PUBLIC TRANSPORT IN GAUTENG: ORDER OUT OF CHAOS

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ABSTRACT

New transport policies in South Africa place emphasis on the promotion of public transport. When there are few resources available for the management of growth, the situation often leads to over –populated cities having infrastructure provisions of very low quality. This is most visible when the urban transport network of a city grinds to a halt with traffic congestion. An inefficient urban transport system that undermines the time is lost. The urban transport problem however, should not be thought of only as congestion. The problem of urban transportation however, is particularly acute in cities of developing countries like South Africa, where rapid urbanization is met with the lack of resources and the scarcity of expertise. Indeed, this paper's work is an account of different strategies and methods Gauteng province used in dealing with them.

Therefore, this paper explores the improvement of public transport operational performance in Gauteng Province through the development of appropriate and sustainable public transport key performance indicators (KPIs) and corresponding levels of service (LOS) that address basic user needs. The appropriateness of established LOS is tested in low income areas with low car ownership, where there is an obvious need for an improvement in public transport operations.

1. INTRODUCTION

For the past twenty years or so, both the proportion and the number of people living in urban areas have been increasing rapidly in developing countries. This increase is also marked by a concentration of population in large cities. The relationship between urban and transportation is perhaps one of the most important aspects of developing in a city. The provision of transportation plays a major role in sustaining development in a city, whilst at the same time, development directly affects transport demand. Without an adequate transportation system there would be a limit to growth. Until 2006 the Gautrain website included a feasibility report that referred in several places to the fact that traffic has been growing at 7% a year. The report also stated that – "the shortcomings of the existing public transport system, which is plagued by a plethora of problems, is well known".

It is almost 50 years since the first comprehensive urban transport studies took place in the United States (in Detroit (1953) and in Chicago (1956)). During that time there have been changes to the processes adopted, but this paper argues that the general approach to transport analysis in South Africa remains fundamentally the same as in those first studies - an aggregate four-stage computerized transport model. As such, public transport operations in South Africa, and in particular Gauteng Province, are riddled with problems. The service is characterized by poor performance, most evident in late arrivals, over crowdedness and non-availability outside peak hours, among other. Most often, old and unsafe vehicles are being used for public transport operations. This compromises the safety of passengers and results in an unacceptable rate of accidents involving public transport vehicles.

2. BACKGROUND

The international track record, however, indicates that TDM strategies – whose implementation, in essence, depends on changing the decision-making behaviour of travellers – have achieved limited success. A perhaps unfair and crude local illustration in South Africa and in Gauteng in particular, is the failure of the Car Free Day in 2005 and 2006 respectively to register any significant response in addressing road congestion and travel behaviour amongst car users. It is posited that one of the main reasons for poor TDM success is a general inability on the behalf of the practitioners responsible for formulating and implementing TDM strategies, to understand the temporal dimension within which changes occur. While comprehensive masterplanning has given way to more strategic forms of planning, most transport plans and strategies are essentially 'blue –print' in nature. In other words their focus is on a desired end-state, rather than on the process through which this end-state is to be achieved. The proposed implementation of the interventions necessary to achieve this end state over time, is more the result of resource constraint and the need to match phases of implementation with budget cycles (i.e. the resources are not available in one budget cycle to implement the plan in its entirety) than the result of an understanding of the triggers and pace of behavioural change. It follows that for plans and strategies to become more effective, the temporal dimensions of decision-making behaviour and behavioural change need to be better understood, and more sophisticated theories of decision-making over time need to be developed.

The Gauteng Province is unique in the sense that it is largely urban, mostly metropolitan in nature and landlocked. It is facing an increasingly urgent set of transport challenges including:

- High levels of population growth with a corresponding increase in urban mobility demands;
- Apartheid settlement patterns have not been addressed and instead there has been increasing levels of urban sprawl leading to poor economies for public transport provision;
- Fairly good access to a mode of public transport is not safe, affordable or reliable and has a poor image;
- Travel time are long with 14% of peak period travelers traveling longer than 60 minutes per trip;
- Increase levels of congestion with traffic volumes in the N1 corridor between Johannesburg and Pretoria growing at 7% per annum for more than a decade; and
- The state of road network is deteriorating due to lack of investment and there has been minimal investment in new road infrastructure in the last 26 years.

However, already there is a sense that while there are serious challenges, there are also emerging opportunities including the Gautrain Rapid Rail project which is seen as an important catalyst for pursuing integration and the 2010 FIFA World Cup which is seen as an opportunity to create public transport legacy projects. This is seen as a way of decreasing congestion, thereby creating intermodal transport system equal those in the developed countries.

1.1 Evolution of Transport Planning Models

South African passenger transport policy has arguably embarked upon a shift from a supply-side focus to a demand-side focus. Other countries have undergone similar policy reemphasis (Cairns 1998[3]; Owens 1995[38] and Goodwin *et al* 1991)[24]. As a consequence of this policy shift, transport strategies centred on the provision of road infrastructure to meet forecast traffic demand, in essence, are being replaced by transport strategies centered on travel demand management (TDM), intelligent transportation systems and the promotion of cleaner transport modes. Significant in South Africa, section 27.2(f) of the National Land Transport Transition Act (22 of 2000) requires the formulation of 'general strategies on travel demand management' as part of each planning authority's mandatory Integrated Transport Plan.

The evolution of transport planning models is briefly traced, through a consideration of the policy developments and socio-economic environments which have influenced transport model changes. In this way it is possible to identify four periods of model development:

- 1950s – 1960s: developments in response to accelerated highway construction and advances in computing;
- 1970s – 1980s: developments in response to criticisms of aggregate methods;
- 1980s – 1990s: developments in response to criticisms of static, trip-based analysis;
- 1990s: developments in response to environmental pollution, and policy shifts towards travel demand management (Behrens, 2004)[2].

1.2 Problems of urban transport network

When there are few resources available for the management of growth, the situation often leads to over –populated cities having infrastructure provisions of very low quality. This is most visible when the urban transport network of a city grinds to a halt with traffic congestion. An inefficient urban transport system that undermines the time is lost. The urban transport problem however, should not be thought of only as congestion. Grant (1977:170)[26], for example classified four types of transportation problems.

- Problems of movements in which difficulties are encountered in satisfying the demand for travel.
- Problems of non- movement, in which difficulties are encountered in making, journeys due to the non existence of facilities.
- Problems of location, in which difficulties are encountered due to the proximity or unavailability of transportation infrastructure provisions and services.
- Problems of change, in which difficulties are created as a result of changing or improving existing facilities.

It is clear that the majority of public transport commuters in Gauteng are concentrated in the previously disadvantaged areas in the province, where average household income is low and commuters are captive to public transport. These areas include Soshanguve, Mabopane, Mamelodi, among others.

Public transport is less convenient than private transport, although it can be seen as an opportunity for those with no transport available. These inconveniences, however, need to be minimized in order for the service to be attractive. The identification of these and other problems is often an indication of the wants and needs of passengers. The most pressing transport problems in Gauteng relate to congestion on the roads in the morning and after work, the availability and accessibility of public transport services, service capacity (i.e. crowding) in taxis and trains, frequency of service, cost of public transport, and safety and security issues (GPDPTRW, 2002)[18]. These are areas for which public transport LOS ought to be formulated.

2. CONVENTIONAL METHODS OF ANALYSING HABITUAL TRAVEL BEHAVIOUR AND BEHAVIOURAL CHANGE

It could be argued that the implementation of the more recent demand-side focused transport strategies in Gauteng have been hampered by a set of professional practices – more specifically, methods of analysing behavioural responses to transport system – changes – that are unable to estimate the consequences of the changed transport policy environment. Goodwin (1997:8)[22], for instance, argues that "our ability to treat the new policies analytically; to understand their effects; to assess their costs and benefits; is seriously hindered by our inheritance of an analytical tool-kit that is bright, impressive, of unchallengeable intellectual achievement, and wrong."

The 'analytical tool-kit' Goodwin is referring to above is the conventional four-step travel demand forecasting model – comprised of 'trip generation', 'trip distribution', 'mode choice' and 'trip assignment' sequential independent sub-models calibrated on cross-sectional travel data. It is not the intention of this paper to provide a detailed critique of the four-step model. Suffice to say that the model lacks a robust temporal dimension from two perspectives. Firstly, it is unable to consider the detailed sequencing of activities and trips across the course of the day. Secondly, it is unable to consider the pace of behavioural change over time resulting from policy and system changes, and what has been done to prevent congestion. Past methods of travel choice analysis have asked just how people choose between different modes, rather than how and when people choose between different modes – although it should be acknowledged that demand forecasting for some mega-projects (e.g. the Channel Tunnel) 'ramp up' demand over the first five or so years, in part, to take account of response lags (Flyvbjerg 2005)[13] and Davies *et al* 1995[6]. Such 'ramping up', however, appears typically to be based upon crude assumptions of the percentage of total forecast demand being realised in initial years (e.g. 50% of demands in the year one, 75% in year two, etc.) rather than any particular understanding of the pace of behavioural adaption and change.

In response to the former inability to consider the detailed sequencing of daily activities, a considerable body of research has now emerged in the form of so-called 'activity-based methods' that attempt to estimate the detailed scheduling of household activities over the day and the associated trip-making that results from the need to travel from the site of one activity to the next (Arentze and Timmermans 2000[1], Ettema and Timmermans 1997[11], Dargay 2002[7], Jones 1990[31], and Jones *et al* 1983)[32]. Such methods provide a more robust basis upon which to analyse the likely effects of TDM measures aimed at changing trip timing behaviour (e.g. flexible working hours, staggered school hours, free public transport fare and congestion changing periods, etc.) or trip substitution (e.g. compressed work weeks, telecommuting, home delivery services, vehicle use restrictions, etc.).

While the literature that has emerged in response to the inability of conventional cross-sectional methods to consider the pace of behaviour change over time is less well developed, there is a growing body of literature that suggests that individuals do not deliberately reappraise all aspects of their travel decisions on an almost trip-by-trip basis as, in crude terms the utility maximisation theory-based mode choice step of the conventional four-step model assumes. In essence, this body of literature argues that, if a travel choice has proven in past experiences to be of benefit or at least satisfactory to the traveller, that travel choice becomes habitual. The literature labels this conversion from deliberate to habitual decision-making as a transition from 'preference-based' to 'script-based' choices, or from 'planned' to 'impulsive' behaviour (Gärling and Axhausen

2003)[15]. Travel habits are argued to be broken typically when some form of ' life shock' (e.g. moving house, changing jobs, children starting school, etc.) occurs which forces a reappraisal of the habit and leads to another deliberate habit-forming decision(De Saint Laurent)[8].

This conceptualisation of travel choices as habits broken by shocks provides a more robust basis upon which to analyse policy hysteresis generally and behavioural response lags to TDM strategies in particular, and, at least theoretically, provides an explanation for why – as found, for instance, by Fearnley and Bekken (2005)[12] in a review of studies of demand elasticities in the short- and long-term, and by Goodwin (1996)[25] in a review before-and-after studies of road capacity increases – longer term effects of transport system changes are in the region of one and a half to three times the effects within one year of the change.

An unrelated small group of studies of the composition of morning peak period traffic streams provides some corroboration of this conceptualisation of travel behaviour change as a dynamic and event-based process, and provides an alternative to the conventional assumption that behavioural change occurs until some form of equilibrium is reached (Chatterjee 2001[4], Cherrett and McDonald 2002[5], Del Mistro and Behrens 2006)[9]. The trip assignment step of the conventional four-step model, for instance, following John Wardop's (1952)[42] first principle of equilibrium, assumes that drivers will shift between alternative routes in response to congestion impacts on generalised travel cost until some form of equilibrium state is reached in which the generalised cost of travelling on all routes actually used is equal and less that those which would be experienced on any unused route, and that thereafter the travel behaviour remains stable. The studies have found that underlying travel patterns that in aggregate form appear reasonably stable are dynamic individual changes in travel behaviour. In other words, while the stream as a whole exhibits similar characteristics over time (in terms of volume, density and speed), the individual vehicles which make up the traffic stream are gradually changing. Similar observations might be made of peak period passengers travelling in buses or trains. The term 'churn' has been coined in the traffic engineering field to describe this phenomenon. A system that appears stable could therefore be the result of individuals making reciprocal changes in their travel behaviour. Aggregate or system-wide change is the result of asymmetry in 'churning' individual decisions – labelled by Goodwin (1999)[23] and Van Wissen and Meurs, 1989[40] as 'asymmetric churn'.

The 'churn' observed in traffic streams and on public transport services can be attributed to three main causes. The first is the result of repetitious intra-personal variability in travel behaviour (see Hanson and Huff 1988[29], Pas and Sundar 1995)[39],and thus still potentially habitual in nature. The second cause of 'churn' is the result of isolated events necessitating an *ad hoc* non-permanent behavioural change, and thus neither representing habitual behaviour nor a deliberate behavioural change. The third cause of 'churn' is the result of reciprocal individual changes in travel behaviour created by new deliberate 'preference-based' choices replacing habitual 'script-based' choices. Important from the perspective of implementing TDM strategies and understanding the likely pace of behavioural responses to TDM measures, is the methodologically difficult task of separating habitual repetitious and *ad hoc* non-permanent 'churn', from deliberate discrete 'churn' resulting from behavioural change triggered by a 'life shock'. Understanding the latter cause of 'churn' offers potentially important insight into the formation of realistic expectation of behavioural change in response to TDM strategies over the short-, medium- and long-term. South African choice passengers therefore may be 'stubborn' in their use of the motor car, to coin the *Moving* South Africa label (NDoT 1998)[37/35], but they do nevertheless periodically change their behaviour patterns, thus opening periodic windows of opportunity to influence the outcomes of these changes.

The concept of 'asymmetric churn' offers a potentially more useful conceptual framework within which to formulate TDM strategies, than the conventional notion of incremental behavioural adaptation until some form of equilibrium end-state is achieved. In other words, if a desired TDM strategy outcome is an increase in public transport share of modal split at the expense of the motor car, then for every one person switching to a car from public transport use, more than one person would need to switch to public transport from car use. Our growing understanding of habitual travel and 'shocked' change tells us that these changes are happening anyway. The keys to effective TDM intervention are, on the one hand, understanding the 'life shock' or 'triggers' which lead individuals to deliberately reappraise their travel decisions and to change travel behaviour, and then influencing the variables that create the necessary circumstances that prompt decisions leading to the desired pattern of asymmetry, and on the other, understanding which groups are most susceptible to changes so that TDM measures might be targeted strategically and most effectively. With regard to the former, pioneering exploratory studies have been undertaken to investigate how car use habits might be broken – see, for instance, Fujii and Kitamura's (2003)[14] experiments in providing car drivers with free bus tickets, and Garvill *et al's* (2003)[16] and Kenyon and Lyon's (2003)[33] experiments in providing car drivers with improved information of alternatives.

3. PROPOSED PUBLIC TRANSPORT KPIS AND LOS WITH THEIR CURRENT STATUS.

The identified needs formed the basis for the development of ideal public transport KPIs. These KPIs provide a mechanism to evaluate the performance of the public transport system. Various locals' studies were scrutinized to obtain appropriate KPIs for application in Gauteng NDoT, GPDPTRW, 2003b[19]. The following KPIs together with corresponding minimum and target LOS were tested for application in Gauteng.

Although status quo information was not available for all KPIs, and analysis of the province revealed the following findings:

- The availability of public transport currently varies between 14 to 18 hours, although satisfaction rating are low with regard to the availability of public transport late at night and over weekends (GPDPTRW, 2004c)[20].
- Perceived walking distances for train services are by far the longest and are the only mode for which walking distances exceed the proposed minimum level of service of 1000 meters. However, walking distance LOS for rail services should not be considered, due to the rigid nature of rail

infrastructure and costly infrastructural intervention required. For the other modes, maximum walking distances of 1 000 meters, set by the National White Paper on Transport Policy (1996)[36], appears to be practical.

Table 1- Ideal KPIs with Minimum and Target Levels of Service.

No	Parameter	KIP	Level of Service (1)		
			Bus	Rail	Taxi
1	Availability	Hours of service	18 (24)	18(24)	18(24)
2	Accessibility	Walking distance to public transport	100m (500)	n/a	750m (400)
3	Service capacity	% Capacity utilization (volume to capacity ratio)	1.00	1.00 (0.90)	1.00
4	Frequency	Number of departures per hour in peak period	6(12)	6	12
5		Number of departures per hour in off –peak period	1(2)	1(2)	4
6		Average waiting time in peak period	10 mins (5)	10mins	5 mins
7	Cost	Percentage of income spent on public transport	10%	10%	10%
8	Safety	Maximum age of vehicles in the fleet	12yrs	30yrs	10yrs
9	Security	Number of security officers per 1000 peak hour passengers.	1	1	1

Note: Target LOS are indicated in brackets.

- Although status quo service capabilities are acceptable for bus and taxi services, train services are more problematic in this regard, with overcrowding evident on most urban commuting railway lines, i.e. excess of 1.00 (GPDPTRW, 2004c)[20].
- In terms of waiting time, 15 minutes appears to be the acceptable maximum for commuters during the peak period, translating into frequencies of at lest four departures per hour. All modes have perceived average waiting times less than the proposed minimum of 10 minutes implying that equivalent frequencies per hour can be met. However, current frequencies during the off-peak period fall short of the proposed LOS (GPDPTRW, 2004c)[20] and (GPDTRW, 1997)[17].
- Although approximately 60% of public transport commuters spend more than 10% of personal income on public transport, the average spending is estimated at only 1.1% above the proposed level of service. This implies that the goal of 10% set by the National White Paper (1996)[36] is realistic for application in Gauteng.

4. TESTING OF KPIS AND LOS FOR APPLICATION IN GAUTENG.

a. Development of a Model to Predict Impact of Operational Changes.

A strategic model was developed to predict the impact of improved public transport levels of service on passenger demand (service/demand model), the result of which is used in the resource model to calculate the required resources, i.e. estimate cost of implementing proposed operational changes (resource/supply model). The framework of the model is shown in Figure 1.

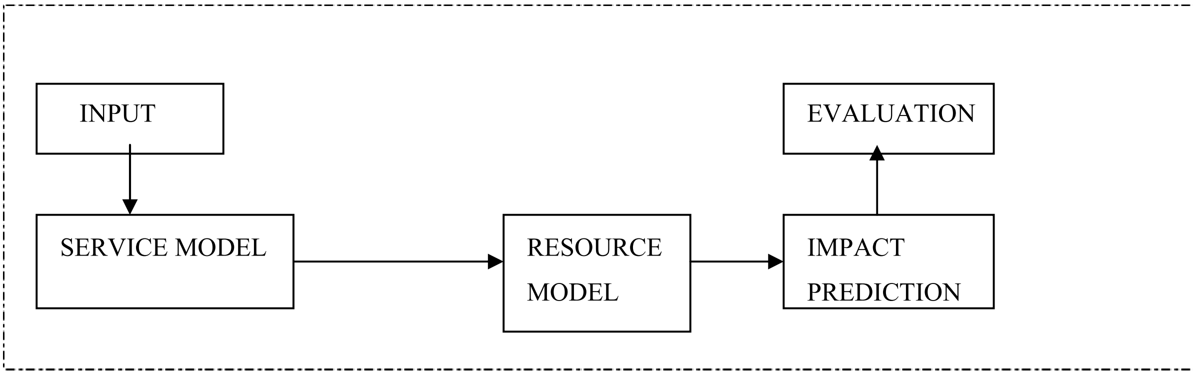

Figure 1- Framework of the Model.

The model structure is depicted in figure 2. The numbering in the short discussion below corresponds with the numbering in the figure. The following should be noted:

1. Utility functions calculate the utility derived from each mode based on attributes such as walking distances, waiting time, cost of public transport and frequency of vehicles.
2. The probability of selecting each mode is calculated based on utility derived from each mode as well as the utility derived from competing modes in the choice set.
3. The probability of each mode is multiplied by the total number of public transport commuters during the AM peak period to obtain the number of passengers for each mode. The model assumes a fixed demand, i.e. users attracted from modes other than public transport are not taken into account. Moreover, in times of economic prosperity, users leaving the public transport market are not accounted for.
4. Based on the vehicle capacity of each public transport mode, the number of vehicle trips required to serve the particular passenger demand is calculated.
5. The critical peak hour passenger volume is calculated in order to determine the vehicle fleet size. The number of passengers is also used to calculate the annual fee income as well as the number of security officers required per certain number of passengers.
6. If any safety measures are introduced, the aging vehicles in the vehicle fleet will be replaced, adding to the capital expenditure of the operator/ authority. In the model, no distinction is made between these two bodies. The capital cost of acquiring new vehicles is discounted over the expected lifespan of the vehicle, at a discount rate of 8% per annum.
7. The annual vehicle kilometers are calculated based on the number of vehicle trips per annum, which is then used to calculate the running operating cost of each mode as well as other travel-related expenses which account for costs not included in any of the operating cost components (e.g. start up cost of service change, information provision, etc)
8. Total annual operating cost is calculated by swimming operating cost of stops/stations, fixed vehicle standing cost, running cost of vehicles, other travel-related expenses as explained earlier, and the cost of providing

security at stations/in vehicles, and the additional cost of improving on walking distances.

9. Total annual capital costs are calculated by adding the cost of replacing aging vehicles in the fleet and the cost of additional vehicles required due to an increase in the number of peak hour passenger trips. No other capital costing factors are taken into account, as it is assumed that they are already in place (such as ways, termini and existing vehicles). This was confirmed by site visits to the pilot areas.
10. The impact of LOS changes is reported by certain important indicators. These are the calculation of annual number of passengers and number of passenger kilometers to determine annual capital, operating and total cost per passenger and per passenger kilometers. The deficit annual fare income and total annual cost is also reported.
11. The proposed service change/s are evaluated by scrutinizing the indicators for efficiency and effectiveness, and if necessary,
12. Policies can be adjusted to produce more cost efficient/cost effective outcomes.

b. Methodological Approach.

In developing the demand model, discrete choice modeling techniques were applied. Discrete choice analysis is the modeling of choice from a set of mutually exclusive and collectively exhaustive alternatives. The analysis uses the principle of utility maximization, which models a decision maker to select the alternative with the highest utility among those available at the time the choice is made (Hensher, 2003)[30] and (Ghoor, 2005)[21].

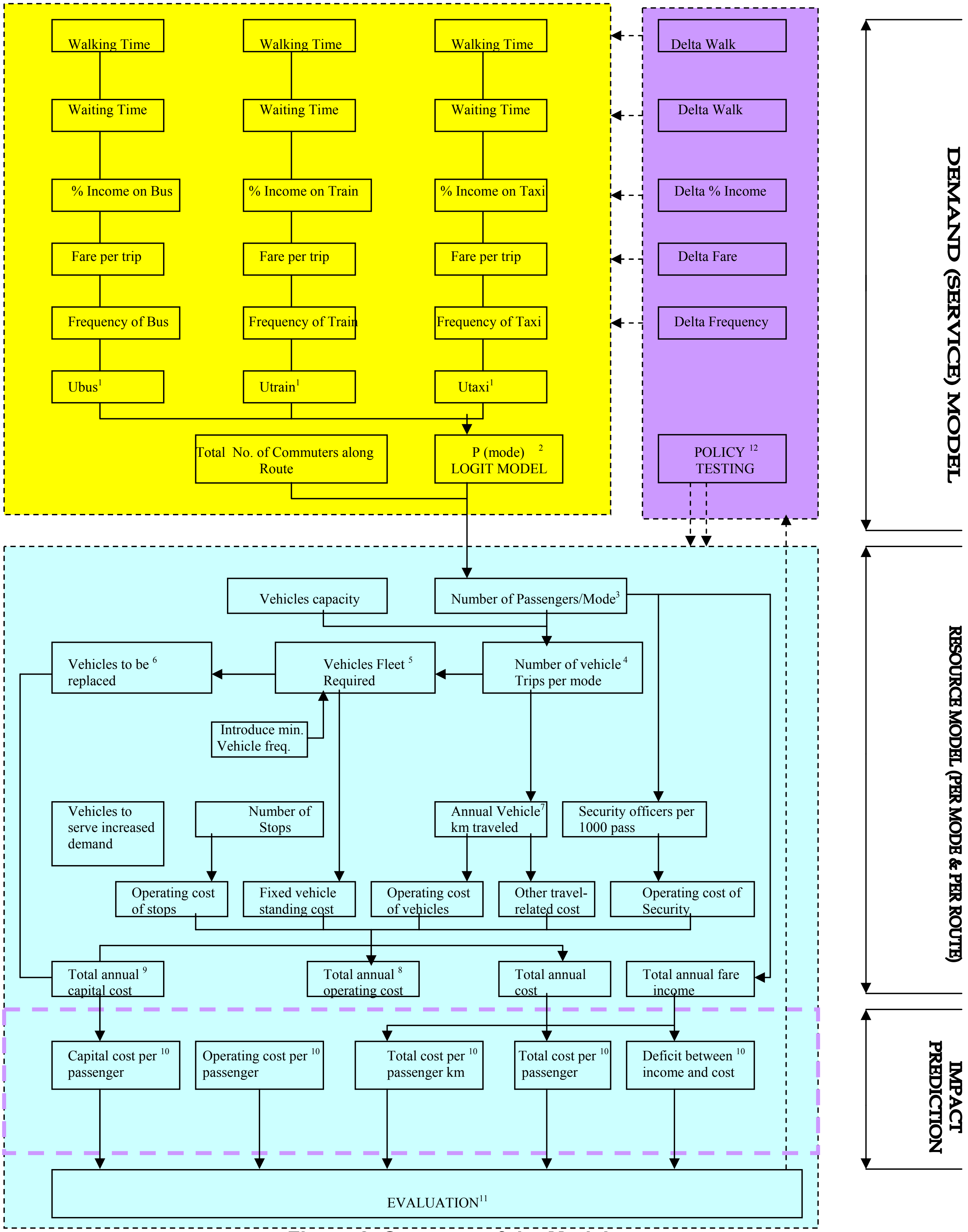

Figure 2- Structure of the Model.

The final demand model took the form as shown in Table 2.

MODEL			% Income Spend		Frequency (dep/hr)	ASCs		
						bus	Train	Taxi
PT modes	Coefficient	-0.062	-3.328	0.257	0.000	0.000	-2.370	4.693
Rho-sq= 0.59	T- statistic	-6.4	-25.3	-14.7	2.86	fixed	-11.3	11.0
	Value of time (R)			R3.04				

Initially, the model considered four modes: bus, train, minibus-taxi and car (the latter to place public transport context), but it was found that the inclusions of the car mode disturbs the calibrating of the model. Considering the market segment under discussion, it is questionable whether car is a viable transport option. Moreover, travel time is not included as a variable (as it was not identified in the needs analysis), but would have contributed significantly to differences in utility between car and public transport.

One utility function was developed with different alternative specific constants (ASC) for each of the public transport modes. Only the variables walking time, frequency (and waiting time), fare/trip and percentage income spent on public transport could be incorporated into the utility function. The potential dominance of the ASCs at the outset of the calibrating process suggested that the ASCs seek to replicate the modal split values, and thus reducing the explanatory power of the model. However, in the final model, the contribution of the ASCs is estimated at only 22%, which is not reason for concern. In light of all these shortcomings, it should be mentioned that the model is still capable of predicting the actual modal split with good accuracy.

5. SENSITIVITY ANALYSIS

Sensitive tests were used to establish the impact of variables on mode choice in the demand model. It was shown that:

- A change in fares had the most impact on mode choice, and therefore readership, in the range R3.50, with elasticities in excess of one:
- Peak period frequency was most responsive in the range five to 15 departures per hour, with moderate elasticities, and
- Walking time had the most impact in the range zero to 20 minutes, with elasticities ranging between -0-10 and -0.21

These findings provide a useful indication of where the focus for policy changes should be placed, for the market segment in question. Special caution should be exercised when designing policies involving public transport fares for the low-income (Handy, *et al* 2005)[28]. Sensitivity tests of the resource model revealed the facts listed below;-

- A change in fares resulted in the highest impact on public transport income and cost with elasticities in excess of one.

- Frequency changes had a moderate impact, with elasticities between 0.44 and 0.98.
- An increase in hour of service had a minimal impact on all services, and the measure can, therefore, be implemented at a rather low cost.
- The model was found to be extremely responsive to a reduction in train crowding, with a 10% reduction resulting in a 12% increase in cost.

The main shortcomings of the demand model relate to the fact that the current model results are limited to captive, disadvantaged communities traveling for the purpose of work (commuter trips), and the inability of the model to predict demand changes due to improvements of attributes not included in the model, which could subsequently result in the underestimation of possible shifts in demand.

6. ANALYSIS AND RESULTS.

The main output indicators include cost/one-way trip, which is calculated by dividing total annual cost by the number of passenger trips per annum, as well as subsidy levels required, calculated as the total annual cost minus the total fare income. The predicted impact of changes to levels of service is given in Table 3.

Table 3- Predicted impact of changes to public transport levels of service

MODE	Policy Tested	Impact on Cost/ One-way	Impact on Subsidy Levels	Impact on Modal Split[1]
	Base Model Values	**R5.17**	**R14.7 m**	**27.02%**
BUS	Minimum Levels of Service	+ 80%	+ 230%	+ 1.3%
	Target Levels of Service	+260%	+ 940 %	+ 27.3%
	Base Model Values	**R1.25**	**- R11.6 m**	**29.54%**
TRAIN	Minimum Levels of Service	+ 430%	+ 680%	+ 6.37%
	Target Levels of Service	+ 930%	+ 1150%	+ 6.37%
	Base Model Values	**R6.17**	**R25.2 m**	**43.44%**
MINIBUS-TAXI	Minimum Levels of Service	+ 20%	+ 110%	-
	Target Levels of Service	+180%	+ 950%	+ 4.53%

(1): Modal split changes are expressed as percentage change relative to the base modal split values.

The implementation of target LOS will require increases in subsidies in the order of between 10 and 12 times the current subsidies. The impact on modal split (demand) is minimal, although the improvement of bus operations to the proposed target LOS is expected to have the most significant impact. The increase in demand for the implementation of target bus LOS is estimated at +27. 3%, relative to the base case modal split, which will result in 7.4% additional passengers?

The most cost-effective measures across all modes is the introduction of a minimum level of security, equal to one security guard per 1 000 peak hour passengers. The introduction of acceptable levels of frequency during the AM peak period has proved to be most distances are most expensive in the case of minibus-taxi services.

7. CRITICISMS OF THE SOUTH AFRICAN APPROACHES

Apart from the general criticisms of aggregate four-stage models highlighted above, there has also been some limited concern voiced in South Africa regarding the appropriateness of these models to local conditions. Specifically, Davies *et al* (1995) pointed to the following problems:

- The importance of walking is sometimes overlooked;
- There is poor interaction between public transport and private transport models;
- There is a lack of qualified professionals;
- Technology transfer is "black-box" rather than a source of knowledge;
- The Mini-bus taxi mode is not easily matched with EMME/2; and
- Social stresses inhibit good data collection required for accurate modeling.

Other authors, writing about the developing world specifically, have raised major concerns regarding the appropriateness of the aggregate four-stage model for developing world conditions. Dimitriou (1990:169)[10] suggests that many of the problems with the four-stage model can be traced back to the assumptions underpinning the earliest models, which are largely inappropriate for developing world conditions. For example, the US developers of the 1950s saw the urban transport problem as mainly one of how to overcome motorised traffic congestion. This is sensible in a country where the majority of residents are vehicle owning. The converse is true in developing countries. In addition, early developed world models were not used to study informal transport and so this essential travel mode is treated in an ad-hoc manner in most models. Aggregate four-stage models assume some long term stability in the variables affecting travel demand. This presumption is especially questionable in a rapidly growing developing country.

More recently, Vasconcellos (2001)[41] and Lanzendorf (2003)[34] have been equally critical of the application of aggregate four-stage models in developing countries. He points out that not only is the use of transport models flawed from technical and ideological standpoints, but there are also problems with how the outputs are used in appraisal. Full environmental appraisal (which would include a full safety analysis; disruption and costs to non-motorised transport users) are generally not present. The attribution of monetary costs to accidents and time, which is necessary for economic appraisal, becomes particularly problematic in the developing world where there are large variations in values due to, for example, extreme differences in incomes.

8. CONCLUSIONS.

Based on the discussions above, the following conclusions can be made:

- The approach of integrating demand/resource (supply) modeling techniques is suitable for analyzing public transport operational performance.
- Minimum levels of service for bus and minibus-taxi services are achievable in light of their impact on cost and subsidy levels.
- The improvement of public transport levels of service to the set target may be unaffordable, due to tremendous increases in cost and subsidy levels. However, the improvement of public transport operations may be viable if the alternative is to build more roads for cares, encouraging congestion that would ultimately impact negatively on the economy and the environment.
- In applying discrete modeling techniques, more accurate data on alternatives in the choice set ought to be found, either by tailored stated preference surveys, or by synthesis of the data on a secret level.
- The results are relevant to the low-income market segment with high public transport utilization. Additional research should also be done for the low-income market with low public transport utilization, as there is an obvious need for the improvement of the service.

Moving South Africa goes on to suggest that there is a need to resist further dispersion, promote investment in public transport rather than road building and to consolidate non-motorised modes. In the light of this, three action sets are proposed:

- Densification of transport corridors, which should improve levels of service through corridor-based public transport offering increased speeds and frequencies;
- Optimal deployment of modes, which requires customer-based planning "matched to local travel patterns…and the preferences of specific customer segments"; corridor supportive infrastructure investment such as priority or dedicated bus and taxi ways and intermodal transfer stations and tough road space management "through a combination of controls and pricing, backed by improvements in the public transport system".
- Improving firm level performance in the provision of urban transport services. (Wilkinson and Behrens, 2002)[43] and (GPMC, 1998)[27].

What does all of this mean for Gauteng transport analysis and modeling? It points towards an increased emphasis on:

- walking, as an important mode for those without access to motorised transport; as a mode used to access public transport; and as an alternative for choice users to motorisation;
- public transport and taxi systems;
- detailed knowledge of customer needs
- integration of modes;

- demand management within a framework of integrated land-use and transport planning, aiming towards densification;
- Upgraded modal fleet, facilities, stops and stations;
- Peak frequencies of 5 to 10 minutes, off frequencies of between 10 to 30 minutes and hourly night services;
- Electronic fare integration;
- Integrated feeder service including walking, cycling and taxi networks; and
- Car competitive public transport option which enable strict peak period car use management.

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