DECADES OF LEARNING FROM TRENDS IN LAND USE AND TRAVEL
TRAVEL AND TRANSPORT DEMAND ESTIMATION IN THE CITY OF TSHWANE

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ABSTRACT

The estimation of transport demand by means of computer software models plays a major role in the planning of transport infrastructure and services of cities. Continuing changes in the land use and transport patterns of a rapidly developing city such as Tshwane is a challenging process. The City of Tshwane (CoT) has a relatively long history of travel demand modelling that can be traced back to 1975. Significant changes in the demography, employment and economy, city structure and travel patterns took place over the last two decades. The institutional capacity of the CoT to develop and use travel demand models was increasingly challenged to keep abreast with improvements and complexity of IT technology and modelling software during this time period. New types of model software platforms became internationally available, which broadened the fields of application. The significant changes in the factors driving transport demand, required the City to adapt its land use and transport policies, which in turn required changes in the modelling requirements. A key policy change was the shift in the planning focus from private transport to public transport.

This paper provides a summary of the trends that were observed with regard to the city's population and employment, travel patterns, policy testing needs of the CoT as well as changes in municipal boundaries and software development. Relating these changes in the city's conditions to the various models developed over time provides valuable insights into aspects such as data needs, monitoring of the transport conditions, and the use of transport models in the development of transport plans.

These changes in the city over time required a major upgrading of the CoT travel demand modelling system to develop the recent 2015-2020 Comprehensive Integrated Transport Plan (CITP) of the CoT. The Paper highlights the characteristics of the latest macroscopic travel demand model together with its planning and policy testing capabilities, as well as the benefits of the model.

Similar to other cities in South Africa, the City of Tshwane also faces the challenges of a lack of institutional capacity to manage and use the modelling system. Training and capacity building therefore formed an important part of the 2015 modelling and transport planning process, which is reviewed in the Paper.

INTRODUCTION

This paper provides a summary of the trends that were observed with regard to the City of Tshwane's (CoT) population and employment, travel patterns, policy testing needs of the CoT as well as changes in municipal boundaries and software development. By relating these changes in the city's conditions to the various models developed over time provides valuable insights into aspects such as data needs, monitoring of the transport conditions, and the use of transport models in the development of transport plans.

The travel demand model for the City of Tshwane has a long history. The first model was developed in 1975 and updated in 1989/90 when it was known as the PREMET[1] model. This model was updated in 1996/7 to cover the Greater Pretoria Metropolitan Area which consists of Pretoria, the surrounding Peri Urban areas and areas from the then Bophuthatswana. The boundaries were later changed when the Tshwane Metropolitan Municipality were proclaimed and the models were then updated in 2000/1. The proclamation of the City of Tshwane and the need to establish a major base line for the Comprehensive ITP for the city for the 2015-2020 period, was the driving force to update the survey data and model in 2013. Despite the gaps in historically modelled data and planning reports, a comparison of these changes provides valuable insight.

The purpose of this paper is to indicate how significant the changes in land use and travel patterns are rather than to explain their causes. Furthermore, the paper aims to indicate the implications thereof for travel demand models as well as the importance to incorporate these changes regularly into the travel demand models.

OBSERVED CHANGES IN POPULATION AND EMPLOYMENT

City Boundaries

Significant changes took place with regard to the area covered by the Metropolitan Authority over time as indicated in Figure *1* below, while the municipal areas in terms of square kilometres (km^2) for different years are provided in The Northern Pretoria Sub-Structure (NPSS), Pretoria and Centurion municipalities were combined to form the Greater Pretoria Metropolitan Council (GPMC) which resulted in an increase of 1,85 times in area compared to the old Pretoria. Peri-Urban areas, sections of Northwest Province were later added to form the Tshwane Metropolitan Municipality (TMM) resulted in an increase of 1,90 times compared to the GPMC. Kungwini Local Authority and Nokeng Tsa Taemane Local Authority were added to form the City of Tshwane (CoT) resulting in an increase of 2,90 times compared to the TMM. The total increase in area from the old Pretoria to the CoT is 10,19 times.

Table 1.

[1] PREMET refers to Pretoria Metropolitan

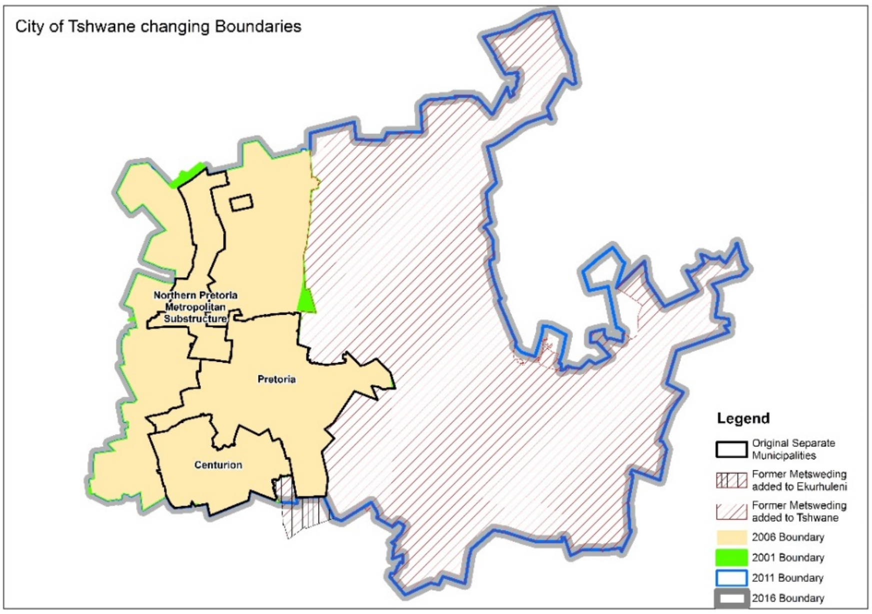

Figure 1: Changes in City Boundaries

The Northern Pretoria Sub-Structure (NPSS), Pretoria and Centurion municipalities were combined to form the Greater Pretoria Metropolitan Council (GPMC) which resulted in an increase of 1,85 times in area compared to the old Pretoria. Peri-Urban areas, sections of Northwest Province were later added to form the Tshwane Metropolitan Municipality (TMM) resulted in an increase of 1,90 times compared to the GPMC. Kungwini Local Authority and Nokeng Tsa Taemane Local Authority were added to form the City of Tshwane (CoT) resulting in an increase of 2,90 times compared to the TMM. The total increase in area from the old Pretoria to the CoT is 10,19 times.

Table 1: Changes in Municipal Area over time, leading to the formation of the City of Tshwane

Category	1990 (Pretoria)	1996 (GPMC)	2000 (TMM)	2013 (CoT)
Total Area	625,5 km^2	1158,6 km^2	2 198,5 km^2	6 368,4 km^2
Increase factor	-	1,85	1,90	2,90

The large increases in the municipal area had a major impact on the travel demand model in terms of its size and complexity. The model was initially developed in 1975, updated in 1990 and later updated in 1996 to cover the GPMC area. The next step was to develop a new model based on new Household Interview Survey (HIS) data when the TMM was established. This was followed by the most recent model update for the purposes of the 2015-2020 CITP, also based on new HIS data after the establishment of the CoT.

Population and Employment

Changes in population are influenced by changes in the municipal area, influx of persons, increased economic activities and employment. These changes are reflected in Table *2*. The population almost doubled from 1996 until 2000 mainly due to the larger area covered by the GPMC compared to Pretoria. The population increased by a factor of 1,36 from 2000 until 2013 despite the area of the CoT being 2,9 times larger than the TMM area. The additional areas are mainly rural with a few small towns and hence densities are very low.

The employment in 2000 was 1,03 times compared to 1996. For 2013 the employment was 1,5 times that of 2000. In 1996 there were 1,1 economically active persons for every worker (the term worker refers to formal and informal workers). This ratio increased to 2,1 by 2000 and reduced to 1,9 by 2013.

Table 2: Population and Employment

Category	Population			Employment		
	1996	2000	2013	1996	2000	2013
Persons	786 992	1 566 534	2 134 876	712 732	740 891	1 113 957
Growth Factor	-	1,99	1,36	-	1,03	1,50

The average densities increased from 6,8 economically active persons per hectare to 13,07 economically active persons per hectare due to the inclusion of areas with higher population densities indicated in Table *3*. This ratio decreased to 3,35 by 2013 due to the inclusion of areas with very low densities such as agricultural land and large nature reserves. The current area covered by the model has metropolitan, rural and rural town characteristics compared to only metropolitan characteristics in 1996. This presented a challenge to simulate the varying characteristics in one model.

Table 3: Average Densities

	Population			Employment		
	1996	2000	2013	1996	2000	2013
Average density	6,8	13,07	3,35	6,15	6,18	1,75

The increase in total municipal population and employment is not only due to the increase in the area but also as a result of densification in specific areas. To illustrate the growth in population and employment for the same geographic area over time, the NPSS, Pretoria and Centurion were selected[2] and are shown in Table *4*.

Table 4: Population and Employment in comparable areas

Category	Subarea	Population			Employment		
		1996	2000	2013	1996	2000	2013
Persons	NPSS	185 879	342 818	325 937	48 373	77 849	91 527
	Pretoria	510 319	747 326	1 000 433	592 402	501 913	690 842
	Centurion	90 794	122 388	261 363	71 957	81 458	181 883
Growth factors between years	NPSS	-	1,84	0,95	-	1,60	1,19
	Pretoria	-	1,46	1,34	-	0,85	1,38
	Centurion	-	1,35	2,14	-	1,35	2,23

An increase in population was recorded in all three of these areas from 1996 until 2000 with the highest factor of 1,84 in the NPSS followed by Pretoria and Centurion. In the period from 2000 until 2013 the NPSS experienced a reduction in population while the other two areas experience an increase in population with the Centurion population increasing by a factor of 2,14.

An employment increase was experienced in the NPSS and Centurion (1,6 and 1,35 respectively) in the period from 1996 until 2000, while Pretoria experienced a decrease in employment. From 2000 until 2013 all three areas experienced an increase in employment with the employment in Centurion increasing with a factor of 2,23 followed by Pretoria and the NPSS.

Population and employment not only increase or decrease in the large areas, but there was an internal relocation of population and employment taking place in the same time intervals. Some areas experience larger changes than expected and other areas experience smaller changes than expected by the author. This can be attributed to both the increase in

[2] The population and employment for 2000 and 2013 were extracted for the same boundaries in order to do these comparisons.

population and relocation of population. These changes are highlighted in Table *5* where selected residential areas were selected.

Table 5: Changes in Distribution of Population and Employment in selected residential areas

Area	Population			Employment		
	1996	2000	2013	1996	2000	2013
Atteridgeville	83 842	167 747	152 537	11 712	15 481	152 537
Brooklyn	17 009	18 285	36 235	36 170	41 925	36 235
Mamelodi	96 675	156 150	158 331	9 444	13 819	158 331
Montana	22 443	25 412	50 265	10 799	12 319	50 265
Soshanguve	163 678	318 873	279 702	11 966	26 411	279 702
Wierda Park	26 676	31 053	70 150	17 520	15 974	70 150

Table *6* indicate changes in areas which are predominantly employment areas. Decentralisation of employment from the Central Business District (CBD) to residential areas is evident. The number of employees within the CBD decreased significantly from 1996 to 2000, thereafter increased somewhat to 2013, but experienced an overall decrease of 19 % from 1996 to 2013. The other important change is the encroachment of employment into residential areas.

Table 6: Changes in Distribution of Employment in selected areas

Area	Employment		
	1996	2000	2013
Lyttleton	27 921	26 827	51 892
Pretoria CBD	194 781	130 208	158 250
Pretoria West	63 109	41 510	46 561
Rosslyn	26 529	29 674	37 860
Silverton	63 065	52 902	61 826
Valhalla	18 359	11 596	10 072

Population and employment changes in some areas were such that the proportion contribution to the total changed as indicated by the percentage contribution to the total in Table *7*. The CBD's contribution to the total employment decreased from 27% to 16%. The selected residential areas' proportional contribution to employment also increased except for Atteridgeville when 2013 is compared with 1996.

The impact of urban decentralisation of employment is typical of growing cities, caused by various factors, including increased congestion in the CBD, longer travel times from residential areas, and development of decentralised nodes such as Centurion, Hatfield, Menlyn and Akasia (Van Zyl, 2003).

Table 7: Changes in the proportion of population and employment of selected areas of the City of Tshwane over time

Area	Population			Employment			Area	Employment		
	1996	2000	2013	1996	2000	2013		1996	2000	2013
Atteridgeville	11%	14%	10%	2%	2%	2%	Lyttleton	4%	4%	5%
Brooklyn	2%	2%	2%	5%	6%	7%	Pretoria CBD	27%	20%	16%
Mamelodi	15%	19%	16%	1%	2%	2%	Pretoria West	9%	6%	5%
Montana	3%	2%	3%	2%	2%	4%	Rosslyn	4%	5%	4%
Soshanguve	21%	27%	18%	2%	4%	3%	Silverton	9%	8%	6%
Wierda Park	3%	3%	4%	2%	2%	5%	Valhalla	3%	2%	1%

OBSERVED CHANGES IN HOUSEHOLD CHARACTERISTICS

The average household size reduced from 3,9 persons per household in 2000 to 3,2 persons per household in 2013, see

Table *8*. Unfortunately, household interview survey data prior to the 2000 model update is not available. The number of persons per household for both the low and high-income groups decreased, but for the middle-income group an increase is observed. By 2013, the variance in number of persons per household for the different income groups had reduced. The number of workers per household had reduced substantially by 2013 compared to 2000.

Table 8: Household size and workers/household

Category	Persons/Household		Workers/Household	
	2000	2013	2000	2013
Low income	3,5	3,1	1,6	0,5
Middle Income	2,9	3,5	1,4	1,1
High Income	4,1	3,3	2,4	1,4
All Income	3,9	3,2	2,0	0,8

The average income per household increased substantially for each of the three income groups from 2000 to 2013, see Table *9*. The average income per household increased from R4982 per month to R7044 per month which represents an increase of 41%. Private vehicle ownership for the low-income group increased while a decrease in ownership was recorded for the middle and high-income groups. On average, a decrease of 25% in vehicle ownership was recorded over the period from 2000 until 2013. This is counter-intuitive in view of the strong relationship between income and vehicle ownership. The overriding impact could have been the reduction in household size due to increased breaking up of households and decline in the number of children per family.

Table 9: Income/household and vehicle ownership per household

Category	Income/Household		Private veh./Household	
	2000	2013	2000	2013
Low income	917	1727	0,09	0,23
Middle Income	4195	7362	0,53	0,37
High Income	14115	24261	1,88	1,52
All Income	4982	7044	0,64	0,48

OBSERVED CHANGES IN TRAVEL PATTERNS

Table *10* provides insight into changes in the distribution between trip purposes. The proportion of Home-Based Work (HBW) and Home-Based Shopping (HBS) trips increased, while the proportion of Home-Based Education (HBE) decreased. HBE trips remained the dominant trip purpose from 2000 to 2013. This lead to the decision to model the HBE trips more accurately based on the 2013 HIS.

Table 10: Trip purpose distribution

Year	HBW	HBE	HBS	HBO	EW	NHB
2000	35%	59%	1%	5%	-	-
2013	44%	51%	4%	1%	<0.5%	<0.5%

HBW = Home-based Work; HBE = Home-based Education; HBS = Home-based School; HBO = Home-based Other; EW = Education-work; NHB = Non-Home based

Table 11 shows the modal split according to main mode used and indicates that the private vehicle's share stayed constant, but significant changes took place with regard to public transport modes' market share. A major shift occurred from Bus to Mini-bus Taxi (MBT) and also to Walk. Since 2000 bus subsidies reduced and MBT increased its competition by offering parallel services to Bus, resulting in withdrawal of bus services and declined levels of service. It is surprising that PRASA Rail showed an increase in share, although it has suffered from the same problems than Bus.

Table 11: Modal split

Year	Walk	Priv. Veh.	Mini- bus Taxi	Bus	PRASA Rail	Gautrain	Metered-Taxi	Motor cycle
2000	8%	25%	14%	51%	1%	-	-	0%
2013	34%	25%	26%	12%	3%	0%	1%	0%

The average travel time (in minutes) as indicated in Table 12 changed significantly from 2000 to 2013. For some trip purposes, such as Home-Based Work and Home-Based Other, the average travel time increased significantly as a result of the expanding size of the municipal area as well as the move of the Gauteng provincial government and a few other major employers from Tshwane to Johannesburg since 2000.

Table 12: Average travel time

Year	HBW	HBE	HBS	HBO	EW	NHB
2000	21	47	31	28	-	-
2013	61	42	42	55	42	41

DATA REQUIREMENTS AND SURVEYS

Household interview surveys (HIS) in the form of face-to-face interviews with the head of sampled households were the main survey instrument used to obtain travel characteristics of transport users for planning and calibration of the travel demand models. Surveys had been conducted in 1985, 1990, 1999, 2008 and most recently, in 2013. The survey intervals were 5 years, 9 years, 9 years and 5 years. HIS needs to be conducted every 5 years in view of a growing and fast changing metropolitan area such as Tshwane, coinciding with the major updates of the Integrated Transport Plan (ITP) and the travel demand model. Between 1990 and 2008 there were two consecutive survey intervals of 9 years, which is totally inadequate in view of the major changes that occurred in the city.

Household surveys are expensive and hence cities in general do not always have the funding to conduct surveys every 5 years. However, in view of the value of planning data, this is a worthwhile investment for a city, not only for transport planning, but also for land use planning as well as planning of supply of engineering services, such as electricity, water, and waste management.

Due to the vast development in technology, for example in IT, the internet and social media, GPS and cell phones providing accurate location data, surveys became increasingly more accurate and efficient. Initially interviews were done using pen and paper, while more recently, computer aided personal interviews (CAPI) was used. The questionnaire is coded on a software platform with built-in real-time validation of data, interviewers use tablets to record data and use GPS to record survey locations, as well as electronic maps to assist respondents to indicate origin and destination (O-D) locations of trips for various purposes. Survey data is uploaded to the server every day for further processing, validation and analyses. Accurate O-D information was always a problem with the older pen and paper surveys using hardcopy maps, which has been resolved to a large extent with the use of technology.

With the increase in city boundaries and population, increasingly large sample sizes were required. However, the cost of surveys also became more expensive, which pushed the sample size down. In 1999 the sample size was 7 883, while in 2013, the sample size was 8 891, although a sample of 10 500 was actually required.

In view of the changing dynamics of transport policies over the last few decades, implementation of modern of transport systems such as BRT and Gautrain, as well as the increased complexity and capabilities of travel demand models, there was a need for more and more data to be collected. Policies changed from a focus on private transport and roads, and the so-called "predict and provide" planning approach, to public transport and a 'scenario planning" approach. Subsequent policy trends included increased emphasis on non-motorised transport, universal access, and travel demand management.

The HIS in 1999 collected limited socio-economic information and only basic travel information of commuters for model calibration, although the emphasis on public transport already started in that survey. In 2013, a wide range of data was collected, including:

- Household characteristics;
- Personal characteristics of respondent;
- Information on people with physical challenges;
- Trip information for various trip purposes, including learner transport; and
- Attitudinal information.

The major trend in modelling towards individual choice simulation of transport users' travel choices, requires detailed information of users' choice behaviour. Initially, revealed preference surveys (RP) of users' current and alternative modes of transport was used, and later on stated preference (SP) surveys of users' choices of hypothetical travel scenarios. The SP surveys provides for a much more policy sensitive, reliable simulation of choice behaviour and improved calibration of choice models. The first RP and SP surveys in Tshwane were conducted in 2002 in the large northern residential areas amongst low-income, captive public transport users (CoT, 2002)[3]. The survey data proved very valuable in understanding mode choices of bus, train and mini-bus taxi and also for calibrating a more sophisticated and reliable mode choice model for the macro travel demand model. More recently, in 2008 a major SP survey was conducted for the planning and demand modelling for Tshwane's BRT, A Re Yeng, which was especially useful for testing the demand for a new mode of transport, such as the BRT.

Internationally there is a trend towards the use of GPS technologies for travel surveys to reduce the size, and hence costs, of conventional interview travel surveys as well as to collect more accurate and detailed trip data. Local research conducted on the use of GPS technology to collect detailed spatially referenced travel diaries of a sample of students and staff at the University of Stellenbosch concluded that GPS coupled with statistical analysis can be used to collect accurate daily activity and travel information (Nel and Krygsman[4], 2012). The GPS recorded more activities and number of trips compared to the conventional questionnaire survey method conducted at the same time. It is recommended that the CoT uses this approach in its next major household travel survey.

TRANSPORT DEMAND SOFTWARE DEVELOPMENT

Similar to other cities, the CoT sourced software from international suppliers. Internationally, software development improved in terms of capacity and functionality as a result of international policy and IT development trends. In this way the CoT kept up to date with international software capabilities.

[3] Re-Calibration of the Regional EMME/2 Transportation Demand Model

[4] Nel, JH, Krygsman, SC, The use of Global Positioning Systems in Travel Surveys, Experience from a Pilot Project. Proceedings of the 41 st Annual Conference of the Operations Research Society of SA, 2012.

Macro four-step models were for a long time the only type of model to be used in transportation planning and were in general known as transport travel demand models or static models. Later micro-simulation models (time-dependant models) were introduced, which enhanced the capability and field of application for modelling significantly. These models simulate the movement of individual vehicles which are graphically portrayed on the geometric layout of intersections and road sections. This lead to the need to have time-dependant models that cover the same areas as macro models, which in turn lead to the development of meso-simulation models. The latter fills the gap between macro and micro models. Currently there is software that integrate these three types of models into one model. Another type of model that was developed and later integrated with the transport models are pedestrian simulation models.

Transport modelling was initially predominantly applied and used in the field of transportation planning. The changes in software development enhanced the field of application for transport models to such an extent that it can provide support to planners from a wide range of fields, including transport planners, traffic engineers, road engineers, public transport planners and town planners. These models can be applied to planning, operations, design and control of movement (vehicles and pedestrians).

Transport models have become not only larger but the data that form part of these models have become more detailed and as such these models became a very valuable data basis.

CITY OF TSHWANE MODEL DEVELOPMENT

Improvements in the travel demand model of the CoT were driven by both changes in land use and travel patterns as well as the international and local policy environment. International transport policy trends from private to public transport were mentioned in the Section on “Data Requirements and Surveys”. Increased interaction between local and international planners and officials, as well as more direct access to international knowledge through the internet and social media, resulted in local policies to keep closer track of international trends. Locally, the change in the government and resulting change in government policies to integrated development and the focus on the transport needs of large community settlements far from employment opportunities provided increased impetus to the promotion of public transport and non-motorised transport coupled with mixed and higher-density developments.

Table 13 gives an indication of the evolution of the travel demand model for the City of Tshwane. The number of zones increased due to the increase in the study area, and later on, also to provide for better integration with micro models. The zone sizes were also reduced which offered higher accuracy. The number of employment categories was adequate in all the models, but the number of population categories was too low, which hindered the model’s capabilities. The population categories were therefore significantly increased in the 2013 model. The initial number of two income groups constrained the model’s responsiveness and a third income category was hence introduced in 2013. The number of modes used in the modal split model covered the four main modes such as private vehicles, mini-bus taxis, bus and rail.

In the 1996 model mini-bus taxis were modelled as a separate private vehicle mode, which was not a realistic simulation of MBT operations. However, due to improved functionality of the software and improved survey data mini-bus taxis were modelled as a public transport mode in 2013. The models for 1996 and 2000 were morning peak hour models only, while the model of 2013 was developed for the morning peak hour, off-peak hour and afternoon peak hour. This necessitated more trip purpose categories.

Both the number of future land use scenarios and target years are less in the 2000 model compared to the 2013 model. Whilst the earlier models consist only of a strategic travel demand model, the model for 2013 consists of a strategic travel demand model plus micro-simulation models for 13 core areas, which were integrated with the strategic travel demand model. The addition of micro-simulation modelling expanded the field of model application considerably. The model can now be applied not only to estimate the demand and identify capacity problems, but also to take into account the time-dependency of traffic. This allowed the testing of road capacity, traffic control, intersection capacity and traffic management measures relating to the characteristics of infrastructure, vehicle behaviour and the provision of real-time travel information.

Table 13: Comparison of travel demand models

Model Item	1996	2000	2013
Number of zones	510	844	2044
Number of Population Categories	2	7	16
Number of Employment Categories	11	15	17
Number of Income Groups	2	2	3
Number of modes	4[1]	4	6 + heavy & 2 future
Number of trip purposes	2	3	6
Number of time periods	1	1	3
Model type	4-step	4-step	4-step + micro
Databank size	Not available	0,5 GB	2,5 GB
Number of future land use scenarios	Not available	2	1
Number of future target years	Not available	4	3

Note 1: The taxi mode was modelled in the same way as private vehicles

Key travel characteristics of the 2013 model

The total population within the area covered by the model in 2013 is 4 312 400 persons comprising of 53% low income, 25% middle income and 22% high income. Employment comprises of 1 385 600 formal workers, 156 600 informal workers and 1 052 100 persons in education. Formal workers comprise of 48% low income, 26% middle income and 26% high income while education comprises of 49% low income, 25% middle income and 26% high income.

During the morning peak period the highest number of person trips are generated (1 870 230), followed by the afternoon peak period (1 329 760) and the off-peak period (1 243 120). The majority of person trips in the morning peak hour is home-based work trips (46%) followed by home-based education (43%). The other trip purposes combined contribute 11% of the morning peak hour trips.

Home-based work person trips are over long distances and quite spread out with the intra-zonal trips insignificant. Home-based education trips are just the opposite with the majority of trip over short distances, fewer trips over long distances and concentrated to specific areas.

The modal split for high income morning peak period person trips are 7% for non-motorized transport, 70% for private vehicle and 24 for public transport. The middle income group's modal split is 16% non-motorized transport, 29% private vehicle and 55% public transport while the modal split for the low income group is 19% non-motorized transport, 31% private vehicle and 50% public transport.

INSTITUTIONAL CHALLENGES

The City of Tshwane lost its specialist modelling expertise and currently does not have any in-house specialist modelling capacity. This is due to persons being promoted, resigned or moved to different posts. The CoT did embark on the training and capacity building of officials on travel demand modelling over the last couple of years, but much more effort and on-the-job training is required to regain adequate expertise.

A hands-on training course was provided for the officials of Tshwane during the 2015 CITP project. The course covered both the 4-step modelling process as well as micro simulation where the emphasis was on practical model development. For both the 4-step and micro simulation a small model was built starting with the network, zones, public transport, matrix development and assignments/simulation.

Another problem relates to in-house access to modelling software. Although the CoT acquired the relevant software some years ago, the city could not keep up with the license requirements due to a lack of funding. Officials are therefore not able to use the software and hence they lost the knowledge gained during the training over time. In view of the value of in-house expertise to manage modelling projects and to apply the model for various planning purposes, it is important that the CoT keep up with software licensing payments and the continued capacity building of a small team of transport planners.

SUMMARY AND CONCLUSIONS

The paper reviewed demographic, socio-economic, and key travel patterns over time between 1996 and 2013, a period of 16 years. The main purpose was to determine the magnitude and direction of changes in various key factors and draw conclusions regarding the implications for transport planning and travel demand modelling for the City of Tshwane.

Major expansions in the municipal boundaries occurred which impacted on the demographic and socio-economic profile of the citizens of the municipality, which in turn impacted on travel patterns. Changes were also caused by in- and out-migration of people and businesses, while the travel behaviour of residents themselves changed due to changes in the supply of transport, infrastructure and technology. These changes were accommodated over time in the models developed for Pretoria, the Greater Pretoria Metropolitan Council, Tshwane Metropolitan Municipality and most recently the City of Tshwane.

In the case of the City of Tshwane certain changes were unexpected due to the changes in the city boundaries, but other changes occurred gradually over time. These changes resulted in models becoming out of date and less accurate over time. The more rapid and significant these changes are, the quicker the model becomes outdated. The transport policy environment internationally and locally is dynamic and also requires improvements and changes to software, model design and calibration.

Planning data and travel demand models are valuable tools in the city and transport planning environments and can contribute greatly to planning provided they are kept up to date. The tempo of changes as reflected in the population and employment, demography and travel patterns, as well as in technology and transport policy requires that models need to be updated much more regularly than the actual 5 to 9 years that occurred in the city. It is important that the city schedules and budgets ahead of time for regular updating.

Household Interview Surveys in the past were not always done on a regular basis. A regular basis has subsequently been determined as a 5-year interval as prescribed by the National

Transport Act (2009) and a planning data base was established for 2013. It is important that the data base be regularly updated from now on.

On the positive side, the CoT's travel demand models always incorporated the latest software development and modelling techniques available at the time. Transport modelling software reacted to various driving forces and improved and evolved over time. Travel demand modelling software has a much higher capability compared to the past. The models became much bigger in terms of the number of zones and the total length of the transport network, as well as more complex and sophisticated in terms of functionality. These involved the inclusion of more variables, simulating travel behaviour with the use of individual choice models and SP techniques, more accurate simulation of the informal mini-bus taxi services, and modelling modern transport modes such as the Gautrain and BRT. Modelling capabilities are further enhanced by micro- and meso- modelling software, and recently, integration of the three levels of modelling.

Research for the purposes of the Paper was in itself a challenge due the difficulty in finding historic data and reports. This emphasised again the importance of the secure storing and documenting of survey data and planning reports. Surveys and travel demand model development are relatively expensive, but in view of the value gained to make informed decisions by the city's management, this is a small price to pay. Secure and proper storage of survey data and reports will increase the value of the database by allowing for research and monitoring of trends. By making the database available to all the potential users in the Municipality, such as for town planning, economic development, and engineering services, will also increase the value of the database.

Similar to other cities in South Africa, the City of Tshwane also faces the challenges of a lack of institutional capacity to manage and use the modelling system. As a result of staff movements and lack of funding to update its software licenses, the CoT struggles to manage the survey and travel demand modelling process required of a modern rapidly changing city. High priority needs to be given to an adequately capacitated Travel Demand Modeling Unit with the required software in support of maintaining an up to date transport planning database and travel demand modelling tools.

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