system. While the first one discussed is privately-owned, the second one is funded by the Government.

a) WhereIsMyTransport

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

Based on the purpose of this paper, the aspect of the *WhereIsMyTransport* application that is deemed most important is the operational environment toolset provided to the operator. Operators can currently, in real time, manage their fleets, assign routes, create schedules and monitor their drivers. The *WhereIsMyTransport* platform thus caters for vehicle tracking, asset protection, fleet management as well as personnel management. In essence, this toolset ensures safety and security while improving productivity and bringing discipline. However, being at the early stages of deployment, full functionality has not yet been attained.

b) 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 1. This table has been composed with the help of the CoCT's IRT department. A discussion of each of the performance areas listed in Table 1 follows:

1. System planning tool used to create the (optimized) base model.
2. Controlling software used to monitor real time vehicle movement.
3. Real time analyzing software used to review and (re)optimize system with regard to schedule adherence.
4. Business Intelligence (BI) objects used from a cost cutting perspective for post-analytic purposes (e.g. conducting trend analysis and reviewing routes).
5. Use onboard validators and turnstiles at stations to provide data on the number of taps/stop/route as well as load data and origin-destination data.
6. Use equipment to monitor inter alia harsh braking, swirling, aggressive acceleration and sharp cornering with the aim of reducing risky driver behavior.
7. Real time workforce, workflow, fault reporting and Service Level Agreement (SLA) monitoring system.
8. Market the MyCiti service to maintain a favorable public image.
9. Attend to inquiries, queries, complaints and compliments.
10. Monitor performance of operators and/or contractors and verify the quality of the data with on-site surveys. Operational plans - stipulating deviations with respect to route schedules and fare management - that need to be implemented in the case of a special event.

At first glance, the measurement tools currently used by the MyCiti system may appear to be relatively all-inclusive. However this is not the case. 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 impossible to attain an idea of the overall system health. As a result, the sustainability of the MyCiti system is at question.

VI. Discussion

The status quo on the technology deployments presented herein elucidates: 1) the shortcomings- and the unsustainable nature of the current modular measurement systems and 2) the complexities associated with the sustainable implementation of the ITS applications.

VII. Results

By considering the local ITS industry and the larger performance measurement field, Table 2 has been established. Although Table 2 is still in the early stages of development, the fundamental aspects of performance

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TABLE 1: MyCiti's Performance Measurement Toolbox

	Performance Area	Name	Type	Age
1	Base System Planning	Diva	Computer Software	2012
2	Vehicle Tracking	Lio		
3	Schedule Adherence			
4	Operational Performance	BI Analysis	Business Objects	
5	Financial Performance	AFC Financial Analysis	Microsoft Excel	
6	Driver Behavior Risk Management	Drivecam	Equipment/ Web-based	2013
7	Asset/ Maintenance/ SLA Management	Forcelink	Web-based & Mobile Interface	
8	Public Relations	Marketing	Service Promotion (Media)	2011
9	Customer Care	Customer Interaction	Service Provision (Social Media)	2010
10	Quality Assurance	Performance & Quality Monitoring	Performance Evaluation & Quality Assurance Checks	
11	Event Management	Special Events	Operational Deviation	

measurement and the primary features of ITS projects are addressed. A Sustainable Balanced Scorecard (SBSc) as the reference model for the performance framework has been adopted. This SBSc builds on the done work in [5].

The SBSc is to act as a management tool for assessing the effective development and maintenance of ITS applications as well as for evaluating the feasibility of continuous investments in transportation technology. Horizontally the SBSc is subdivided into five sustainability perspectives. These are: 1) learning and growth, 2) internal processes, 3) financial management, 4) society and 5) environment. Vertically the SBSc is subdivided into performance environments (level 1) and performance areas (level 2). Refer to Table 2.

VIII. Conclusions

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 transportation environment support this statement. The CoCT's TMC is an example of this. Since the realization of this transit- and traffic operations' facility, extensive deployment of technology and the relating supporting ITS devices have been implemented.

Moreover, the South African transportation 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 the performance measurement of FMS, the *WhereIsMyTransport* application provides an operational environment toolset to the transportation 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. An all-inclusive and easy-to-understand framework that can stimulate the achievement of the ultimate ITS performance management regime is needed. It is believed that the SBSc developed herein serves as the foundation for such a regime and hence also fosters the achievement of sustainable transportation.

IX. Future Research

With the completion of the research project on which this paper is based, the SBSc presented in Table 2 will be further developed by identifying each performance area's representative performance measure(s) as well as each performance measure's relating KPI and standard. With the aid of Multiple Criteria Decision Analysis (MCDA) principles, the overall system health will then be determined and portrayed on a consolidated performance dashboard.

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TABLE 2: Sustainable Balanced Scorecard

Sustainable Balanced Scorecard											
Learning & Growth		GOVERNANCE, PLANNING AND DECISION MAKING									
	1	*Regulation Management*				*Service-Operation Coordination*			*Research & Development*		
	2	Safety & Security Enforcement	Contract Performance Management	Legal Operational Requirements	Policy Plan-ning	Special Event Planning	Institutional Cooperation	Interoperable Operations	Continuous Improvement	Record Manage-ment	Data Manage-ment
Internal Processes		SERVICE-PROCESS EXCELLENCE									
	1	*Operational Performance*			*Technology Performance*		*Emergency & Response Performance*	*Asset Maintenance & Management*			
	2	Service Reliability	Service Quality	Operating Efficiency	Technology Reliability	Technology Quality	Incident Management	Asset Maintenance	Asset Management		
Financial Management		ECONOMIC PROSPERITY									
	1	*Economic Contribution*	*Economic Sustainability*		*Economic Vitality*			*Capital Investment Management*			
	2	Transportation GDP	System Preservation	System Adaptability	Economic Growth	Economic Development	Economic Impression	Capital Improvements	Investment Management		
Society		SOCIAL EQUITY									
	1	*Public Relations*		*Human Resource Management*	*Sustainable Communities*	*Facility Management*					
	2	Awareness Service	Customer Care	Employee Performance Management	Sustainable Living	Servicescape					
Environ-ment		ENVIRONMENTAL STEWARDSHIP									
	1	*Environmental Conservation*			*Resource Conservation*						
	2	Land-use Management	Climate Change Management	Noise Management	Waste Management	Energy Management					

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