THE RELIABILITY OF COMMUTER RAIL SERVICE IN THE CITY OF CAPE TOWN: A GROUNDED THEORY APPROACH FOR IDENTIFYING THE FACTORS AFFECTING THE PROVISION OF A RELIABLE COMMUTER RAIL SERVICE

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ABSTRACT

The 2013 survey conducted by the National Household Travel Survey found that the majority of the commuter rail service users are dissatisfied with the quality of the service due to the lack of reliability characterised by the increase in the percentage of train cancellations and delays. This paper uses the Grounded Theory as its main methodology and develops the theory of commuter rail provision using Systems Archetypes and presents it in the form of a Causal Loop Diagram. The developed theory is then used to recommend a solution loop that seeks to improve the quality of commuter rail service.

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1.   INTRODUCTION

The improvement of public transport system in South Africa has been one of the strategic objectives for the government since the beginning of the post-apartheid era [1]. During the apartheid era, many South Africans were dispersed and relegated to poor areas away from job opportunities, health and educational facilities and economic participation [2]. This social and economic exclusion is still prevalent today, with millions of South Africans still requiring means of travelling to access economic opportunities [3]. This implies that the government is faced with a responsibility of public transport that is reliable, safe, efficient and cost-effective.

The public transport system in Cape Town comprises (primarily) of three modes i.e. taxis, buses and commuter rail service. Contrary to other major South African cities, in Cape Town, the commuter rail service dominates the public transport system [4]. This has led to the Department of Transport (DoT) labelling the commuter train service as the backbone of transport in the City of Cape Town [5][6]. However, the Metrorail (a subsidiary of the Passenger Rail Agency of South Africa (PRASA)) timekeeping document has shown that the commuter rail service has worsened from 2013 [7]. Metrorail is the sole provider of commuter rail services in Cape Town (and the other regions of the country). The 2013 survey conducted by the National Household Travel Survey (NHTS) revealed that the majority of the commuter rail service users are dissatisfied with the quality of the service due to the lack of reliability, characterised by the increase in the percentage of train cancellations and delays [8].

1.1   Train cancellations and delays

The quality of commuter rail service refers to factors including but not limited to reliability, availability, maintainability, safety and cleanliness [9][10]. This paper aims to improve the quality of commuter rail service by focusing on reliability. Metrorail operates an ageing fleet of trains, some in operation since 1958, and they predominantly make use of the percentage of cancellations and delays as the empirical indicator to measure the reliability of their fleet [11]. The train cancellations and delays are at the heart of Metrorail's activities because they indicate the ability of Metrorail to provide a reliable service. Therefore, the concern variable (CV) for this study is the *percentage of trains cancelled and delayed* and this is shown in Figure 1.
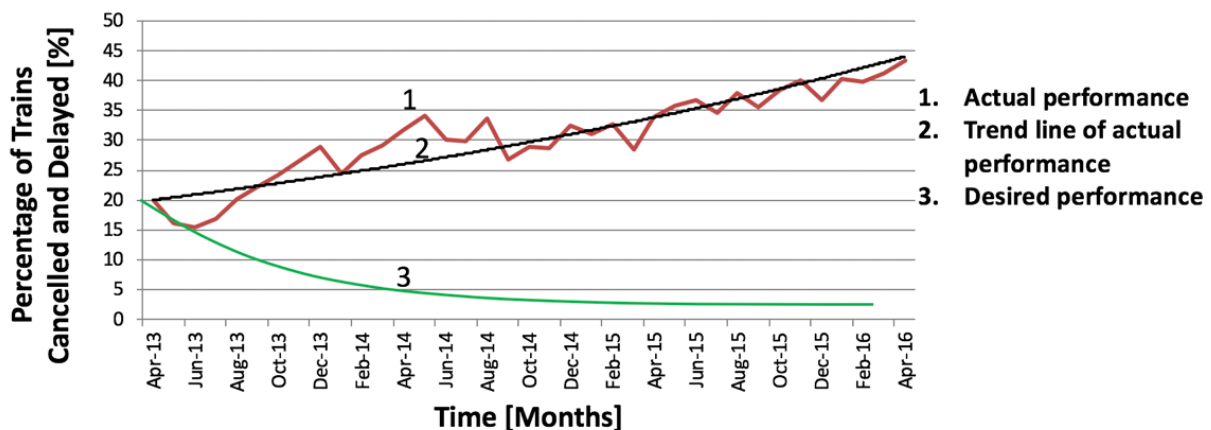

Figure 1: Percentage of Trains Cancelled and Delayed Over Time [7]

Figure 1 shows that train cancellations and delays have been increasing since 2013 and if there is no intervention, the service will continue to worsen. Although there has been an improvement in some of the months, the trend line shows that the overall result is a deteriorating train service. The data that was used for Figure 1 was obtained from the Metrorail time keeping document [7].

1.2   Objective of this paper

Researchers in the area of public transport tend to focus their studies on the issues faced by the commuters [12][13][14][15]. In studying the reliability of commuter rail in the city of Cape Town (within a region known as Western Cape), this paper takes a slightly different approach and focuses on the factors that affect the provider

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of commuter rail. In addition to identifying these factors, this paper seeks to develop a theory that describes the causal relationships between these factors and use this theory to inform recommendations for improvement.

1.3   Research Questions

Maxwell [16] points out that research questions are useful for explaining what the study is intended to learn and understand. The research questions are useful in determining what data to collect and what methods to be used in the analyses. The following research questions were structured and used in this study:

Question 1: What are the factors affecting the provision of a reliable commuter rail service in the City of Cape Town?

Question 2: How can these factors inform recommendations to improve the commuter rail service?

Based on the objective of the study, an appropriate research methodology was chosen to answer the research questions and realise the study's objective and is described in section 2 below.

2.   THE RESEARCH METHODOLOGY

As noted by Maxwell [16], the primary difference between a qualitative and a quantitative study is that the qualitative study involves the collection of data that is mainly in the form of words whereas the quantitative study involves the data that is either in the form of (or can be expressed as) numbers. Cresswell [18] emphasises that the quantitative research focuses on variables, measuring objective facts, applies statistical analysis and turns to ignore context. He further adds that this approach is useful in testing whether the predictive generalisations of an existing theory hold true. However, the qualitative approach primarily focuses on understanding social life and the meaning that the people attach to it. The qualitative approach was chosen for this study because it is an approach well suited for developing theories and understanding phenomena [16].

This qualitative study used Grounded Theory (GT) as a research methodology, developed by Glaser and Strauss [17]. The GT methodology was chosen because it is useful for developing theory that is grounded in data, allowing the theory to evolve from the research process as a product of an interplay between the data collection and the data analysis [17][19]. The use of GT in the research process is useful in preventing the researcher from forcing data into already existing theories, while ensuring that a new theory in the provision of commuter rail service is generated. Easterby-Smith, Thorpe and Lowe [20] point out that through the use of GT, the structure is derived from the data by systematically analysing it to identify themes, patterns and categories. This means that the study does not begin with a preconceived theory but the theory is allowed to inductively emerge from themes, patterns and categories.

As mentioned in section 1, Metrorail is the provider of commuter rail services in Cape Town, therefore, the research is conducted using Metrorail- Western Cape managers as study participants. All departments were included and the details of data collection are given in section 3.

The outcome of the data collection cycles and the GT process are the categories that are used as the building blocks for constructing the theory that reflects the factors and relationships involved in the provision of commuter rail service. Figure 2 illustrates the dynamic interplay between the four data collection cycles and analysis. GT demands that data collection and analysis occur concurrently rather than in a linear sequence [21][22]. The research process iterates between the commuter rail sector (cycles 1-4) and the theoretical world (GT methodology).
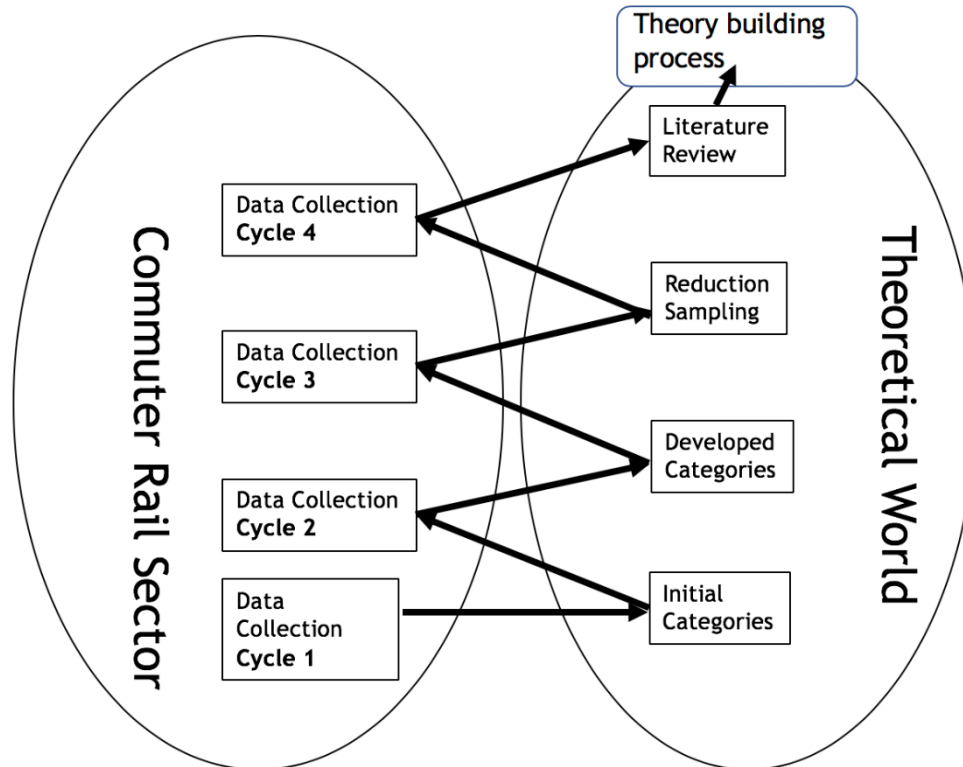
Figure 2: The research process

3. CONCURRENT DATA COLLECTION AND ANALYSIS

This section follows the research process presented in section 2. The dynamic interplay of data collection and analysis is presented in preparation for the theory building process which is presented in section 5.

3.1 Data Collection and Analysis of Cycles 1-3

Semi-structured face to face interviews were conducted as the primary means of data collection for cycle one. Three Metrorail managers from the Training and Development, Train Operations and Recruitment and Selection departments were interviewed for cycle one. The collected data was coded into propositions (open coding) and a total of 80 propositions had been collected by the end of cycle one. From these propositions, 16 categories emerged.

For cycle two, three more managers from Business Development, Finance and Supply Chain Management were interviewed. The data collection of cycle two was not only limited to interviewing but was extended to include documentary research [23] using the rail-related practitioner journals as the source of data together with newspaper articles and company documents such as the PRASA corporate plan, financial reports and recovery documents. In addition, data was collected by means of participant observation. Five PRASA management meetings were attended and recorded to be used as a source of data. New categories emerged and some of the new propositions were coded for existing categories. At the end of cycle two, seven more categories had been added and two categories modified, which led to a total of 23 categories and 130 propositions.

For cycle three, the last three managers were interviewed from the Infrastructure, Rolling Stock and Customer Service departments. Fifty more propositions were added after conducting these interviews and attending Metrorail management meetings. This contributed five more categories and a re-labelling of some of the existing

categories. The addition of five more categories increased the number of categories from 23 to 28 categories. The participants for research cycles one to three were selected such that all the departments were included.

The data gathering process from cycle one to cycle three increased the researcher's understanding of the situation as more insight was gained. This allowed the categories to be developed as more data was collected. Some of the categories were re-labelled to give a more comprehensive naming of the concepts contained in those categories. An example of this is the category that had initially been labelled as *'shortage of personnel'* in cycle one and was developed to *'internal capacity'* in cycle two, the same category was re-labelled as *'availability of resources'* in cycle three. Each category was reviewed as more propositions (props) were collected and some categories remained the same as others were re-labelled. The results of the first three cycles are presented in Table 1.

Table 1: Categories after three cycles

Category	Props	Category	Props	Category	Props
Availability of Resources	14	Training	5	Technology Management	6
Internal Processes and Systems	13	Communication with Commuters	7	Decentralisation	4
Supply Chain Management	7	Ageing Assets	9	Profitability	3
Vandalism	11	Management skills within PRASA	8	Management of Contractors	6
Rail Modernisation	8	Political Interference	3	Maintenance Execution	1
Availability of Monetary Resources	13	Stakeholder Integration	5	Asset Protection	1
Passenger Experience	9	Rail Regulation	1	Employee Wellbeing	2
Public Transport Modal Integration	3	Interdepartmental Relations	6	Misalignment of functions and Departments	3
Influence of Labour Unions	7	Service Demand	11	Effectiveness of Management	9
Employee Performance	5				
Total propositions = 180					

3.2   Reduction Sampling

After the three cycles of concurrent data collection and analysis, the emergent categories were reduced to the strongest categories (referred to as core categories) through reduction sampling. The reduction sampling process was not an easy process because the validity of the study had to be maintained by ensuring that categories are not forced to labels where they do not belong. Often, the researcher had to go back to the original propositions that were contained in the category to ensure that the concepts that emerged from data are not lost during the reduction sampling process. This was a rigorous and iterative process and it broadened the understanding of what is truly going on.

Holton [24] emphasises that the category labels chosen as core categories should have more explanatory power and should account for most of the variation around the focus of the study. This study employed the use of an affinity diagram (AD) to do the reduction sampling [25]. During the reduction sampling process, seven categories emerged as core categories and these categories were used as the building blocks for theory formation in the theory building process. Table 2 illustrates the reduction sampling process using an AD and the seven emergent core categories are shown (in bold) with the remaining categories subsumed under these core categories.

Table 2: The AD used for reduction sampling

1. Availability of Resources	2. Internal Processes and Systems	3. Vandalism	4. Quality of Management
Availability of Resources	Internal Processes and Systems	Vandalism	Employee Performance
Availability of Monetary Resources	Supply Chain Management	Asset Protection	Effectiveness of Management
Training	Communication with Commuters	Passenger Experience	Employee Wellbeing
Profitability	Maintenance Execution		Management skills within PRASA
	Rail Modernisation		Management of Contractors
	Technology Management		Decentralisation
			Political Interference
5. Interdepartmental Relations	6. Service Demand	7. Ageing Condition of Assets	
Stakeholder Integration	Service Demand	Ageing Assets	
Interdepartmental Relations	Public Transport Modal Integration	Rail Regulation	
Misalignment of functions and Departments			
Influence of Labour Unions			

3.3 Selective Sampling (Cycle 4)

The milestone for cycle four was to attempt to saturate the core categories. Saturation refers to the state where the criterion given by Corbin and Strauss [26] is met. This criterion was used to saturate the core categories and is discussed in this section. Cycle four was a selective sampling cycle because the data collection was informed by the core categories that emerged in the first three cycles. Based on these core categories, decisions were made with regards to where to collect data, what data to collect and from whom.

(i)   No new or relevant data seem to emerge regarding a category.

In an attempt to saturate the core categories, the goal was to collect between seven to 10 propositions with the hope that the categories can be saturated. Six out of the seven categories were saturated within seven propositions as no new relevant data seemed to emerge. The exception was the *Availability of Resources* which could not be saturated in less than seven categories and required ten propositions to be saturated.

(ii)   The category is well developed in terms of its properties and dimensions.

Categories were constantly compared and checked to ensure that they are well developed in terms of their properties and dimensions. This also ensured that all the categories are at the same level in the ladder of abstraction.

(iii)   The relationships among categories are well established and validated.

The relationships among the core categories are established using an interrelationship diagram (ID) adapted from [25] and validated through the collection of data in cycle four. The usage of an ID is discussed in detail in section 5.2.

4.   LITERATURE REVIEW

A comprehensive literature review is usually the first step in most research studies. However, one of the unique features of the GT methodology is the timing of the literature review. The GT literature review is based on the grounded theory results and therefore focused on those results. It is meant to be relevant to the situation at hand rather than a general review of the current literature. Even-though a quick literature scan is done at the beginning of the study, a comprehensive literature review is only conducted after the core categories have emerged from data and these categories are used to direct the review of literature.

As pointed out by Glaser and Strauss [17], conducting the literature review after the data collection allows the categories to emerge naturally from the empirical data during the analysis. The categories emerging from the fourth cycle were used to conduct the literature review. The insights collated from the literature review were woven into the existing categories in preparation for the theory building step as shown in Figure 2. The detailed grounded literature review based on the emergent categories has not been included in this paper because of the length constraints and also because of the focus being on the results of the GT process. However, an overview of scholarly work has been included in this section.

According to the PRASA Corporate Plan [9], Metrorail operates in Gauteng, KwaZulu-Natal, Western Cape and Eastern Cape regions and has a network covering more than 15% of South Africa's rail network. Metrorail provides more than 2.2 million passenger trips every weekday to the South African public. Metrorail operates a total of 698 train trips every weekday, 360 trains on Saturdays and 225 trains on Sundays in North, South and Central suburbs of Cape Town [9]. According to the NHTS [8], more than sixty percent of the working population in Western Cape region relies on commuter rail as the primary mode of public transport. This high percentage has led the Department of Transport [3], City of Cape Town [5] and many other transport authorities referring to commuter rail as the "backbone" of public transport in the city of Cape Town. Unlike the rest of South Africa where the commuter rail has only just about 10% of the public transport market share; in the Western Cape, the commuter rail enjoys over 60% market share of the public transport as shown graphically in Figure 3 and discussed in detail by Clark and Crous [4].

Whilst the commuter rail enjoys the majority of the public transport market share, various authors have pointed out elements of poor commuter rail service delivery provided by Metrorail. Clark and Crous [4] discussed one of the greatest problems faced by the commuters; the problem of overcrowding. Ryneveld [13] has shown that over seventy percent of commuters have voiced their concern with the issue of overcrowding. Metrorail has attributed this problem to the majority of their fleet running with fewer coaches than required and this has often led to fatalities [9]. Moreover, there is an increasing rate of injuries on the commuter rail service due to violence and crime which threatens the security of commuters [4]. The increasing rate of crime on the commuter rail system and other safety related issues have added to the growing negative user perception as pointed out by the NHTS [8].

According to the NHTS [8], the availability and reliability of train service remains the greatest problem and cause of frustration for the majority of the commuter rail users. Ryneveld [13] has pointed out that the frustration of commuters due to the availability and reliability of train service has resulted to a number of serious instances of vandalism and cases of arson with whole trains being burnt.
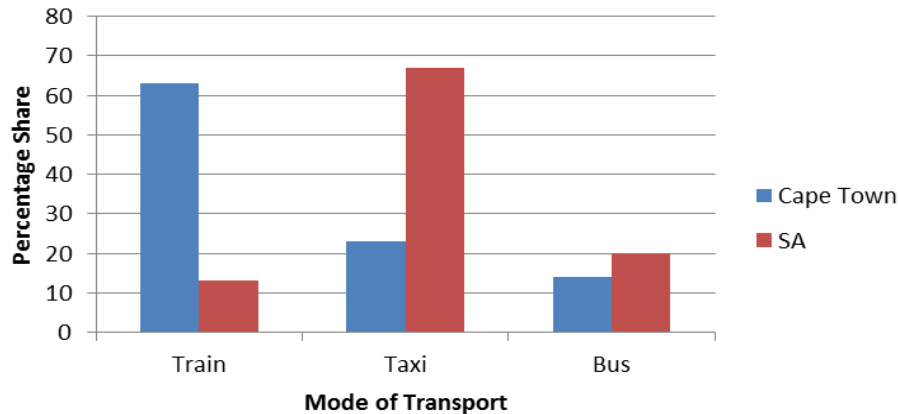
Figure 3 Comparison of public transport market share (adapted from Clark and Crous [4])

The literature review of commuter rail transportation revealed that there is limited scholarly work available on the topic of commuter rail transportation in South Africa. It is probable that the reason for this limitation is the monopoly that exists in the field of commuter rail as PRASA is the sole provider of rail transport (excluding the luxury rail transport providers).

5.   THEORY BUILDING PROCESS

This section used the core categories developed in the previous sections to build a theory that answers the research questions and realises the aim of the study.

For this paper, the theory was built using the modelling process described by Beer [27]. Beer [27] asserts that a managerial theory must be built by first constructing a well-established and accepted scientific model. Figure 4 is a graphic representation which was adapted from Beer's work on modelling managerial situations using scientific analogies. Beer's modelling process was broken down into seven steps that are used to convert the core category labels into a theory that answers the research questions.

5.1   Step 1: Framing Core Categories as Variables

The first step in the process was to frame the core category labels as variables. This was achieved by first doing a concept analysis of each core category label. The concept analysis focused on three aspects i.e. antecedents, defining attributes and consequences. Once the concept analysis of the core categories had been completed, the concern variable was used to decide on which of the three aspects was most strongly related to the concern variable and to use that aspect to transform the core category label into a variable. This ensured that all the variables used in the final theory were relevant to the concern variable. The final results of step one are presented in Table 3.

5.2   Step 2-7: Using the resultant variables to finalise the theory in a CLD

Step two through to step seven built upon the results of step one. The resultant seven variables together with the CV were used as the building blocks for the final theory. Initially, the ID was constructed using the seven resultant variables from step 1 and the CV. The construction of the ID (step 2) was done using the question; "Does the change in variable A cause a change in variable B or does the change in variable B cause a change in variable A?" The ID took into account the direct relationships between the variables and ignored the indirect relationships. The resulting ID is presented in Figure 5.
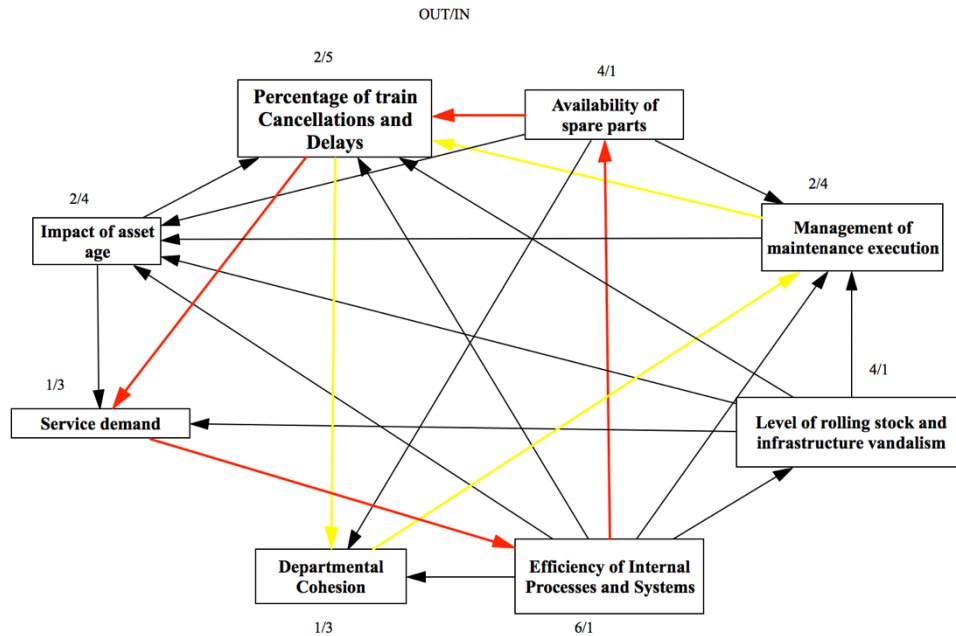

Figure 5: The ID of the 7 core categories with the CV (adapted from Brassard [25])

The CV emerged as the outcome whilst the driver is the *Efficiency of Internal Processes and Systems*.

The percentage of cancellations and delays is the result of what happens in the system and has a direct relationship with all the variables involved. This means that the train cancellations and delays are just a result of what happens elsewhere in the system. An example of this is the influence which the availability of spare parts has on the outcome. The availability of spare parts has an influence on the number of train-sets that operate in-service with defective components (the terminology used for this condition is *cut-outs in service*). When there are no spare parts available, the cut-outs in service will increase and this increase of cut-outs in service compromises the level of reliability of trains.

The significance of the concern variable emerging as an outcome is in that the focus has to be put on the other parts of the system to effectively impact on the concern variable. Focusing on the availability of spare parts or the management of maintenance execution or the efficiency of the internal processes and systems will have a far-reaching impact than to focus on the delays and cancellations in themselves.

The *Limits to Growth* generic archetype was chosen as the archetype for the theory building process because the research focus of this study is concerned with the issue of growth/decline (in the percentage of train cancellations and delays) which is used as an empirical indicator of the quality of commuter rail service. Braun [28] points out that the *Limits to Growth* archetype is used when the concern is about growth/decline. This archetype was originally introduced in the 1970's and is discussed by Braun [28] in detail. Based on the structural aspects of the Limits to Growth generic archetype and inferring these structural aspects (step 6) to the ID of Figure 5, the resulting causal loop diagram (CLD) is presented in Figure 6.
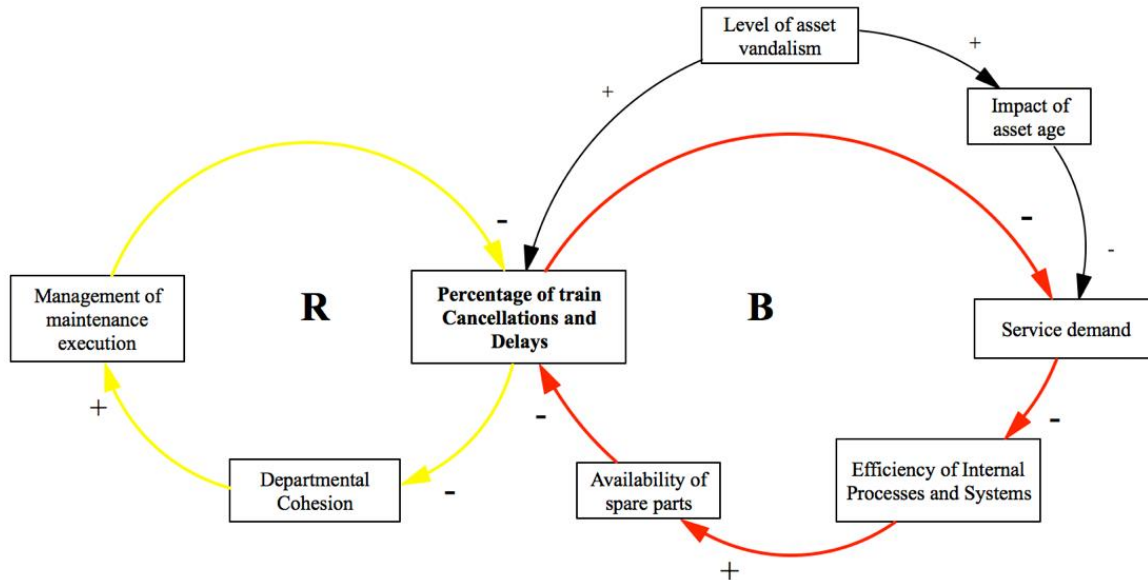
Figure 6: The emergent theory presented as a CLD

The emergent theory presented in Figure 6 represents the theory of providing the commuter rail service in the city of Cape Town; it is a depiction of the underlying system structure. As suggested by Clayton and Michael [29], a theory has an ability to predict which actions will lead to what results and can also assist in interpreting the prevailing situation by giving insights to what is happening and why it is happening.

The reinforcing loop (R) shows that the percentage of train cancellations and delays is closely linked to the ability of management to implement the correct maintenance strategies and to manage the execution of maintenance. As discussed in detail by Swanson [30], the management of maintenance execution is critical to the operations as it leads to high availability and reliability and conversely, the poor management of maintenance execution may lead to failures, poor utilisation of equipment and delays. Based on the interviews conducted, the low cancellations and delays of trains are viewed as successful results and lead to high morale within the departments. This improves the ability of departments to work together to achieve even greater success and when the departments are working in cohesion, the management of maintenance execution improves even further. This creates a reinforcing loop which yields the desired result of reducing the percentage of train cancellations and delays and thereby improving the reliability of commuter rail service.

The balancing loop (B) shows that an improvement in the percentage of train cancellations and delays leads to a high demand of train service and conversely, deterioration in cancellations and delays repels commuters. Clark and Crous [4] found in their study of public transport in Cape Town that due to the decline in the reliability of the train service, those commuters who can afford alternatives have increasingly shifted away from rail transportation. As shown in the theory, the limiting condition in the provision of commuter rail is the impact that the age of the asset has on the service demand. This limiting condition creates a slowing action in the system; PRASA has revealed that the network of 2 000 km is currently subject to 103 km of speed restrictions where trains are operating at lower than normal speed due to the poor condition of the track. The rolling stock and infrastructure are in an ageing condition and the track components are severely worn out and have reached the end of their life cycle [9].

The *efficiency of internal processes and systems* refers to the ability of the internal process and also the internal systems to respond to the business requirements and how efficient the response is. The ID that was presented in Figure 5 showed that this variable is the driver in the system. This means that the internal processes and systems offer an area of the most significant leverage if one wants to make improvements in the system. It is easy to understand why the efficiency of the internal processes and systems emerged as the driver; all the other variables depend on how the processes and systems that have been put in place respond to the business

requirements. If the procurement process (which is part of the internal processes) can respond to the high demand of spare parts, the percentage of cancellations and delays can be reduced and conversely, if the demand of spare parts is not met, the percentage of cancellations and delays increases.

The emergent theory is used to inform recommendations to improve the commuter rail service. Based on the work of Wolstenholme [31] on system archetypes, a solution archetype can be constructed by using some element of the achievement action to minimise the reaction in other parts of the organisation/system. The proposed solution to resolve the concern of the increasing percentage of cancellations and delays is to introduce a reinforcing loop in parallel with the intended consequence reinforcing loop and this is done to unblock the resource constraint [32]. This is illustrated in Figure 7.

The efficiency of the internal processes and systems emerged as the driving variable in the research results. All the other variables depend on how the processes and systems that have been put in place respond to the business requirements. This result implies that improving the efficiency of the internal processes and systems offers a leverage point, i.e. high returns can be gained by focusing on this area.

Figure 7 shows the solution loop that was derived from the research results. An element of achievement action (*Management of maintenance execution*) is used to introduce a reinforcing loop (R1) in parallel with the intended consequence reinforcing loop (R) and this is done to unblock the resource constraint. It is recommended that management does not only focus on managing maintenance execution but also focus on the efficiency of internal processes and systems.
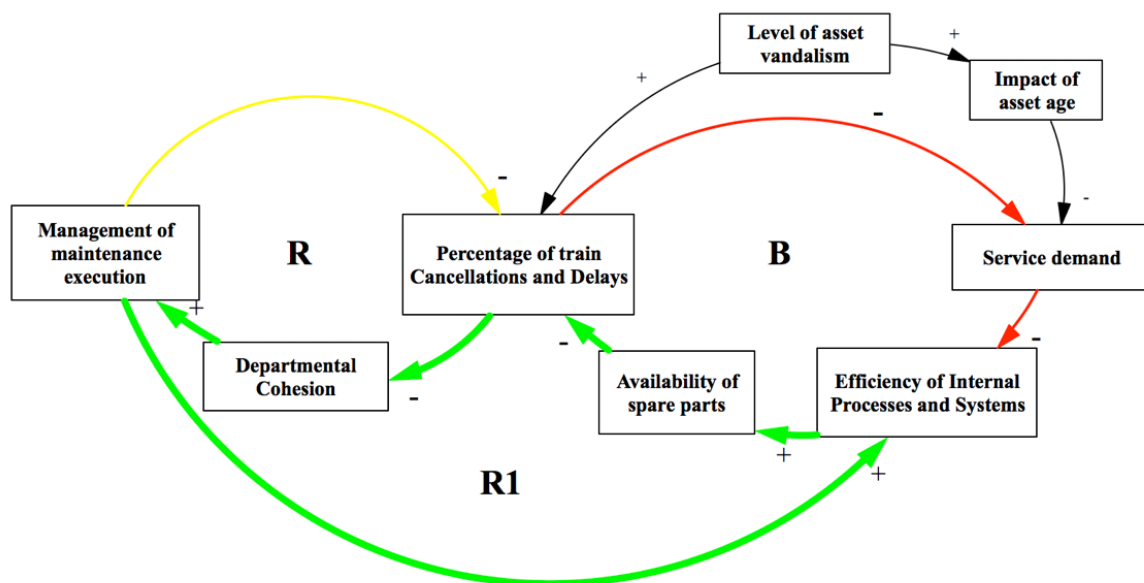

Figure 7: The solution loop for the provision of commuter rail service

6.   CONCLUSION AND RECOMMENDATIONS

This paper investigated the concern of the reliability of commuter rail service in the Western Cape characterised by the increasing percentage of delays and cancellations of the train service. GT was used as the main methodology for the study and the commuter rail service provision theory was developed using Systems Archetypes and presented in the form of a CLD. Four cycles of data collection seeking categories, building on previous cycles as analyses were conducted after each cycle. The theory was built after conducting a comprehensive literature review and combining the theoretical aspects of Beer's [27] work to further develop core categories as variables and present the theory as a CLD, illustrating and recommending that management of the rail service not only look at maintenance execution but other factors which include the efficiency of the internal processes and systems. It is further recommended that future studies may explore international commuter rail service providers and compare the results of this study to international rail providers.

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