GAUTRAIN: DEMAND AND REVENUE FORECAST

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1. Introduction

Estimation of passenger trip volumes and revenue is a key task in determining the feasibility of the Gautrain Rapid Rail Link. This information is vital to the development of a business case. It is also essential in route choice and optimising route alignment, station location and service patterns and in the subsequent evaluation of economic benefits to the region.

This paper describes the forecasting method, data collection and analysis, forecasting assumptions, new rail service scenarios tested and the results of the various forecasts. **At the time of preparing this paper some information has not been made public yet. Depending on the approval processes, this information may be used when the paper is presented.**

2. Forecasting Method

A detailed demand model for the Gautrain Rapid Rail Link was developed in order to forecast the level of rail passenger demand and the likely future growth in travel demand. It also enabled the impact of changes in competing modes to be assessed. The model also made it possible to compare different rail alignment, station locations, line extensions and service changes.

2.1 Base Model

A network-based transportation model was developed using EMME/2 modelling software. This model contained a coded rail network, defined as a set of links, nodes and routes, with information on rail service patterns, journey times, fares, frequencies and rolling stock capacities. Dedicated feeder and distribution bus services as part of the total Gautrain Rapid Rail Link transportation system were also coded. It also contains a detailed regional highway network from which rail trips would primarily be diverted. The highway network was also used as a base upon which bus feeder services were overlain thereby increasing the accessibility of rail stations.

The highway network was based upon the existing PWV Road Network model. This model was constructed using EMME/2 transportation modelling software and covered the Gauteng province. The PWV model has been developed over the past 25 years to plan and evaluate road network developments in Gauteng by the provincial government. During 1999 Gautrans updated the PWV model to a new 2000 base year for use in appraising a toll road strategy for the province. This version of the model was used in the Gautrain Rapid Rail Link modelling as it contained the most up-to-date travel and network data available for the study area.

2.2 Market segmentation

Two broad segments were identified as key potential markets for the new rail service: existing road users and airport users. Of these, existing road users were the primary targets, both because of the size of this segment and the importance of achieving a modal shift away from road to relieve an increasing shortage of highway capacity on key links, notably the Ben Schoeman freeway.

The road user segment was itself recognised to be heterogeneous. Four sub-segments were therefore identified (i.e. by previously disadvantaged individual (PDI) / white and business / non-business) and separately sampled in stated preference attitudinal surveying. Weighted averages of the different segmental values of time and modal biases were then applied in EMME/2 modelling, reflecting the observed composition of corridor road users.

Due to the legacy of the past, the economic development of the average members of the previously disadvantaged population groups took place differently to that of their white counterparts. In order to conduct a fair patronage forecast, the attributes for the different ethnic groups had to be valued separately. Planning data, socio-economic and demographic information recorded and kept by government organisations also still distinguish between ethnic groups. For these reasons reference is being made to PDI member / population as well as ethnic groups in this paper.

The ethnic and journey purpose composition of road users varied between the peak and off-peak periods. No explicit modelling of the off-peak period was undertaken due to time constraints. The faster road journey times, and possibly lower time-sensitivity of off-peak road travel, was instead reflected in the relatively low expansion factor of 5,0 applied to a.m. peak hour forecast rail demand in estimating average annual weekday trips.

The airport was considered likely to generate rail demand, both from passengers and workers. Sampling for the stated preference attitudinal research reflected this segmentation and a separate spreadsheet-based forecasting model was developed specially for this market. Journey purpose (business and non-business) segments were identified for the passenger market and ethnic group (PDI and white) segments for airport workers.

It was apparent from the origin-destination and stated preference surveys of airport workers that their residential location and cost-sensitivity was likely to preclude their significant use of the rail service as envisaged. It was therefore conservatively assumed that no diversion of existing airport worker trips would accrue to the new rail service.

Forecast of the likely diversion of air passengers was made using stated preference results and competing highway times obtained from the EMME/2 model. Forecasts of rail mode share, patronage and revenue were undertaken in a spreadsheet with an adjustment made to EMME/2 forecast diversion from road to avoid double counting of airport rail demand.

2.3 Zoning and Network Definition

The existing zoning and highway network of the PWV EMME/2 model was adopted. Enhancements to the network included:

- Coding of the proposed new rail line, including various altrernative aligments
- Coding of additional road links to reflect accurately road accessibility to stations
- Coding of car park 'links' at stations
- Coding of walk links to permit inter-modal transfers (e.g. between bus/Metrorail and Rail and between Car and Rail)
- Centroid connectors to provide walk links between stations and adjacent zones
- Walk access links between stations and access modes
- New rail service route information, including fares and frequencies
- Dedicated bus feeder services to improve access to stations.

2.3.1 New Rail Alignment and Service Scenarios

A series of alternative alignments, extensions to the minimum network, service frequency and phased construction were developed during the conceptual planning of the Rail Link. 26 options were modelled for ridership and revenue for the 2000 base year.

There are the two main north-south alignments, namely the direct alignment between Pretoria and Johannesburg via Sandton and Rosebank and an eastern route via Bruma Lake as indicated in Figure 1. Both alignments were combined with a direct link between Johannesburg International Airport and Sandton.

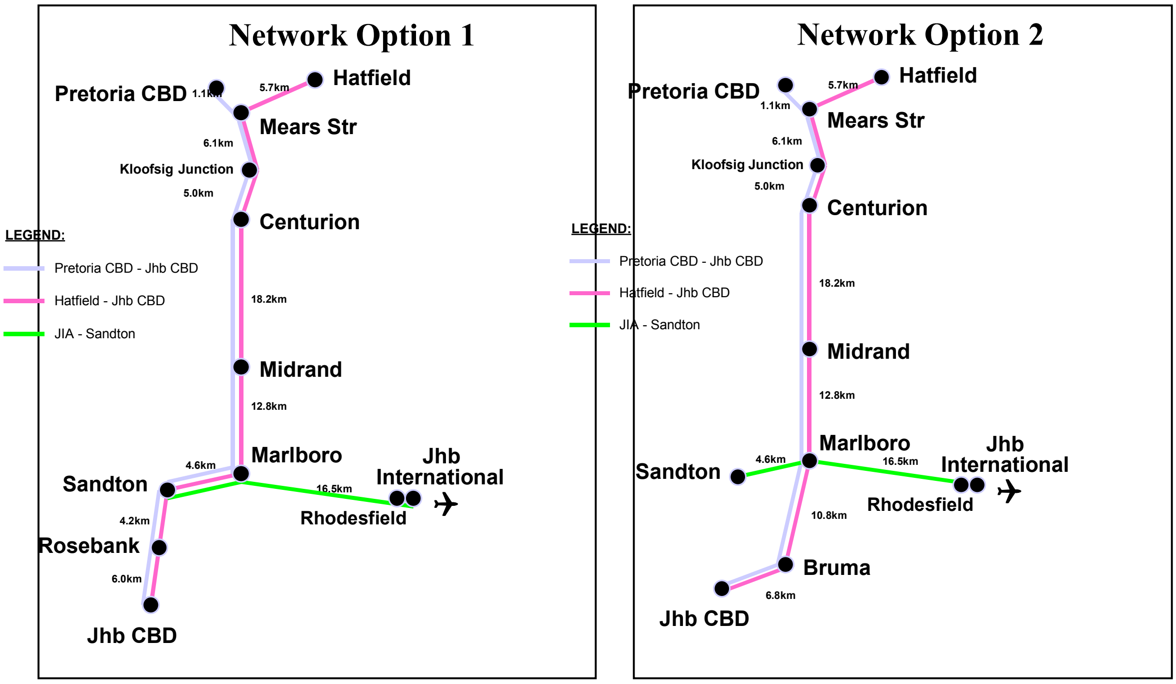

Figure 1: Rail Alignments

Other scenarios analysed included:

- Alternative route via Melrose Arch between Sandton and Johannesburg
- Possible extensions of the Johannesburg International Airport line to the East Rand (Dunswart) and from Hatfield to Menlyn in Pretoria
- A light rail option to complement the eastern alignment via Bruma, serving passengers between Sandton and Johannesburg CBD
- Various options on the Pretoria end of the line to serve the eastern suburbs and Menlyn
- Service options to provide a direct service where passengers would otherwise have to transfer between trains. These included a direct connection between Johannesburg International Airport and Johannesburg CBD, and Hatfield to Sandton on the Bruma alignment
- Increased service frequency (twelve trains per hour in stead of the base case of six trains per hour)
- Phased construction where the exclusion of the Johannesburg International Airport-Sandton and Sandton-Johannesburg links were analysed.

2.4 Model Structure

The demand modelling was undertaken using a conventional four-stage network model consisting of the following sub-models:

- Trip generation and attraction
- Trip distribution
- Mode choice
- Assignment.

The model, as with other network models, required four types of data: zonal, trip, network and behavioural. The model structure is illustrated in **Figure 2 – Model Structure**.

The base year model was developed for a weekday peak hour, reflecting its original basis in the PWV Model. Model results were then used to obtain estimates of daily and annual demand. Because it is only a morning peak hour model, matrices contained a predominance of commuting journeys. Further refinement of the model will include the development of off-peak matrices with a greater representation of business (in course of work), leisure and other journey purposes.

2.4.1 Trip End Models

The trip end models are conventional. During model development statistical relationships were derived to predict zonal trip generations and attractions, for each journey purpose, as a function of zonal characteristics (e.g. population, employment, employed, car ownership and income).

The trip end relationships were applied to projected levels for key trip generation and attraction determinants and estimates of forecast year trip ends derived. These then provided inputs into the trip distribution model.

2.4.2 Trip Distribution Model

The trip distribution model produced forecast year trip matrices. The inputs to the trip distribution model were the base year (2000) trip matrices and forecast year total zonal trip generations and attractions. Separate matrices were created for the 2000 base year and 2016, 10 years after opening. The trip distribution model used the Furness method available in EMME/2.

2.4.3 Mode Choice Model

The mode choice model split car person trips between car and the new rail service based on relative modal generalised costs. The model inputs were car and rail journey times and cost matrices obtained ('skimmed') from model networks. The networks contain link and mode generalised costs, computed using estimated flow volumes, link and public transport route characteristics and behavioural values (e.g. values of time, modal biases, interchange penalties) obtained from stated preference analysis.

The mode choice model is a binary (new rail vs. car) logit model, applied through a macro within the EMME/2 modelling software. The mode choice model produced modal trip matrices, for each forecasting year. The rail matrix was then split between car and bus access modes based upon the relative generalised costs of the two access modes. The modal trip matrices produced by the mode choice model were subsequently assigned to the modal networks within EMME/2.

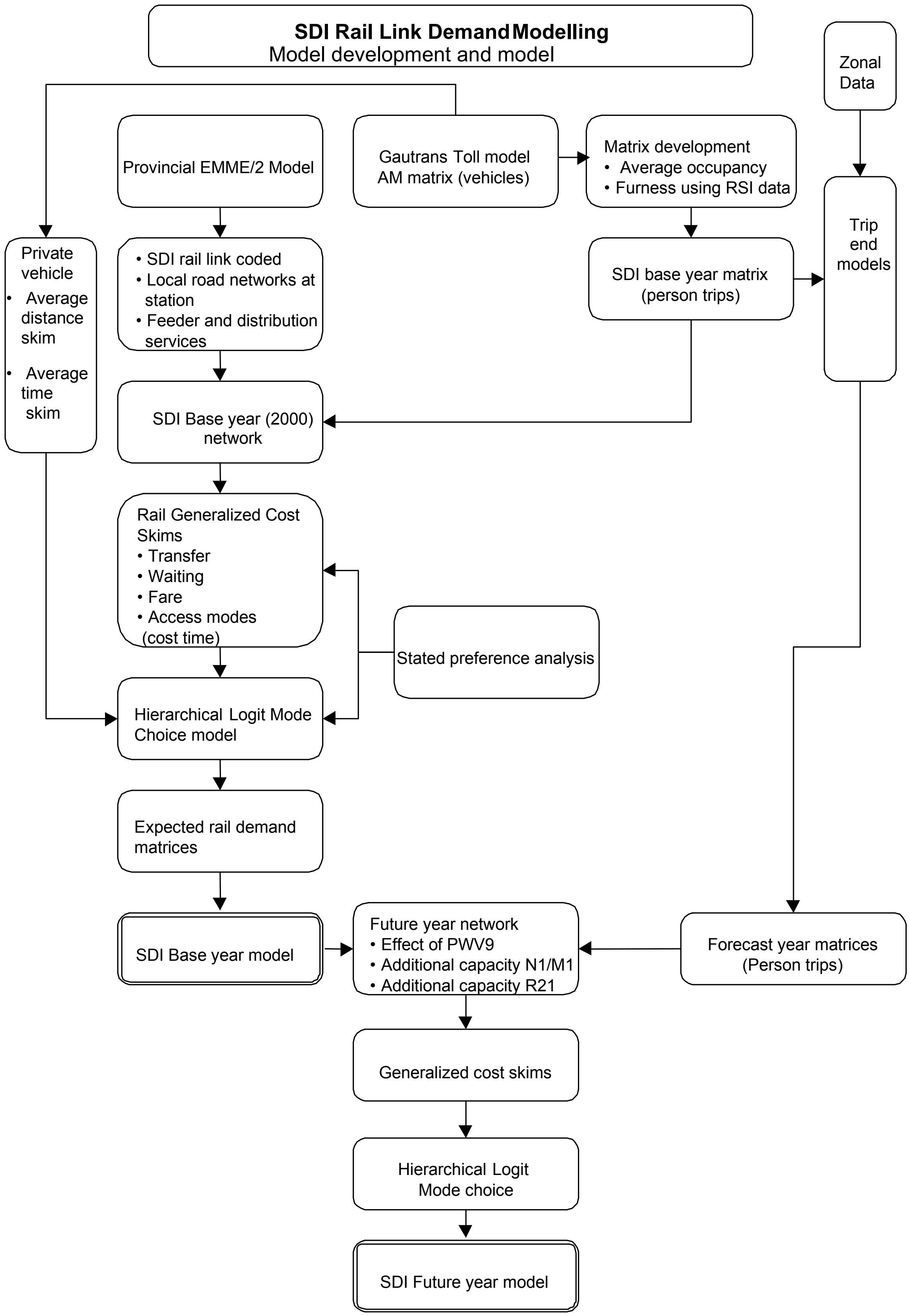

FIGURE 2: MODEL STRUCTURE

2.4.4 Assignment Model

This sub-model assigned modal trip matrices, output from the mode choice model, to modal networks within EMME/2. Assignment was undertaken using the Stochastic User Equilibrium (SUE) method, which assigns a portion of the total demand at a time. Each portion of demand was assigned using different generalised costs. Link costs were derived by sampling from an assumed distribution of values around the average link cost. Flows were then assigned on each O-D to their least-cost route.

The advantage of the SUE method is that it permits multi-routing of trips on any O-D flow. This reflects real driver route-choice decisions, which, for a number of reasons, typically exhibit multi-routing.

2.5 Forecast Horizons and Scenarios

A base year (2000) demand model was developed and this formed the basis for the 2016 forecast year model. 2016 was selected to test the demand 10 years after implementation. The planned year of implementation is 2006.

Road improvements and new roads within the Gautrain Rapid Rail Link corridor will influence future rail demand. The sensitivity for road network improvements has been tested in both the base year and 2016 models.

2.6 Induced Demand

Demand forecasting focused on the estimation of diversion of trips from car to the new rail service. The new rail service, by creating an important new travel opportunity, will result in some increase in the total travel market. No formal modelling of this induced demand was undertaken. However, reflecting the observed induced demand of approximately 20% for new rail initiatives internationally, it was conservatively assumed that induced demand would account for 10% of final demand for the new service.

2.7 Diversion from public transport

Journeys along the new rail corridor are currently served, to varying degrees, by MetroRail commuter rail services linking Johannesburg, the Johannesburg International Airport at Isando, Centurion at Irene and Pretoria, and by bus and taxi services. It was not considered likely that there would be a substantial diversion of existing users of these services to rail. However, it was assumed that 7.6% of new rail demand would be from this source. As with induced demand, this assumption was based upon the observed response to new services internationally.

3. Data Collection And Analysis

PWV Model trip data was augmented by a survey of airport passengers and workers. The behavioural data of the PWV model were replaced and augmented with further information on values of time, modal biases, etc. from stated preference surveys conducted on both road users and airport passengers and workers. Independent projections of socio-economic zonal data were commissioned from specialist consultants. These augmented those contained within the PWV Model database.

Examination of the PWV Model matrix indicated that the relative number of Johannesburg area trip ends were to/from the CBD as compared with the newer business centres to the north, particularly Sandton. It was believed that the PWV matrix too strongly reflected historic Origin-Destination (O-D) patterns. The study team therefore sought to update the matrix selectively using the most recent data available, i.e. from the 1999 Roadside surveys on the N1 and R21. The effect was to increase the volume of trips to/from northern Johannesburg, and especially between the eastern part of Pretoria and the Greater Sandton area, and to reduce trips from the old CBD.

These factors were then used to update total PWV matrix zonal trip generations and attractions. The PWV matrix was then updated, using the updated trip ends, through the Furness matrix balancing method.

3.1 Johannesburg International Airport Demand

An origin-destination survey of airport workers and passengers was undertaken at Johannesburg International Airport (JIA) to supplement the available information. Johannesburg, including the northern suburbs, accounts for 52% of airport passenger trips. A further 21% are to/from the East and West Rand. Greater Pretoria accounts for 27% of trips. The geographical composition of air passenger demand shows only small variation between domestic and international passengers.

3.2 Behavioural Data

The stated preference (SP) survey analysis provided the model's behavioural data. It had the following uses within the modelling:

- Provides weights for generalised costs components for use in building networks
- Provides mode share parameters for use in mode choice models.

The resulting networks and mode choice modes are inputs into the final assignment of trips to the Gautrain Rapid Rail Link (including its access and egress modes) and highway networks.

3.3 SP Survey Analysis and Results

SP data were analysed statistically at both market segment and whole sample level. Generalised cost coefficients, reflecting the importance travellers place on individual attributes such as access/egress time, fare/cost, service frequency, etc.) were obtained for use in computing modal generalised costs. Values of time were derived from the relative weights attached to in-vehicle time and cost.

The SP analysis also provided modal biases ('mode specific constants'). These reflected the net effect of other mode choice determinants not included within the SP survey design. Separate modal biases were derived for Gautrain Rapid Rail Link (with respect to car) as a main mode and feeder bus (with respect to car) as a Gautrain Rapid Rail Link access mode. The modal biases were then applied in the mode choice model.

The values of time and modal biases are presented in Table 1 They were obtained from the SP econometric modelling and were used within the 'logit' mode choice model to forecast the rail mode share.

Table 1 : Behavioural Values Used in Modelling

SEGMENT	IN-VEHICLE TIME	MODAL BIAS (CONSTANT)
Car – PDI – Non-Business	27	-0.35
Car – White – Non-Business	32	0.0
Car – PDI –Business	40	0.0
Car – White – Business	63	0.0
Air Passengers – Business	161	.96
Air Passengers – Non-Business	38	.63
Airport Workers – PDI	7	0.0
Airport Workers – Whites	36	0.0

Different values were sought for key market segments. These were then trip-weighted to reflect the ethnic group/journey purpose profile of road users obtained from 1999 RSI surveys on the N1 (Table 2).

Table 2 : N1 Road User Profile

	PDI	WHITES
Business	13%	30%
Non-Business	22%	35%
TOTAL	35%	65%

The value of time for the average road user was therefor calculated as follows:

(0.13 * 40) + (0.30 * 63) + (0.22 * 27) + (0.35 * 32) = 41.24

4. Forecasting Assumptions

A number of assumptions were made regarding the specification of the Gautrain Rapid Rail Link service, including access/egress provision, and the level of service on competing modes.

4.1 Fares

The Gautrain Rapid Rail Link fare structure was developed through a comparison of existing taxi fares, bus fares, private car cost and travellers' willingness-to-pay for the Rail Link as determined through stated preference analysis. It was intended from the outset that rail fares would be less than the fuel cost of a car over distances above 20 km. The fare must also be more expensive than the fare for existing rail and taxi as the new train purports to offer a higher quality service.

A comparison of the costs, by distance travelled, for users of taxi, bus, private car and Gautrain Rapid Rail Link is diagrammatically illustrated in Figure 3.

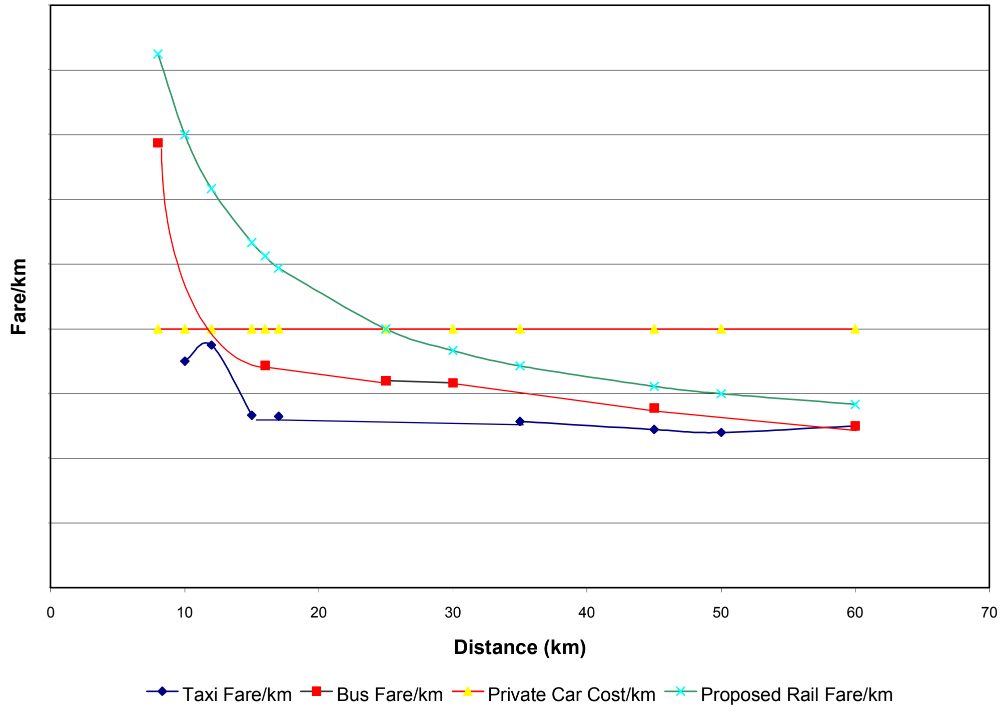

Figure 3 : Transport Fares and Costs with respect to Distance Travelled

The Gautrain Rapid Rail Link fare developed for use in the modelling, and for revenue calculations, assumed a boarding fee per journey plus a fee per km travelled

It is clear that for a distance above 25 km the rail fare per kilometre is between that of the private car user and the taxi and bus users. The Gautrain Rapid Rail Link fare used in the demand forecast is 10-15% higher than the fare for a taxi trip over the same journey distance.

A higher fare was assumed for the airport link users, in line with practice elsewhere worldwide. These higher fares reflect the relatively high time sensitivity of air passengers, especially those travelling for business purposes, and lower car availability. It also reflects their more positive attitude to the new rail service, as compared to general road users, indicated in the stated preference research.

Non-airport passengers travelling between Rhodesfield (Kempton Park) and Sandton would pay the standard fare as for travellers between Pretoria and Johannesburg.

4.2 New Rail Service

4.2.1 Rail service characteristics

The following characteristics were assumed for the new service:

- The base rail service tested consisted of a north-south (Pretoria – Johannesburg CBD) service and an east-west (Sandton to Johannesburg International Airport) service
- Real running times were based on a preliminary assessment using 1m/s² acceleration rate and a 0,8 m/s² deceleration rate with a maximum speed of 200 km/h
- Rail rolling stock capacity of 800 persons per 8-car train set
- Rail-to-rail interchange penalty of 10 minutes
- Train service frequency was assumed to be every 10 minutes on each route.
- An average of 5-minute waiting time for a train was assumed which is half the headway.
- Alternative service patterns and frequencies were tested.
- At the Pretoria end of the corridor it was assumed that a third of the trains (2 trains per hour) would run to and from Pretoria Station, while the other two-thirds (4 trains per hour) would run to and from Hatfield Station.
- A rapid transit system between Sandton and Johannesburg was also tested, in certain options, to supplement the possible alignment from Pretoria to Johannesburg via Bruma.

4.2.2 Walk Access

Walk access was allowed at both the access and egress ends of the trip

Walking speed was assumed to be 5 km/h.

4.2.3 Private Car Access

Private car access was only allowed on the access portion of a rail trip. It was assumed that travellers would use either the dedicated bus service or walk at the egress end.

Private cars were allowed to park at the station and at decentralised park and ride facilities which were linked to the station by dedicated feeder bus services.

A time penalty of 5 minutes was added to reflect access and parking time at the park and ride facilities and at the station.

A R4, 00 per day parking fee was levied on vehicles parked at the park and ride facilities and at the station.

4.2.4 Feeder Bus Services

Bus service frequency was assumed to be every 10 minutes, except at Sandton where the frequency was reduced to 30 minutes because of the large number of bus service passengers terminating at Sandton Station.

The bus service was subject to congestion on the road network and 10% travel time was added to the journey time to reflect the time spent at bus stops. A penalty was imposed on car to bus transfer to reflect the resistance against bus use as evident from the stated preference results.

5. Forecasts

5.1 Base Year (2000) Forecasts

A comparison between the Rosebank, Bruma and Melrose Arch alignments indicates that the Rosebank alignment attracts approximately 12 400 and 64 000-peak hour and daily passenger trips respectively. The am peak hour is 7,7% more than the 11 500 trips of the Bruma alignment and 24% higher than the 10 000 trips of the Melrose Arch alignment. The am peak hour passenger kilometres of the Rosebank alignment is 26% and 29% higher than those for the Bruma and Melrose Arch alignments respectively. The annual fare box revenue for rail trips only of approximately R305 million is 11% and 19% more than for the other two basic network options.

5.2 Link Flow Volumes

Figure 4 illustrates the link flow output as produced by EMME/2 for the Rosebank alignment. The volumes indicated in these figures don’t include passengers diverted from other modes of public transport and induced demand, which were estimated separately and added to the EMME/2 results

The figures indicate the estimated number of a.m.-peak hour passenger trips per direction between stations. The data is also presented in a weighted band width format which corresponds with the estimated number of passenger trips. The maximum link flow occurs in a north to south direction between Centurion and Midrand stations. The maximum estimated number of a.m.-peak hour trips on any station to station link is 7400. The maximum link flow in the south to north direction is between Centurion and Mears street stations with an estimated number of 370 a.m.-peak hour passenger trips.

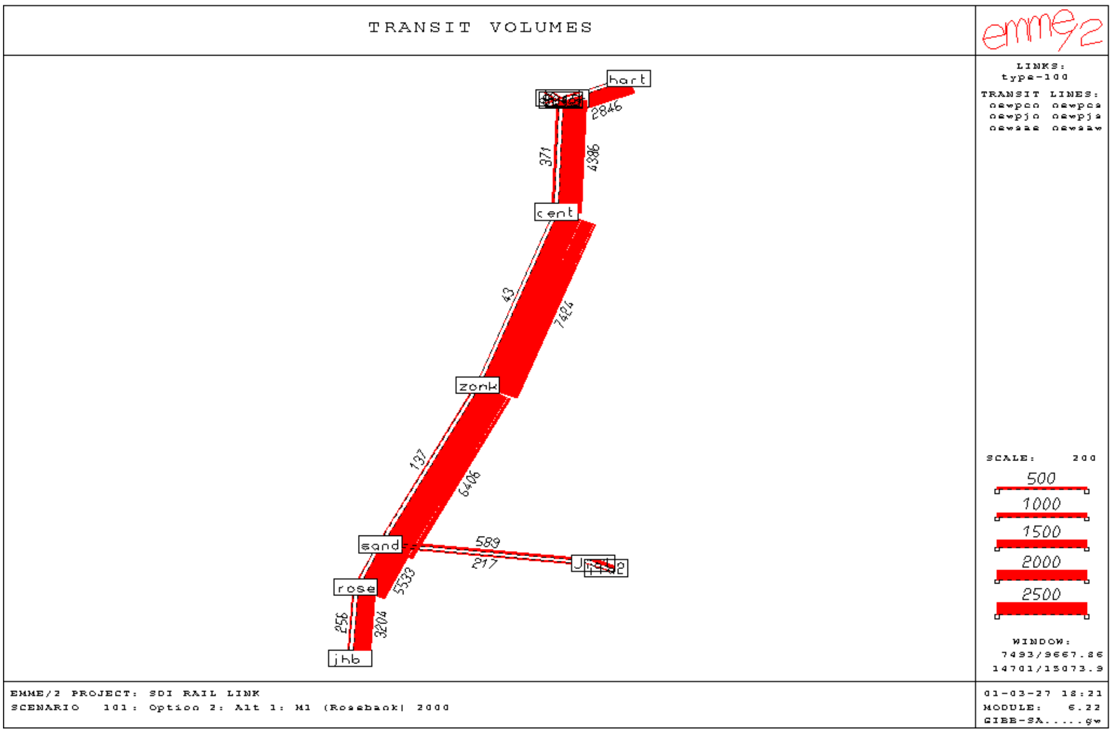

Figure 4 : Option 1 (Rosebank Alignment) Link Flows

5.3 Rail Market Share

In order to determine the Gautrain Rapid Rail Link market share, the rail and road passenger flows crossing screen lines north and south of Midrand were recorded. These screen lines cross all roads in a north-south direction. The screen line north of Midrand indicated that the rail market share in the southbound direction is 19.7%. At the screen line south of Midrand the southbound rail market share is 9%.

5.4 Future Year Forecasts

A forecast for 10 years after implementation (2016) was carried out assuming that the growth will continue at the trend reflected by the zonal characteristics determined during the development of the model. The information obtained does not, however, consider the influence of AIDS on population growth, nor does it reflect the impact of telecommuting and the development of the modern day electronic city. The results for the 2016 land use scenario, indicated that a total number of approximately 23 000 morning peak hour trips will be generated. This is assuming that no additional roads will be constructed and represents an average annual growth of approximately 4 % in rail patronage. The growth in vehicle trips on the N1 averaged 7% per annum over the previous 10 years.

5.5 Rail Sensitivity Towards Road Improvements

The full toll road network scenario, as it was proposed in the Gautrans Toll Strategy was tested. The new roads tested in this scenario consist of the following:

- PWV9 with frontage roads
- K60 between PWV9 and R101
- Addition of one lane per direction on N1
- Addition of one lane per direction on R21

This road network with the Gautrain Rapid Rail Link was tested for the 2016 land use and demographic scenario. The results indicated that the proposed road network improvements would reduce the rail ridership by approximately 6%. Depending on the toll fare levels, rail ridership could decrease more at lower toll fare levels or even increase slightly at higher toll fare levels. This indicates the sensitivity for travellers of toll cost, rail fare, travel time, etc and the important influence that the rail link and major road system have on each other.

6. Conclusions

From the results of the EMME/2 demand model developed for the Gautrain Rapid Rail Link, it can be concluded that, in the base year, the proposed service would attract approximately 12 400 passengers, travelling 442 000 km in total, during the morning peak hour. This equates to 64 000 daily passenger trips and 2 265 000 daily passenger kilometres. The estimated annual rail revenue is R304 million in the base year.

It can further be concluded that the demand model has been developed to sufficient accuracy to be able to carry out comparisons between various alignments and service options and to determine the feasibility of the project. However, further model developments are required to be able to make the model available to bidders for use in preparing their best and final offers.