PLANNING AND ELASTICITY PARAMETERS FOR TRAIN USE: LEARNING FROM THE DETERIORATION OF PRASA METRORAIL

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ABSTRACT

PRASA Metrorail's level of service is rapidly declining and consequently passenger volumes are reducing. By analysing these levels of reduction between 2009, 2015 and 2019, elasticity parameters for several service aspects were determined. Although many declining service aspects would have influenced the actual trip time and service frequency, the presented timetable schedules had not changed significantly. Instead, the decline in service manifested itself as a reduction in reliability with increasing service cancelations and poor punctuality. With these developments, the elasticity parameter for 'Reliability' is calculated as +2: with every 1% reliability decrease, passenger volumes reduced by 2%. This would mean that passengers respond very elastically to this aspect, meaning reliability is a real dissatisfier.

Similarly, the elasticity parameter for 'Customer Satisfaction', representing the subjective perception of all quality level of service aspects, is calculated as +3.

1. INTRODUCTION

1.1 Problem Statement

Since its inception in 2009, the Passenger Rail Agency of South Africa (PRASA, previously SARCC) has seen, on average, a slow decline of level of service, customer satisfaction and consequently, passenger volumes. In the past few years (since 2015), this decline increased dramatically. PRASA's Annual Reports mention many reasons for this deterioration: poor maintenance, increasing safety and security issues, cable theft and vandalism (such as burning trains), resulting in delays and service cancelations. This poor service delivery is hindering the social and economic objectives of passengers, the operator and government, and of society at large.

This decline gives researchers the opportunity to study these developments and determine transportation planning and elasticity parameters for train transport. This knowledge could then assist in further transportation planning and estimating the impact of future service improvements, as foreseen in PRASA's Modernisation programme.

1.2 Objective of this Paper

This paper investigates the relation between the service decline and passenger volumes, and from that, determines elasticity parameters for passenger train use in relation to:

- Reliability (cancelations and punctuality).
- Customer satisfaction (representing all service aspects).

This analysis was done on developments in train service over the past 12 years (2008/09 to 2019/20) for the aggregated Metrorail network, and not for individual stations, corridors or regions.

1.3 Overview

Firstly, section 2 outlines some theoretical background on the passengers' influence aspects and elasticity parameters. In section 3, the developments of PRASA's level of service and passenger volumes are presented. With that information, in section 4, elasticity parameters are determined. Finally, section 5 provides conclusions and recommendations.

2. THEORETICAL BACKGROUND

This section continues with the work done by Onderwater (2017), on theoretical background of the passengers' quality influence aspects, and determining service elasticity parameters.

2.1 Transportation Elasticity Parameters

In economics in general, as is the case for transport economics, the most common way to measure the sensitivity of one variable to another is 'elasticity': the measure of the percentage change that will occur in one variable (in this case: passenger demand) in response to a 1-percent increase in another variable. The theory of elasticity is based on Pindyck (2009), and widely applied in transportation by Litman (2013), amongst others.

Price and time elasticity are most common as these aspects are relatively easy to measure. Other transport qualities are difficult to quantify and measure, such as safety, comfort, effort, and are also very subjective. The price and time elasticities are negative: patronage will *de*crease as fares or trip time *in*creases. When the elasticity is greater than (+/-) 1 (greater in magnitude, absolute value), demand is classified as elastic. With an elasticity parameter smaller than (+/-) 1, demand is classified as fairly inelastic. This is generally the case in transportation, with price and time elasticities in the order of magnitude of -0.5 (Onderwater, 2017; Litman, 2013). With completely inelastic demand (elasticity = 0), consumers would buy a fixed quantity of a goods (such as travel), regardless of its price or quality changes.Although elasticities are often reported as single estimates, there are many factors that can affect the sensitivity, and the actual value will vary widely depending on attributes such as trip purpose, income, peak/off-peak. (Litman, 2013).

An elasticity parameter is determined by comparing the relative development of the independent variable, with the development of demand. Often, multiple variables play a role. For that reason, researchers should first determine all possible influence aspects, then isolate them to determine the individual variable's elasticity parameter.

2.2 Passenger's Economic Assessment

From a user perspective, transport incurs monetary costs, utilises time, and requires physical and/or mental effort. Each passenger has these three types of budget available. Passengers make an individual economic assessment of their trip, comparing the costs of the provided level of service with their budget (Onderwater, 2017).

Distinction should be made between the public transport (PT) system's attributes, and passengers' perceived quality (in relation to the individual budgets). For example, headways or frequency is a system's attribute, resulting in waiting time, which is affecting the passengers' time budget. Similarly:

- Changes in fare levels (CPI corrected) impact on travel costs (money budget);
- Network and station density relate to access time, costs and comfort to get to the PT's station (time, money and effort budgets);
- Speed impacts the travel time (time budget);
- Reliability (cancelations and delays) impacts on insecurity of time, causing stress (time and effort budgets);
- Safety and Security impacts the feeling of unsafety, causing stress (effort budget).

Many other aspects are not quantifiable and often subjective, and would impact mostly on the effort budget. Changes in service attributes will impact on (the perception of) different quality levels and budgets, and this will eventually affect the use of the PT / train service. The response would be different for different train users, such as Choice Users (mostly the Gautrain market) and Captives (mostly the Metrorail market). In this paper, the focus is on the Metrorail Captive market.

2.3 Influence Aspects

Onderwater (2017) investigated different influence aspects for passenger train use, clustered into 3 groups:

2.3.1 Socio-Economic Aspects

The socio-economic influence aspects include population, employment, jobs, economic growth, and car ownership. Economic growth is closely related to the increase of number of jobs. However, as economic wealth increases, car ownership would also increase, and more people would become Choice Users (less PT Captives). This could result in a reduction of PT patronage. Therefore, one must be aware of double-counts.The elasticity parameter for changes in population and/or number of jobs = +1.0: with a 1% increase of population or jobs, mobility is expected to grow with 1%.

2.3.2 Internal Train System Aspects

Passenger demand will respond to 'internal' improvements of the train system or decrease when quality declines. The key aspects to consider are:

- Fare price (money budget), which is the total monetary price of traveling by train, consisting of train fares and the additional cost required for feeder services;
- Travel time (time budget), including access and egress time, waiting time (service frequency) and in-vehicle time;
- Other comfort and convenience aspects (effort budget) are often difficult to quantify and very subjective. However, it is possible to measure customer satisfaction, which would indirectly measure the appreciation of all aspects.

For Captives, the elasticity for PT use is low. Captives have little alternative than to use PT and would hardly see any mode shift to car use. Alternatively, one could decide not to travel.

However, there would be a modal shift between train use and road-based PT (bus, minibus-taxi) when circumstances change, like with the recent deterioration of train services.

The elasticity parameters for price and time are in the order of magnitude of -0.5, depending on the exact passenger market, peak/off-peak travel purposes, etc. (Onderwater, 2017; Litman, 2013).

2.3.3 Other Transport System's Aspects

As Metrorail passengers are mostly Captives, they hardly ever have a car available. Therefore, their mode choice is hardly impacted by changes in aspects of the car system (fuel price, toll, congestion). Captives, however, are impacted by the quality of other PT systems, such as BRT, bus and minibus-taxi; and this could cause shifts between different modes of PT.

3. PRASA METRORAIL DATA

The influence aspects mentioned in the previous section, and its changes and performance developments over time, are analysed below. The study made use of publicly available data from PRASA's Annual Reports and Corporate Plans, as well as the Railway Safety Regulator's (RSR) State of Safety reports, all from 2008/09 to 2019/20. However, it was found that it was not always easy to isolate the data for Metrorail only. PRASA sometimes presents data for the total rail company (including long-distance train service) or the whole group (including their bus services), and not always for Metrorail separately. Similarly, RSR's safety data is sometimes inclusive of Transnet and other operators, and not always presents a split for PRASA only, and certainly not for Metrorail separately. Although audited and approved, the data sometimes seems inconsistent and varies without an immanent explanation. It also seems that some data is measured indirectly. For example, passenger volumes are not based on actual counts, but on fare revenue collection.

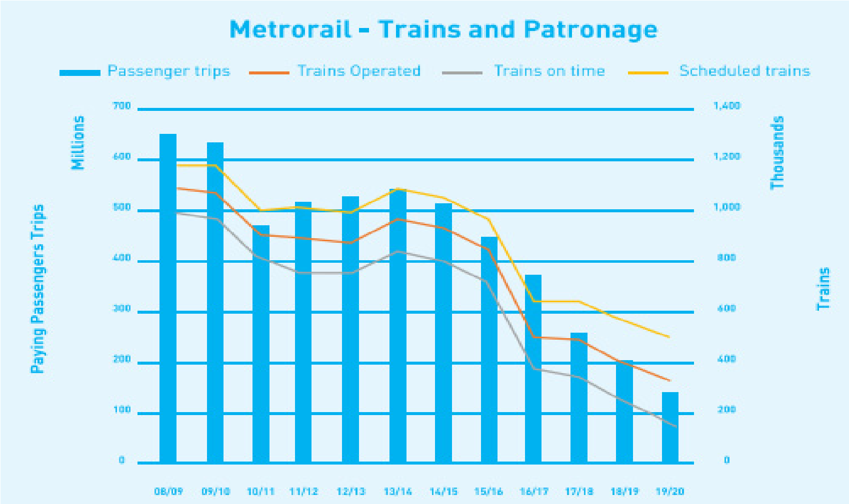
In the sub-sections below, the development of Metrorail passenger volumes (the dependent variable), as well as the changes of the different influence aspects (independent variables) are discussed, over 3 main timelines:

- 2009 (2008-2010): the start of PRASA, when service was still reasonably good.
- 2015 (2014-2016): just before the major deterioration.
- 2019 (2018-2020): the current situation.

At the very end of this study's assessment period (March 2020), the Metrorail services stopped altogether due to the Corona Lockdown. This would have somewhat impacted on the reported averages over the year 2019/20. Due to some fluctuation of data, the numbers in this paper are averaged over a period of a few years and are rounded.

3.1 Passenger Volumes

In the last 10 years, passenger volumes have declined (see Figure 1 and Table 1). Around 2009, there were almost 650 million passenger trips, then a reported dip around 2010 and restoring volumes to over 500 million passenger trips around 2015 (-3% annually). Then, passenger volumes decreased rapidly to approximately 200 million passenger trips in 2019 and even lower towards 2020 (-15% annually).



Source: PRASA Annual Report 2019/20

Figure 1: Metrorail Passenger Volumes, and Trains

As patronage is measured by fare revenue, these passenger volumes are assessed as paid passenger volumes. However, recently, fare evasion is allegedly increasing as many passengers refuse to pay for the poor service. Also, in some periods, PRASA reportedly had difficulty collecting and booking the fare revenue due to system failures, and allegedly fare boxes were sometimes stolen (as reported in PRASA's Annual Reports). This could have impacted on the data on paid passengers. Therefore, as trains still seem full, actual passenger volumes are probably higher.

Table 1: Metrorail Passenger Volumes (rounded)

	Target for a basic service	Start PRASA 2008-2010	Recent situation 2014-2016	*(annual change)*	Current situation 2018-2020	*(annual change)*
(Paid) Passenger Volumes	Growth	640 mil	530 mil	*-3%*	200 mil	*-15%*
Actual Passenger Volumes	Growth				Unknown	

Source: PRASA Annual Reports 2008/09 to 2019/20

3.2 Potential Metrorail Market – Socio-Economic Developments

Over the last 10 years, the population of South Africa increased by an average 1.5% annually. The real economic growth (and related growth of job-opportunities) was low, also indicated by the slight increase of national unemployment. Generally, the population and economic growth in metropolitan areas (i.e. the market for PRASA Metrorail) is slightly higher than the national average. However, a great portion of this growth would have taken place at the fringes of the metropolitan areas and it is unclear what the socio-economic developments were in stations' influence areas only. It is assumed that the potential market for Metrorail had increased with 2% annually. This would ideally have resulted in a similar 2% increase of passenger volumes (not considering other developments).

3.3 Travel Costs – Fare Price Development

Travel costs consist of fare price and other costs to get to the station. Normally, fares would increase annually in line with CPI / inflation, which was on average 5% annually. In PRASA's Annual Reports, information on fare price development is scarce. Reportedly, there were few years without fare increase, partly as planned fare increases were withdrawn due to passenger opposition. This would have resulted in a fare reduction in real terms, which on its own might have resulted in a marginal growth of passenger volumes. In other years, however, fares increased higher than CPI. Analysing PRASA's revenue, divided by the total passenger volumes, shows an average fare increase of 5%. As this is in line with CPI, the direct impact on travel cost budget, and subsequently train trips, would be limited.

3.4 Travel Time and Service Frequency – Reliability

The PT trip time consists of access and egress time, waiting time (depending on the service frequency) and in-vehicle time. In the last 10 years, there were no significant changes in walking routes or feedering PT, that would have caused a different access or egress time. Due to the decline in service levels, it would have been expected that waiting time and in-vehicle time would have changed. However, the presented timetable schedules have not changed significantly (although public available information on service schedules is scarce).

So, in this case, the poor performance is not expressed in lower speeds and frequencies (which normally are the base for time elasticity calculations), but in a poorer reliability. Reliability measures the number of scheduled services being on time (within a certain limit of a few minutes), and consists of Cancelations (services cancelled), and Punctuality (services on-time / not delayed).

3.4.1 Rolling Stock Availability – Cancellations

PRASA Metrorail has approximately 4600 coaches. However, many are not available due to being damaged beyond repair, in general overhaul (on average 450 coaches annually), in regular maintenance, vandalised and burned-down (more so in the last few years), or otherwise not available. The number of coaches in service has reduced from approximately 3500 in 2009, to approximately 3200 around 2015 (-1.5% annually), to below 2000 currently (-9% annually). For the scheduled service, approximately 280 trainsets are required nationally. This number was still available in 2015, then sharply reduced to below 170 currently in service (-9% annually). This is 40% less than what is needed for a full peak service. In order to maintain the presented service frequency, many trains run shorter than the full length of 12-14 coaches. This could lead to further overcrowding. As part of PRASA's Modernisation process, new trainsets were procured. This has resulted in 20 new trainsets imported in 2016-17, and the realisation of a local factory where 60 trainsets would be built annually. This production is delayed and in 2019 merely 10 trainsets were delivered. The total train kilometres per year have decreased from more than 29 million around 2009, to 25 million in 2015 (-2% annually), and below 20 million currently (-5% annually).

With less rolling stock available, an operator would ideally plan a new schedule with lower frequencies. In this case, the lower availability of rolling stock has resulted in many cancelations. In a 'normal' service, cancellations would ideally be below 2%, but are currently above 15% (see Table 2, and Figure 1). Main reasons for cancellations are incidental breakdowns of trains or infrastructure. Generally, service would be restored after a few hours or days of repairs, with few services cancelled in the meantime. Recently, other reasons for cancellations are the longer-period unavailability of trainsets (due to fires) and rail infrastructure, with consequently no train service on those corridors. In recent years this was the case at Cape Town's Central Lines (due to severe vandalism), and Durban's South Coast Line (due to stormwater damage), amongst others. This has resulted in a spike in the cancellation numbers.

Table 2: Metrorail Cancelations, and its influence aspects (rounded)

	Target for a basic service	Start PRASA 2008-2010	Recent situation 2014-2016	*(annual change)*	Current situation 2018-2020	*(annual change)*
Number of Metrorail Coaches	4600	3500	3200	*-1.5%*	2000	*-9%*
Trainsets in Service	280	280	280	*0%*	170	*-9%*
Train kilometres		29 mil	25 mil	*-2%*	20 mil	*-5%*
Cancelations	<2%	2%	4%	*-0.5%*	17%	*-3%*

Source: PRASA Annual Reports 2008/09 to 2019/20

3.4.2 Lower Train Speeds – Punctuality

Aging infrastructure and rolling stock, with poor maintenance, plus high theft and vandalism incidents, will cause many service disruptions, speed restrictions, and subsequent delays.

PRASA's maintenance budget before 2010 was over 12% of the total operational budget (in preparation for the World Cup 2010 services), but has since dropped to below 2%, and only recently got up to some 6%. This indicates a much lower level of maintenance in the period 2012 to 2017, which could explain the developments in train cancelations and punctuality. Theft of copper cables and other assets, and vandalism was already reported a major issue 10 years ago. Such incidences have increased, on average, by some 20% annually, to more than triple. This has led to many speed restrictions and manual authorisation when signals are out of order due to cable theft. With manual authorisation, trains can proceed after verbal approval by the Train Control Centre, although with a restricted speed of 30 km/h.

With so many speed restrictions (and many of them semi-permanent), an operator should ideally accommodate these lower speeds and increase the scheduled trip time. In this case, the timetable schedules have not changed significantly, and the lower speeds have resulted in many delays. The punctuality has dropped from close to the target of 90% in 2009, to just above 80% in 2015, and 65% currently (see Table 3, and Figure 1), with average delays of more than half an hour.

Table 3: Metrorail Punctuality, and its influence aspects (rounded)

	Target for a basic service	Start PRASA 2008-2010	Recent situation 2014-2016	*(annual change)*	Current situation 2018-2020	*(annual change)*
Maintenance as % of Opex budget	?	12%	1.5%		6%	
Reported Theft and Vandalism *		1000	2200		3600	
Punctuality of Train Service	>90%	87%	82%	*-1%*	65%	*-5%*

Source: PRASA Annual Reports and RSR State of Safety Reports 2008/09 to 2019/20

* Reported incidents (by RSR) vary over the years: the presented numbers are averaged over a longer period

3.4.3 Reliability

The total operation's reliability is calculated as the percentage of the scheduled trains actually running (1 - cancelations), minus the percentage of trains delayed (1 - punctuality) and is currently below 50% (see Table 4). More than half of the trains do not run according to schedule, or not at all.

Table 4: Metrorail Reliability (rounded)

	Target for a basic service	Start PRASA 2008-2010	Recent situation 2014-2016	*(annual change)*	Current situation 2018-2020	*(annual change)*
Cancelations	<2%	2%	4%	*-0.5%*	17%	*-3%*
Punctuality	>90%	87%	82%	*-1%*	65%	*-5%*
Reliability		85%	78%	*-1.5%*	48%	*-9%*

3.5 Effort Aspects – Comfort and Crowding

The effort service aspects are subjective and difficult to quantify. Comfort levels of the train service would include comfort at stations and in trains. During peak periods, trains are often crowded, and many passengers need to stand, or even hang outside doors (making it also a safety aspect). Many of these aspects are not measured or reported; or might not have changed significantly. For that reason, these were not able to be assessed in this study. However, these aspects could (partly) be quantified - indirectly - via ‘Customer Satisfaction’ (see Sub-section 3.7).

3.6 Safety and Security

Safety occurrences and security incidents can cause direct harm to the affected passengers, as well as indirectly impact other passengers due to service disruptions (unreliability). Another subjective impact is that these incidents are published in the press. This negative image of the train system could then raise stress to not-impacted passengers: “this could also happen to me”, and even to non-passengers: “rather not use this mode of transport”.

Despite the poor state of maintenance and poor operations, the total number of safety occurrences has increased only slightly, from approximately 1400 safety occurrences reported to RSR around 2009, increased to 1900 in 2015, and down to 1600 currently. The number of serious collisions (two trains colliding during passenger service) was rather stable, fluctuating between 2 and 5 occurrences annually, with 0 to 2 fatalities annually (see Table 5).In the last few years, there was a sharp increase of manual authorisations, due to the failing signalling system because of cable theft. Although this could have possibly resulted in more human errors and more unsafe situations, this has not resulted in a similar sharp increase of reported safety occurrences. It could well be that due to lower speeds, the impact on actual safety remained limited. Apart from train collisions, many passenger fatalities are due to passengers traveling outside the designated coaches, partly as a result of overcrowded trains. This has remained fairly stable, fluctuating around 25-35 passenger fatalities annually.

Most safety occurrences and subsequent fatalities in the rail system is of people being struck by a moving train while walking along or across the rail reserve (stable at 200-250 public fatalities annually, at PRASA tracks). These occurrences would affect the service reliability.

Apart from theft and vandalism, other security incidences relate to crimes reported in trains and stations, and therefore directly impacting passengers’ wellbeing. These security incidents have been fluctuating over the years, but on average have remained more-or-less stable over the longer term, around 750: 2 per day nationally.

Table 5: Safety and Security aspects * (rounded)

	Target for a basic service	Start PRASA 2008-2010	Recent situation 2014-2016	*(annual change)*	Current situation 2018-2020	*(annual change)*
Total Safety Occurrences reported *		1400	1900	*+6%*	1600	*-4%*
Total Collisions and Derailments *		80	90		90	
Collisions during passenger service *		4	2		3	
Passenger Fatalities (trains, stations)		35	25		30	
Crime Incidents on trains, platforms *		800	650	*-3%*	750	*+3%*

Source: RSR State of Safety Reports 2008/09 to 2019/20
* Reported incidents (by RSR) vary over the years: the presented numbers are averaged over a longer period

As can be concluded, the safety and security aspects are poor, but have hardly changed over the longer term; although relatively, the occurrences per passenger or per train-kilometer have increased. However, safety and security are not only measured by objective facts. Subjectively, safety and security occurrences are negatively impacting the image of the train service. Especially when other service aspects are poor, additional bad press on safety and security would worsen its image. Subjective facts cannot be measured, except through the use of Customer Satisfaction surveys.

3.7 Customer Satisfaction

An alternative way of assessing qualitative and subjective service aspects is via Customer Satisfaction, which is surveyed regularly and presented in PRASA's Annual Reports. As a result of the declining service levels, the customer satisfaction has dropped from just above the target of 70%, to 65% recently, and just below 50% currently (see Table 6). The Customer Satisfaction is surveyed amongst actual train users. It is likely that over time, the most-unsatisfied passengers would have found alternative transport and left the Metrorail system, leaving better-satisfied passengers within the system. With the decline in average surveyed satisfaction, the satisfaction level of an individual train users would have declined even further.

Table 6: Metrorail Customer Satisfaction (rounded)

	Target for a basic service	Start PRASA 2008-2010	Recent situation 2014-2016	*(annual change)*	Current situation 2018-2020	*(annual change)*
Customer Satisfaction	>70%	72%	65%	*-1.5%*	49%	*-6%*

Source: PRASA Annual Reports 2008/09 to 2019/20

3.8 Other Transport Systems

As stated in Section 2, most Metrorail passengers are Captives and hardly impacted by changes in the car system. Captives, however, are impacted by the quality of other PT systems such as BRT, bus and minibus-taxi. Most of these PT systems have not changed significantly in terms of service quality (price, time, comfort), and this impact can therefore be deemed negligible. The main change in the last 10 years was the introduction of BRT (as per IPTN plans). Its impact on Metrorail, however, seems limited and is twofold. BRT mostly operates where no rail corridor is available (nationally, only a few corridors run partly parallel) and competition is limited. On the other hand, BRT feedering the Metrorail system is also limited, as the IPTN networks have not fully developed yet. As this aspect is difficult to quantify, and no data is available, this is excluded from this study.

4. DETERMINING PLANNING AND ELASTICTY PARAMETERS

From the data in Section 3, the developments of the dependent and independent variables are summarised in Table 7. From analysing the data, two distinct periods emerged:

- 2009 to 2015: Metrorail service saw on average a slight decrease of service performance and passenger volumes.
- 2015 to 2019: the service performance and passenger volumes dropped significantly.

In order to determine the elasticity parameter of individual variables, all possible influence aspects should be isolated. The impact of several aspects is limited: fare price and other transportation systems have not changed significantly ('nil' in Table 7). These variables can therefore be excluded from the assessment. Other aspects could not be assessed directly (‘n/a’) due to their limited data: trip time and service frequency, comfort and crowding, safety and security. However, these aspects are indirectly included in other variables: reliability and customer satisfaction.

Table 7: Metrorail Variables, summary (rounded)

	Annual development Average 2009 to 2015	Annual development Average 2015 to 2019
Dependent Variable = (Paid) Passenger Volumes	-3%	-15%
Independent Variables:		
- Socio-Economic (Population and Jobs)	+2%	+2%
- Travel Costs (Train Fares)	Nil	Nil
- (Scheduled) Travel Time	N/A	N/A
- Reliability (= Cancelations + Punctuality)	-1.5%	-9%
- Comfort and Crowding	N/A	N/A
- Safety and Security	N/A	N/A
- Customer Satisfaction	-1.5%	-6%
- Car System	Nil	Nil
- Other PT Systems	Nil	Nil

* Nil = Limited impact; N/A = not applicable, not assessed or unknown

In this section, the following independent variables are assessed:

1. Socio-economic developments;
2. Reliability: availability and punctuality;
3. Customer satisfaction, including price, time and frequency, reliability, safety and security, comfort and crowding, subjective image of the Metrorail system.

The first variable is independent from the others, and its elasticity parameter known (+1). Therefore, the next analyses can be corrected for this variable. However, the second and third variables are partly overlapping. Therefore, the resultant elasticity parameters cannot be used in combination

4.1 Socio-Economic Developments

On average, population, which is the potential market for Metrorail, grew with 2% annually. With an elasticity parameter for socio-economic changes of +1, this would indicate that Metrorail should have expected a 2% growth annually (excluding all other impacts). However, passenger volumes declined with 3% and 15% annually over both periods, whereas a 2% growth would have been expected. Therefore, the real passenger volume development should be corrected to -5% and -17% annually, respectively.

4.2 Reliability: Availability and Punctuality

Reliability measures the percentage of scheduled train services running on-time and is determined by the punctuality (percentage of actual trains on-time), minus cancelations (scheduled trains not actually running). For example (using the values from Table 4), currently 65% of actual trains run on-time, minus 17% of scheduled trains not actually running, is 48% of scheduled trains running on-time.

The relative change in reliability is measured as the difference between reliability data of 2 years, divided by that of the base year; averaged over a number of years. For example (using the values from Table 4), reliability dropped from 78% in 2015 to 48% in 2019, is a relative reduction of (48-78)/78 is 38% over 4 years, is -9% annually. Note, the reduction in reliability is not measured by the difference in absolute percentage-points, but relatively compared to a previous level.

Dividing the annual change in (corrected) passenger volumes (-5 and -17% over both periods, see Table 7), by the relative annual changes in reliability (-1.5 and -9%), gives an elasticity parameter between +3 and +2. With every 1% reliability decrease, passenger volumes reduced by 2 to 3%. As a sensitivity analyse, when the passenger volumes were not corrected for population growth, the elasticity parameter for reliability is +2.

4.3 Customer Satisfaction

Customer satisfaction measures the subjective appreciation of the total train service and consists of all independent variables (price, time and frequency, reliability, comfort and crowding, safety and security, subjective image of the Metrorail system).

The relative change in customer satisfaction is measured as the difference between reliability data of 2 years, divided by that of the base year; averaged over a number of years. For example (using the values from Table 6), customer satisfaction dropped from 65% in 2015 to 49% in 2019, is a relative reduction of 25% over 4 years, is -6% annually.

Dividing the annual change in (corrected) passenger volumes (-5 and -17% over both periods, see Table 7), by the relative annual changes in customer satisfaction (-1.5 and -6%), gives an elasticity parameter of +3.

5. CONCLUSIONS AND RECOMMENDATIONS

Poor performance of service impacts on the passengers' trip generation and mode choice, as it increases the burden on their time, money and/or effort budgets. In scientific studies, elasticity parameters for cost and time are well studied. These are fairly inelastic, in the order of magnitude of -0.5 (Onderwater, 2017; Litman, 2013). Other variables are less studied.

5.1 New Elasticity Parameters

In this study, the elasticity parameter for 'Reliability' is determined to be +2 (rounded). This would indicate that passengers respond very elastically towards cancelations and punctuality; a poor reliability is a real dissatisfier!

All service aspects (price, time and the softer effort aspects) are subjectively combined in 'Customer Satisfaction'. In this study, the elasticity parameter for 'Customer Satisfaction' is determined to be +3 (rounded). Again, if passengers are not happy, they would respond very elastically.

These parameters were developed based on a decline in the train service. The same parameters could also be used to determine the effect of improvements of service, although from theory it is not certain whether these would be similar (Pindyck, 2009; Litman, 2013).

5.2 Recommendations

5.2.1 Manage Expectations on Train Service

With the current (seemingly semi-permanent) low rolling stock availability and many speed restrictions, it could be considered to change the timetable schedule to allow for lower -but more realistically planned- speeds and frequencies. This should be clearly communicated to passengers, to inform them of the service, and allow them to better plan their trip. On the one hand, such a poorer schedule would increase the passengers' travel time (which is fairly inelastic), but on the other hand, it would improve the reliability of the scheduled service (which is very elastic), with expectations better met and reduced disappointment. This could also improve the customer satisfaction and could lead (despite all odds) to a growth in passenger volumes.

5.2.2 Improve Service Data

During this study, it was found that certain service information was hardly available in the public domain: current timetable schedules and train fares could not be found on the internet, and historic information was fragmented. Such information should be available, not only for academic purposes, but certainly for passenger convenience. Other information seems inconsistent or is determined indirectly via other variables. As an example, passenger volumes are not regularly counted, but determined from fare revenue collections. It is recommended to improve and extend the data collection of primary variables. One should also retain (and further explain) the definition and method of measuring these variables, for consistent comparisons.

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