A FRESH PERSPECTIVE ON ACCESS, ACCESSIBILITY AND MOBILITY TOWARDS A SMART, ACCESSIBLE TRANSPORT SYSTEM: MEETING THE NLTSF VISION AND REQUIREMENTS FOR GEORGE'S CITP USING A DYNAMIC TRANSPORT MODEL WITH LAND USE INTEGRATION

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ABSTRACT

In South Africa, municipalities are mandated to develop an Integrated Transportation Plan (ITP) every five years, with yearly updates, as per the National Land Transport Strategic Framework (NLTSF). Notably, the NLTSF vision highlights key aspects of Accessibility and Mobility. To fulfil this requirement, we introduced a novel Smart City framework, focusing on the crucial topics of supporting a thriving economy, promoting sustainable economic growth, providing safe mobility options, providing accessible mobility options, socially including all communities, and preserving the environment, which guided the creation of George Local Municipality's ITP.

This ITP features an innovative transport model spanning the George Local Municipality boundaries, distinct from traditional models, by integrating transport and land use down to individual land parcels. The model is dynamic, incorporating floating car data, open-source data, and uses simulation-based trip assignments. While the NLTSF doesn't mandate such a model, it proved invaluable in forecasting future challenges and informed the development of George's new Roads Master Plan.

Designed as a base model, it can be updated with various data sources over time, making it a versatile tool for land-use planning, contributing to George's Integrated Development Plan and Spatial Development Framework. This model can also facilitate detailed analyses for specific intersections or road segments in relation to potential developments, thereby enhancing its utility for future urban planning.

1. INTRODUCTION

Techso-Tolplan-Lyners Consortium was appointed by the George Municipality (GM) to update and develop a Comprehensive Integrated Transport Plan (CITP) as part of GM ongoing mission to be a 'city for a sustainable future'. This CITP for George, which covers the period 2022 to 2028, is the first comprehensive ITP that responds to and guides the municipality in terms of its Integrated Development Plan (IDP), (IDP 2017-2021 Review & 2023 IDP final draft) and Spatial Development Framework (SDF) (2022-2028) leveraging previous and future planning towards reaching the transport vision to “To create an integrated, equitable, and sustainable transport ecosystem in GM that enhances mobility and accessibility, stimulates economic growth, and benefits the community”.

The George CITP is based on the principle of considering National, Provincial and Local Government legislation, policy, guidelines, best practice and addressing challenges to answer and guide the transport system and transport network in obtaining the preferred outcomes supporting the vision. The CITP is prepared in terms of the National Land Transport Act (NLTA) 2009 (Act No.5 of 2009) and in accordance with the Technical Transport Planning Guideline for CITPs by Type 1 Planning Authorities. All Type 1 Planning Authorities must prepare Integrated Public Transport Network Plans (IPTNPs) and will not be required to prepare a full Operating License Strategy and Current Public Transport Record covering the total network in addition to the IPTNP. Technically, according to the NLTA of 2009, George LM is a Level 3 Planning Authority, but is currently recognised as a Level 1 Planning Authority, since it receives National Grant funding from the National Government, partially due to George Municipality having the Go George Integrated Public Transport Network (IPTN).

In this approach, the CITP incorporates the development of a comprehensive dynamic Transport Model (TM), providing an excellent tool for integrating land use with transport planning and associated road network planning for a minimum of a 20yr planning scenario period. The TM is an instrument to complement sustainability planning and assessment ensuring continuity for the future updates, currently every 5yrs as per Minimum Requirements for the Preparation of Integrated Transport Plans (ITPs) as Gazetted (no. 40174) on 29 July 2016. The TM can be updated continually and not only every 5yrs, which provides a better base for early decision making and implementing solutions and improvements creating a more realistic base for the following year and future horizon planning. Furthermore, this CITP expands on the general terminology in transport planning, such as “integrated”, “interoperability” and “safety”, etc. to incorporate more fundamental core values for any user of a transport system, being “Accessibility and Mobility”. This approach creates a common “Lens” through which all the components of a transport system and the integration of the thirteen (13) functional areas of a CITP should be viewed.

Traditionally, transport and land use planning were conducted independently. However, transport models that incorporate land use data help bridge this gap. Although transport models are not mandatory for Integrated Transport Plans (ITPs), the absence of accurate models can lead to unreliable predictions and analyses of transport-related issues, which might be based on subjective rather than objective data. Static transport models fail to accurately depict road conditions at the municipal level; in contrast, dynamic models capture nuanced traffic conditions more effectively. Previously, ITPs primarily focused on integrating various transport modes, rather than harmonising land use with transport planning. With the rapid rate of urbanisation, planning based on five-year scenarios has become too inflexible. Transport models assist in shortening planning time horizons, adapting more quickly to growth.

Advancements in technology and digitisation facilitate quicker decision-making. Integrating this data into a transport model enhances the decision-making process. The shift from traditional emphasis on roads and network design to a more digitised approach allows for the utilisation of near real-time data, enhancing the responsiveness of planning efforts.

Given financial constraints, there is a pressing need for more effective tools to manage resources intelligently. Instead of indiscriminately constructing roads, a more strategic approach to transport planning is necessary. Municipalities face significant planning pressures, and a robust, reliable model can support effective decision-making by prioritising critical issues. Additionally, due to funding shortages, there is a need for tools that can support funding applications to augment local revenue sources.

1.1 Aim of Paper

The primary aim of this paper is to critically examine the traditional focus of ITPs and advocate for a paradigm shift towards a more dynamic, real-time integration approach. This conventional methodology has sought to ensure the efficient planning, management, operation, and maintenance of transport systems and their infrastructure, with an emphasis on financial viability and the implementation of suitable contracting models to meet both present and future requirements.

Despite the successful integration of inputs from SDFs to align with visions at national, provincial, and municipal levels – primarily concentrating on service integration, land use, and policy – the need for a more dynamic tool has become apparent. This paper argues for a tool that not only integrates transport systems but also seamlessly combines land use planning with transport objectives with future capabilities of responding dynamically in real-time to facilitate thorough integration.

Moreover, this paper suggests that the core of such integration must pivot on its effectiveness in improving accessibility and mobility for all users across the spectrum of transport services, from rail to non-motorised transport (NMT). Through this lens, the paper sets out to explore innovative strategies for achieving a more integrated, responsive, and sustainable transport infrastructure.

1.2 Problem Statement

In the face of evolving urban landscapes and escalating demands for sustainable urban mobility, the GM's CITP confronts significant challenges in its quest to align with the municipality's vision of becoming a 'city for a sustainable future'. Despite the CITP's adherence to national, provincial, and local legislation, and its ambitious aim to integrate land use with transport planning through a dynamic TM, there remain critical gaps. These gaps are manifested in the plan's traditional approach towards demand-supply alignment, intermodal connectivity, and the integration of new transport modes, which, while efficient to some extent, fall short in addressing the real-time, dynamic needs of the urban transport ecosystem.

The existing frameworks and tools, despite their comprehensive nature, lack the agility to adapt to rapid changes in urban development, technological advancements, and the community's evolving needs for accessibility and mobility. This paper identifies the need for a more innovative, dynamic, and real-time approach to transport planning that not only anticipates future demands but also fosters a more integrated, equitable, and sustainable transport ecosystem in GM. The inadequacy of current planning tools to fully embrace the complexities of modern urban transport systems and the necessity for a paradigm shift towards more adaptive, responsive planning methodologies form the crux of the problem this paper aims to address, by presenting a Smart City Framework, as well as a Transport Model for input into GM’s CITP.

1.3 Scope of Paper

The scope of this paper includes:

- **Evaluation of Traditional Transport Planning Approaches**: An analysis of the current methodologies in transport planning within GM, focusing on how these approaches address demand and supply, intermodal connectivity, and the incorporation of new transport modes.
- **Dynamic Transport Planning Tools**: Examination of the need for and the development of more dynamic, real-time tools for transport planning. This includes a detailed look at the proposed Transport Model (TM) for innovative planning tools.
- **Integration of Land Use and Transport Planning**: Discussion on how the CITP for George integrates land use planning with transport objectives, with a special focus on the TM's role in achieving this integration.
- **Legislative and Policy Framework**: Overview of the national, provincial, and local government legislation, policy, and guidelines that govern the CITP.
- **Sustainability and Urban Mobility**: Exploration of how the CITP aims to enhance sustainability, accessibility, and mobility across all modes of transport.
- **Discussion**: Identification of the advantages, challenges, limitations and recommendations for our transport planning approach for future updates to CITPs in general.

2. SMART CITY FRAMEWORK

2.1 Purpose of the Comprehensive Integrated Transport Plan

The CITP stands as a statutory legal document with the pivotal role of enabling funding and implementation strategies for an integrated transport system within GM. It is aligned with the regulations and minimum requirements outlined by the NLTA, aiming to weave a strategic vision for cohesive and sustainable transport infrastructure over a designated timeframe. The CITP acts as a guiding framework that encapsulates all dimensions of transportation and mobility, targeting enhanced connectivity, efficiency, and sustainability throughout the urban fabric.

A core purpose of the CITP is to actualise, guide, and catalyse the transformation of George's urban mobility landscape, in alignment with the Integrated Development Plan (IDP) and the Municipal Spatial Development Framework (MSDF), while resonating with national, provincial, and local transport visions. It sets forth specific goals and objectives, leveraging sustainable mobility tools, system components, smart technology solutions, and the utilisation of shared and open resources to achieve desired outcomes.

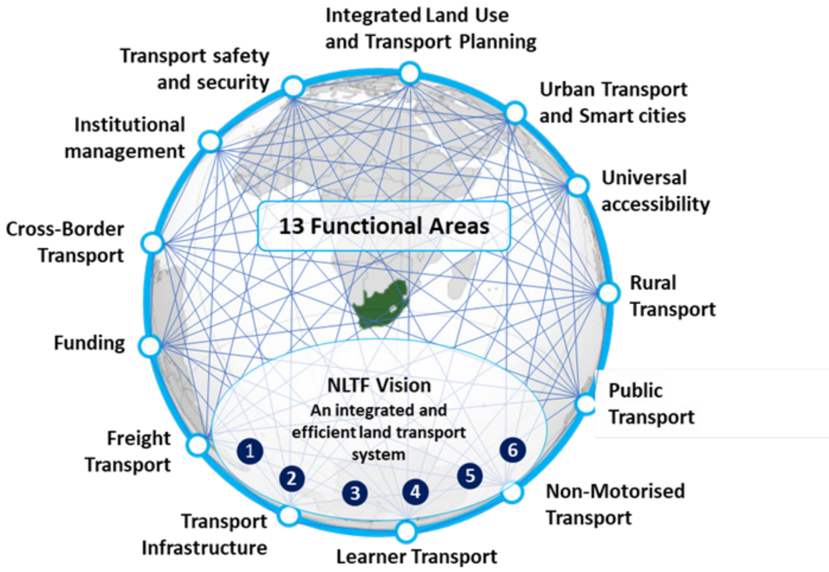
Significantly, the CITP for George champions a transformative change with a '*public transport first*' approach, prioritising access and accessibility to a well-coordinated, scheduled, safe, and sustainable public transport (PuT) system underpinning the George Transport Vision's in support of the IDP and MSDF. Through this, the CITP aims to clearly define each mode's contribution to a holistic and integrated transportation network, marking a critical step towards a more connected and sustainable urban environment.

Ultimately, the CITP's fundamental purpose is to establish a long-term vision that ensures the creation of the most effective and sustainable transport solutions for the benefit of GM and its entire populace.

2.2 Purpose of National Land Transport Strategic Framework (NLTSF)

The NLTA establishes a framework for national land transport strategy, guiding transport planning and delivery across various levels of government, including national, provincial, and municipal. Its aim is to align transport planning with national strategic priorities to achieve social, health, economic, and environmental benefits. The NLTA and the National Land Transport Strategic Framework (NLTSF) have significant implications for constitutional rights, including safety, equality, dignity, and freedom of movement. Therefore, when developing the George CITP, it was crucial to ensure it aligns with the NLTSF, GM's IDP, MSDF, and broader national and regional objectives.

It **sets the overarching goals, vision, and objectives** for each element of the transport system which should be reflected in the Provincial Land Transport Frameworks (PLTFs) and ITPs, and which must align with the NLTSF. Figure 1 below shows the NLTSF vision, and thirteen (13) functional areas covered in the CITP.



NLTF Vision: An integrated and efficient land transport system

1	Supporting a thriving economy	2	Promotes sustainable economic growth
3	Provides safe mobility options	4	Provides accessible mobility options
5	Socially includes all communities	6	Preserves the environment

Figure 1: National Land Transport Strategic Framework NLTSF Vision and thirteen (13) Functional Areas

The NLTSF aims to establish a legacy beyond 2028 based on the principle of sustainability, universal accessibility, and prioritising facets of the transport system for the development of an integrated efficient transport system.

2.3 George Transportation Strategy

In alignment with the IDP goals, the objectives, and goals of the current CITP have been enhanced and reinvigorated through a fresh George Transportation Strategy. This strategy demanded the development of a new Transport Vision for GM, stated as: "*To create an integrated, equitable, and sustainable transport ecosystem in GM that enhances mobility and accessibility, stimulates economic growth, and benefits the community*." This vision aligns with the Transport Mission Statement: "*The enhancement of mobility and* *accessibility of all people in the GM, within equitable justified, affordable and sustainable standards, by providing and managing an effective and efficient transport system comprising of transport infrastructure and integrated multi-modal PuT that will enable and serve as a catalyst for economic development and the upliftment of the community in the region*."

Figure 2 illustrates how the new City Transportation Strategy aligns with the strategic goals of GM's IDP.

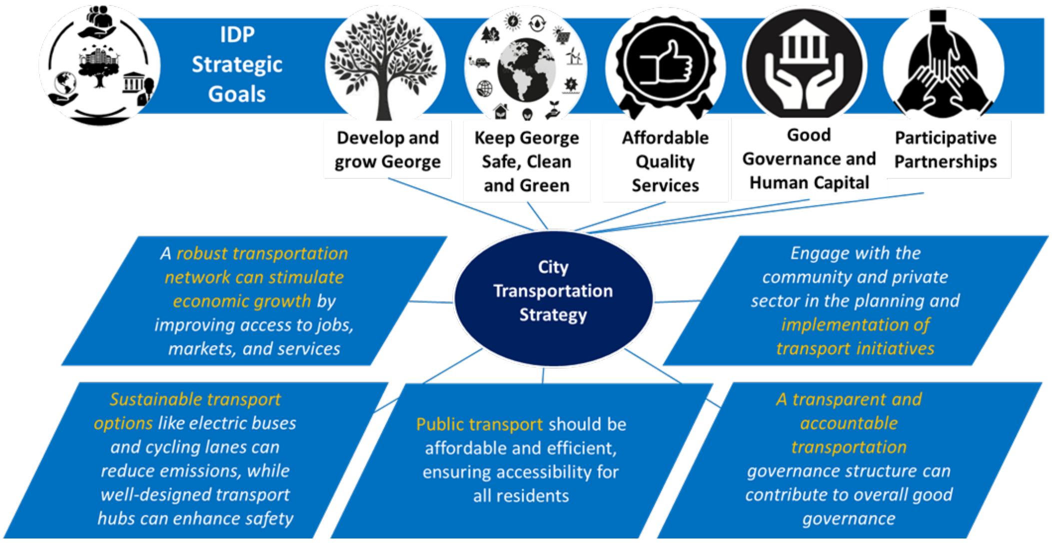


Figure 2: The City Transportation Strategy in context of the five IDP Strategic Goals

2.4 George a "Smart City" - Objectives 2024 and Beyond

Over the last decade, George's demographics and culture have evolved significantly, mirroring global and national trends, as well as those seen in other South African cities. The area has experienced a notable influx of people seeking better life opportunities, contributing to George becoming the fastest-growing municipality in the Western Cape other than Cape Town. According to the 2022 Census, its annual population growth rate of 4.1% since 2011 is the highest among South Africa's intermediate cities.

George has established itself as a manufacturing hub in sectors such as textiles, dairy, furniture, and timber, attracting businesses with its advanced services. The visible expansion of informal settlements underscores this growth. Its strategic location also makes *George a key distribution centre for goods and services, with the local economy supported by forestry, agriculture, light industry, and tourism.*

These developments are crucial for shaping a sustainable transport strategy that supports George's transformation into a Smart City. The implementation of a fully-fledged Smart City is inextricably linked to the adoption of advanced technology for data collection, raising expectations for a fast turnaround in the collection and analysis of traffic data. This tool is essential for decision-making across various sectors, which could include helping commuters make informed choices about trips before departure or while en route. Aligning with regional transport strategies and acknowledging the influence of neighbouring municipalities like Mossel Bay and Knysna is vital for George's role as a catalyst in the Garden Route District's development. Based on the above, Table 1 outlines additional focus areas and objectives to be integrated into the CITP, advancing George's transformation into a Smart City.

Table 1: CITP Focus Area and additional identified Goals

No.	Focus Area	Objective
1	**Digital Integration and Smart Technologies**	Implementing smart traffic management systems, real-time data analytics for public transport, and digital platforms for user engagement and feedback. This will enhance efficiency and user experience.
2	**Energy Efficiency and Renewable Energy Sources**	Focusing on energy-efficient transport systems and exploring renewable energy sources for public transport, like solar-powered buses or charging stations.
3	**Public-Private Partnerships (PPPs)**	Encouraging PPPs to leverage private sector expertise and investment in developing innovative transport solutions.
4	**Data-Driven Decision Making**	Utilising data analytics for transport planning and policymaking, ensuring decisions are based on accurate, real-time information.
5	**Resilience and Adaptability**	Building a transport system that is resilient to environmental changes and adaptable to future technological advancements.
6	**Accessibility and Connectivity**	Ensuring the transport system is accessible to all, including people with disabilities, and is well-connected to key areas like residential neighbourhoods, business districts, and recreational areas.
7	**Education and Awareness Campaigns**	Promoting sustainable transport options through public education and awareness campaigns, encouraging a shift in public attitudes and behaviours.
8	**Innovation in Non-Motorised Transport**	Investing in innovative solutions for non-motorised transport, such as advanced cycling lanes, pedestrian-friendly streets, and e-scooter sharing programs.
9	**Urban Planning Integration**	Integrating transport planning with urban development to create compact, walkable communities that reduce the need for long-distance travel.

3. PTV VISUM GEORGE TRANSPORT MODEL

GM's strategic approach to transport planning incorporates a state-of-the-art dynamic transport model, marking a paradigm shift from conventional static models. This dynamic model is designed to simulate real-world traffic conditions with high fidelity, accommodating the fluctuating nature of travel patterns, demand, and network conditions over time. Unlike static models, which provide a snapshot of travel demand and network performance at a specific time, dynamic models offer continuous simulation, capturing the variability in traffic flows throughout the day and under different scenarios.

The methodology underpinning George's dynamic transport model encompasses several key stages: data collection, model development, calibration, and validation. The model leverages a comprehensive dataset, including land use information, demographic data, vehicle counts, and public transport usage statistics. Advanced algorithms process this data to generate detailed simulations of travel demand, modal split, and route choices across the transport network. This process ensures the model's outputs closely mirror observed traffic conditions, enhancing the reliability of forecasts and recommendations.

3.1 Transport Modelling Objective and Approach

The project aimed to develop a precise mesoscopic travel demand model to accurately capture current and future travel patterns, including upcoming projects and road improvements. The modelling work involved two key components: a 60-minute strategic PTV Visum model for data gap analysis, and a detailed mesoscopic model in PTV Visum, incorporating junction coding, lane configurations, signal control, and a refined demand model. These models are essential for ensuring the study's accuracy and reliability.

During its development phase, the GM considered the Western Cape Government's Mobility Department’s (previously called Department of Transport and Public Work) CitiLab strategic model for Freight demand. Notably, the Provincial CityLab Cube model, aimed at strategic travel demand estimation and route assignment through static assignments, differs fundamentally from George's mesoscopic Visum model. The latter provides a more detailed analysis, recalculating land use at the level of individual land parcels and including NMT modes at the assignment level, a feature not accommodated in the provincial model.

Provincial models generally map broader movements between gateways, while GM's mesoscopic model delves into finer land use details and a wider range of transport modes. Enhanced by high-quality floating car data from Bittracker, this model offers a solid basis for strategic planning. The research method included analysing current and future travel demand, influenced by demographic, economic, and infrastructural changes. This informed the development and refinement of both strategic and mesoscopic models, culminating in rigorous testing to ensure their accuracy, reliability, and effectiveness in forecasting future travel patterns. This process is outlined in Figure 3.

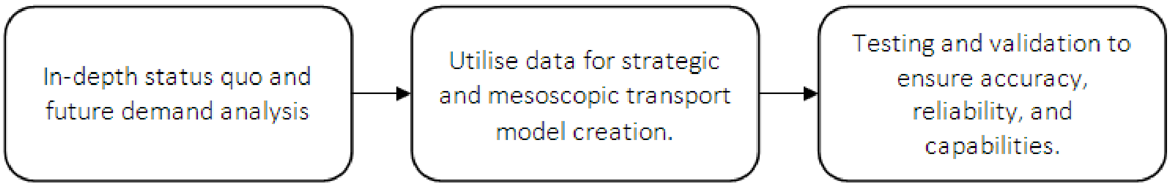


Figure 3: The high-level process towards creating the transport model

To guarantee meticulous development of the model, we adhered to these fundamental modelling principles (assumptions):

1. Maximise the use of existing data (data available to team and open-source data),
2. Focus on the critical two-hour morning and afternoon peak periods,
3. Utilising a tailored land use (development) input method based on available information,
4. Implementing headway-based assignments in absence of formal timetables for some PuT,
5. Applying a revised traditional four-step transportation demand modelling, and
6. Leveraging data and learning from previous models, thus enhancing the model accuracy.

3.2 Data Sources

Table 2 highlights the key data types/source used to develop the TM. Due to page limitations, a full enumeration of all specific data types used in the GM TM cannot be provided.

Table 2: List of Data Type /Source utilised to develop the Transport Model

No.	Data Type / Source	Description
1	**Land Use Data**	Information on current land use patterns, zoning maps, and future land development plans.
2	**Demographic Data**	Population density, household size, employment statistics, and demographic projections.
3	**Transport Network Data**	Maps and characteristics of the road network, including road types, lane configurations, and traffic control measures.
4	**Public Transport Data**	Routes, schedules, stops, and frequencies of public transport services, plus fare structures. Surveys at the four (4) official taxi ranks.
5	**Traffic Volume and Flow Data**	Historical and current traffic counts, peak hour volumes, and directional flows. Manual counts at 45 George CBD intersections in 2018. SANRAL's CTO counts at 7 key points along the N2 and other routes from 2017 to 2020. Gateway counts at 4 gateways in 2021. Manual counts at 33 intersections and 4 gateways in 2021 (Cars, Taxis, Buses, Heavy). Cordon counts at 11 points in 2022

Table 2: Cont'd

No.	Data Type / Source	Description
6	**Travel Survey Data**	Origin-destination surveys, travel diaries, and modal split information.
7	**Traffic Incident Reports**	Data on accidents, road closures, and construction activities.
8	**Environmental Data**	Information on topography, sensitive habitats, and pollution levels.
9	**Economic Data**	Data on local and regional economic indicators, employment centres, and forecasts.
10	**Non-Motorised Transport Data**	Paths, trails, and facilities for walking and cycling, including connectivity and safety features.
11	**Floating Car Data (FCD)/Big Data**	GPS traces from mobile devices or vehicles to capture real-time traffic conditions and travel speeds.
12	**Social Media and Crowd-Sourced Data**	Real-time traffic updates, congestion reports, and user-generated content on travel conditions.
13	**Points of Interest Data**	Locations and details of schools, clinics, hospitals, police stations, social services, pay-points, etc.

3.3 Demand Model

Transport demand models vary from basic sketch planning to sophisticated Agent-Based models that replicate individual traveller and vehicle behaviours, serving as critical tools for enhancing infrastructure, alleviating congestion, and fostering sustainable travel. GM’s CITP notably advances the use of dynamic assignment models over static ones, fundamentally altering the approach to traffic flow analysis and infrastructure planning. The critical distinction hinges on how these models simulate traffic flows and accommodate the variability of travel patterns over time.

Static models assign trips within a fixed timeframe, assuming each trip starts and ends within the designated period. This simplification, while useful for average daily traffic (ADT) estimations, falls short in capturing the nuanced demands of peak hours or periods, where traffic dynamics are more complex and fluid. Static models require adjustments, such as overall trip reduction or shortened trip lengths, to align with observed traffic volumes, leading to a potential misrepresentation of actual traffic behaviour.

Conversely, dynamic models offer a granular view of traffic flow, capturing the temporal spread of traffic volumes throughout the network. This method aligns more closely with real-world observations, where traffic volumes at a given point vary significantly within an hour. For instance, a dynamic model can accurately simulate the staggered departures from residential areas towards a central town, reflecting the gradual accumulation of traffic along key routes and at intersections. This level of detail extends to accounting for the rate at which roads become congested and how this congestion dissipates over time, providing a more accurate tool for traffic management and infrastructure development.

An illustrative example within the CITP documentation showcases the dynamic model's capability by simulating traffic flow from three villages to a central town during peak hours. The dynamic assignment captures the staggered vehicle entries into the main traffic stream, a nuance static models cannot replicate due to their inherent design limitations. This example underlines the dynamic model's superiority in reflecting actual traffic patterns, making it an invaluable tool for planning interventions that can effectively mitigate congestion and improve road network efficiency.

Traffic counts stand as a pivotal data source for demand model development, essential for estimating gateway demand and model calibration. The subsequent section details the traffic count data, which combines Provincial Road Asset Management System (RAMS) data and the South African National Road Agency's Comprehensive Traffic Observations (CTOs), including contributions from various suppliers for a comprehensive dataset. Sourced directly from Syntell, this data ensures the mesoscopic model's accuracy and reliability, offering a detailed view of GM's traffic patterns.

3.3.1 Count Balancing

Balancing traffic counts is essential for the accuracy of transport demand models. Typically, traffic counts from the same day and period at adjacent intersections do not exactly match, leading to disparities between traffic exiting one intersection and entering another. The modelling team undertook a comprehensive analysis, comparing the sums of in-turns and out-turns across the model to minimize these differences before making any adjustments. This process, crucial for ensuring model balance, involved applying various traffic growth rates iteratively until the discrepancies were minimised. Importantly, this iterative application of growth rates is aimed at model balancing rather than predicting traffic growth.

Key steps in model calibration and validation included:

- Updating all counts to reflect 2022 levels by applying a 3% annual growth.
- Utilising PTV Visum's procedure to balance counts with minimal adjustments, ensuring the consistency of turn volumes.

The analysis revealed:

- A high level of accuracy in representing traffic dynamics, with over 98% of the variance in car and bus turn counts explained by the model. However, variance explanation for heavy vehicles (HVs) dropped to 69%, primarily due to their lower volumes and seasonal variations.
- For link counts, the model explained over 81% of the variance for cars and buses and 78% for HVs. The variance in taxi counts was not fully captured, reflecting the impact of various factors like route changes and passenger volume fluctuations on taxi movement patterns.

Demand models for static and dynamic assignments show significant differences. Static models, which do not account for the propagation of flows through a network, are best suited for Average Daily Traffic (ADT) analyses. They often require adjustments such as overall trip reduction factors to reflect observed volumes accurately.

3.3.2 Key Principles/Assumptions

Table 3 presents a summary of the fundamental principles and assumptions underpinning the dynamic demand model.

Table 3: George Demand model key principles and assumptions

No.	Design Feature	Design
1	Software	PTV Visum 2023
2	Structure	Classical Four-Step model: Trip generation > Trip Distribution > Modal choice > Trip Assignment (including calibration for Other to Other (OTO) trips)
3	Base year (calibrated)	2022
4	Horizon years[1]	2027 and 2042
5	Vehicle classes	Cars (light vehicles) Taxis (minibus taxis) Busses (including Go George) Heavy vehicles (Trucks
6	Analysis period[2]	AM peak period: 06h00 to 08h00 Network preloading period: 06h00 to 07h00 Calibrated peak hour: 07h00 to 08h00 The PM peak is a transposed model (due to the lack of an attraction side survey) between 15h00 to 17h00
7	Demand strata	Home-based education trips for low-and high-income person groups (separately) Home-based work trips for low-and high-income person groups (separately) Other to other trips for low-and high-income person groups (separately for low- and high-income earners)
8	Demand assignment	Dynamic demand in 15-minute increments
9	Peak hour demand calibration data sources	- Demand in order of importance - StatsSA 2020 National household travel survey) - Floating Car Data (TomTom and other sources) - Numberplate-based OD matrix - Traffic counts - George integrated zoning scheme land used information (on a surveyor general land parcel level) and valuation roll information - Google floating car data travel times - Many others
10	Trip assignment procedure	AM peak period: 06h00 to 08h00 Network preloading period: 06h00 to 07h00 Calibrated peak hour: 07h00 to 08h00 The PM peak is a transposed model (due to the lack of an attraction side survey) between 15h00 to 17h00

Notes:
(1) Planning models traditionally forecast 10- and 20-year horizons for long-term road network development. Our model employs a more nuanced approach with 5- and 20-year demand horizons, and network projections for 5-10 years, 20 years, and beyond, allowing for the evaluation of individual road network projects within various scenarios. This dual-horizon strategy complies with industry standards, offering a pragmatic balance for transport system management and modelling. It acknowledges the speculative nature of projections beyond two decades, aiming to prevent unnecessary public spending by incorporating the option for users to extend the land use outlook past 20 years, thus enhancing the model's flexibility for future scenario exploration.

(2) The model is finely tuned for a 2-hour peak period analysis, incorporating a dynamic simulation assignment with a preliminary hour of traffic build-up to ensure accurate volume and queue representation throughout the peak assessment. This extended simulation is vital for capturing longer rural trips within the peak period. The model's results differentiate between specific peak hours and the overall peak period, improving result interpretation and offering insights into travel patterns during peak times.

3.4 Mode Choice Models (Supply Model)

The mesoscopic transport supply model, developed in PTV Visum for the CITP, encompasses the private, public, and NMT network infrastructures. The Transport Modelling Strategy (TMS) details the model's development, validation, functionality, capabilities, and scenario management setup. However, it does not cover the evaluation of specific scenarios like those outlined in the George Roads Master Plan, which are detailed in the CITP report. In constructing the transport model, it was necessary to represent the private and PuT networks, NMT infrastructure, and various traffic analysis zones (TAZs).

The approach for integrating the Private Transport Network, PuT Network, NMT Network, and TAZs into the Supply Model involved meticulous planning and analysis. For the Private Network, detailed road configurations and traffic dynamics were mapped using comprehensive and open data sources, OpenStreetMap data, lane configurations, and junction geometry, supplemented by Google and HERE data for traffic analysis. The PuT Network was developed by outlining routes, schedules, and stops to capture the full extent of public transit services. NMT networks were carefully included to represent sustainable travel options like walking and cycling accurately and was adjusted to exclude unrealistic freeway connections. The TAZs were defined to segment the study area, allowing for detail modelling of travel demand and behaviours across different regions, ensuring a holistic and integrated approach to transport modelling, crucial for assigning travel demand and understanding travel behaviour.

3.4.1 Primary Mode Choice Model

The primary mode choice model in George's CITP transport strategy estimates the division between motorised (PuT and PrT) and NMT trips (NMT) across various traffic analysis zones. Utilising exponential functions based on travel distance, derived and calibrated from National Household Travel Survey (NHTS) observations, the model underscores a pivotal relationship: as travel distance increases, the likelihood of opting for NMT decreases, making motorized transport modes more prevalent.

Key functions of the primary mode choice model reflect this dynamic, assigning higher utility values to motorized transport as distance increases. These functions are meticulously calibrated to mirror observed travel behaviours, ensuring that the model accurately captures the essence of travel mode preferences among different income groups and for varied trip purposes. This calibration is vital for understanding the modal split and for planning interventions that encourage sustainable transport options.

3.4.2 Secondary Mode Choice Model

The secondary mode choice model further disaggregates motorized trips between PrT and PuT. Despite challenges in estimating statistically significant functions – due to limited NHTS data on PrT and PuT preferences – a generalized approach was adopted, combining all demand strata. This model's calibration involved adjusting mode-specific constants until observed mode splits were accurately reflected in the assignment results.

Using a multinomial logit function, utilities for PrT and PuT were defined, incorporating variables such as distance, fuel cost, travel time, and public transport-specific factors like fare, number of transfers, and waiting times. These utilities, scaled to account for cost attributes, facilitate a sophisticated analysis of mode choice probabilities, enriching the CITP's strategic planning with nuanced insights into mode preferences across different segments of the population.

These mode choice models, both primary and secondary, are instrumental in George's CITP, offering a granular view of transportation preferences. By accurately representing the interplay between trip distance, mode utility, and traveller choices, these models enable targeted, data-driven decisions aimed at enhancing the municipality's transport system's accessibility, efficiency, and sustainability.

3.5 Quality Assessment Framework

The framework enhances the model's accuracy in reflecting real-world dynamics, bolstering confidence in its decision-making utility. It distinguishes between calibration, the adjustment of inputs to mirror observed behaviours accurately, and validation, the demonstration of the model's ability to replicate these behaviours. This ensures a reliable and validated model output.

The model's calibration level varies with its purpose, guided by several key documents on quality assessment frameworks and transport modelling. These include works by Schlaich, Heidl, and Möhl, the National Cooperative Highway Research Program reports, the US Federal Highway Administration's manual on model validation, the UK Department for Transport's Transport Analysis Guidelines, and the "reasonable man test" (if the test will likely result in no appreciable impact in the model, then test will not be conducted). These resources offer comprehensive recommendations for transport modelling, covering land use verification, trip generation, distribution, mode choice validation, route assignment, path choice comparison, and comparisons of modelled versus observed volumes and travel times, among other aspects.

3.5.1 Modelled Versus Observed Travel Times

The transport modelling team created a tool with Google's API to gather travel time data, importing zone and gateway information for peak and off-peak analysis. By adjusting transport diagram parameters per road class, they ensured the model's accuracy in reflecting travel times across distances and congestion levels. The complexity arises from these adjustments' impact on path choice, impedance models, and consequently, congestion levels. Regression analysis on a large set of Origin-Destination pairs showed the model explains 93% of travel time variances, slightly overestimating by 1%, indicating precision within an acceptable range.

3.5.2 Modelled Versus Observed Volumes

The transport modelling team conducted a regression analysis comparing modelled and observed traffic volumes across all vehicle classes, using the results to fine-tune the model's trip generation, distribution, and mode choice parameters. Key to this analysis is the slope of the regression line between modelled and observed volumes; ideally, it should be close to 1. A slope above 1 suggests the model overestimates traffic flows, while below 1 indicates underestimation of demand.

4. GEORGE CITP

George aims to evolve into a "Smart City" to address the needs of its expanding population with sustainability as its core vision. The development of a “Smart City’ CITP marks a crucial step towards this transformation, emphasising innovative and smart management of the city's growth. The CITP integrates various functional areas as outlined by the NLTA, adding a unique chapter on "*Smart City – Access, Accessibility, and Mobility*" to serve as the plan's central theme, ensuring the transport network enhances everyone's access to opportunities, amenities, and services. This approach is further elaborated within the chapter, underlining the importance of an ITP in providing comprehensive accessibility and mobility. This framework acts as a roadmap for evolving George into a Smart City through cohesive transport planning, execution, and management. The goals outlined below and depicted in Figure 4 will steer the objectives of the CITP, ensuring a strategic approach towards integrated and smart urban mobility.

Figure 4: CITP Transformational Goals and Implementation Building Blocks

The strategy for achieving these goals involves three key components outlined in Table 4, serving as the foundation for their implementation. This structure is designed to facilitate the transformation towards a Smart City by integrating, executing, and managing CITPs effectively.

Table 4: Three Building Blocks for implementing the overall strategy

No.	Building Block	Objective Action
1	**Strategic Planning**	Develop a comprehensive plan that integrates these components into the transport system.
2	**Stakeholder Collaboration**	Work closely with government bodies, private sector, and community groups.
3	**Phased Implementation**	Roll out the plan in phases, starting with quick wins and gradually implementing more complex components.

The building blocks form a crucial foundation for implementing transformative changes in transport planning, execution, and management within the CITP, aligning with NLTSF guidelines. They identify essential elements to be integrated throughout the plan, ensuring cohesion in achieving George's Transport Vision. Listed in Table 5 for reference, these components underpin the "*Access, Accessibility, and Mobility*" Framework, highlighting their pivotal role in George's Smart City Transformation Process.

Table 5: Core Components for a "Smart City" CITP

No.	Focus Area	Objective
1	Integrated Transport Network	Seamless integration of different modes of transport (buses, trains, non-motorised transport) for smooth transit and connectivity. Development of multimodal transport hubs.
2	Smart Traffic Management	Implementation of intelligent traffic systems for real-time traffic monitoring and management. Use of AI and IoT for adaptive traffic signal control, congestion management, and incident detection.
3	Digital Platforms and Data Analytics	Development of digital platforms for journey planning, ticketing, and real-time passenger information. Utilisation of big data analytics for transport planning and operational improvements.
4	Sustainable and Green Transport Solutions	Promotion of electric vehicles (EVs) and the necessary charging infrastructure. Development of cycling lanes and pedestrian-friendly pathways.
5	Public Engagement and Participation	Platforms for community feedback and participation in transport planning. Regular public consultations and information dissemination.
6	Safety and Security	Enhanced safety measures in public transport and infrastructure. Implementation of security systems like surveillance cameras and emergency response protocols
7	Policy and Governance	Establishment of clear policies and governance structures for transport management. Integration of transport planning with broader urban development policies.
8	Economic and Financial Models	Adoption of emerging technologies (e.g., 5G, AI, IoT) in transport systems. Encouragement of innovation in transport services and infrastructure.
9	Technology and Innovation	Building a transport system resilient to environmental changes and adaptable to future needs. Incorporation of climate change mitigation and adaptation strategies.
10	Resilience and Adaptability	Building a transport system resilient to environmental changes and adaptable to future needs. Incorporation of climate change mitigation and adaptation strategies.
11	Accessibility and Inclusivity	Ensuring transport services are accessible to all, including those with disabilities. Designing transport systems that cater to the needs of diverse community groups.
12	Education and Awareness	Campaigns to promote sustainable transport habits. Educational programs on the benefits and usage of smart transport options.

4.1 Purpose of the Access, Accessibility and Mobility Framework

Within the context of George's CITP, the "*Access, Accessibility, and Mobility Framework*" is positioned as its core. It aims to craft a transport system rooted in access, efficiency, and sustainability, addressing the community's diverse needs, and promoting a quality life through eco-friendly mobility. This approach ensures the transport network not only serves current requirements but is flexible for future adaptations, underpinning George's long-term vitality. The framework guides the integration of land and transport planning, fostering departmental synergy and setting standards to unify the CITP's various components into a cohesive vision for George. Adding to George's CITP framework, it's essential that the "Access to, Accessibility, and Mobility Framework" not only serve as the plan's backbone but also embrace a user and data-centric approach. This means prioritising the experiences and needs of all residents in the development of transport solutions, while leveraging data to inform and optimise planning, execution, and management. By focusing on user-centricity and data-driven decision-making, the framework aims to ensure the transport system is not only equitable and sustainable but also intelligently responsive to the evolving dynamics of the municipality, guiding George towards a more integrated, efficient, and forward-thinking future.

4.2 Concepts of Access, Accessibility and Mobility

The framework commenced by describing what Accessibility and Mobility contextually means as summarised below.

Accessibility is about how easily people can reach needed services and facilities, considering the physical network and the availability and affordability of transport options. It's key in urban areas for accessing healthcare, education, jobs, and leisure.

Mobility focuses on the ease of moving within a transport system, looking at travel efficiency, speed, and convenience. The CITP framework clarifies these concepts for practical use in planning, aiming for real integration and serving as groundwork for future development, enhancing both accessibility and mobility in George.

The impact of integrating these smart city building blocks on "*Access, Accessibility, and Mobility*" within GM's CITP is crucial. These aspects are fundamental in ensuring that the transport network serves all users effectively, fostering an inclusive and efficient urban environment. An analysis of the impact on different modes of transport and users are shown in Table 6.

Table 6: Impact on Access, Accessibility, and Mobility and associated Beneficiaries

No.	Focus Area	Impact	Beneficiaries
1	Integrated Transport Network	Enhances the connectivity between different modes of transport, reducing transfer times and improving overall network efficiency.	All users, especially those reliant on multiple modes of transport for their daily commute.
2	Smart Traffic Management	Reduces congestion and improves traffic flow, leading to quicker travel times and less frustration for road users.	Motorists, bus users, minibus taxi user's emergency services, and commercial transport.
3	Digital Platforms and Data Analytics	Development of digital platforms for journey planning, ticketing, and real-time passenger information. Utilisation of big data analytics for transport planning and operational improvements.	Provides real-time information to users, enabling better travel planning and decision-making.
4	Sustainable and Green Transport Solutions	Promotes environmentally friendly modes of transport, contributing to a reduction in emissions and improved air quality.	Environmentally conscious users, future generations, and the community at large.
5	Public Engagement and Participation	Ensures that the transport system evolves in line with community needs and preferences.	All community members, particularly those who actively participate in feedback and consultation processes.
6	Safety and Security	Increases user confidence in the transport system, encouraging more people to use public transport.	All transport users, especially vulnerable groups like children, the elderly, and people with disabilities.
7	Policy and Governance	Provides a structured approach to transport management, ensuring long-term sustainability and efficiency.	Policy makers, transport operators, and users who benefit from a well-regulated transport system.

Table 6: Cont'd

	No.	Focus Area	Impact	Beneficiaries
8		Economic and Financial Models	Ensures the financial sustainability of the transport system, allowing for continuous improvement and expansion.	Taxpayers, transport users, and the local economy.
9		Technology and Innovation	Keeps the transport system at the forefront of technological advancements, enhancing user experience and operational efficiency.	Tech-savvy users, transport operators, and the municipality.
10		Resilience and Adaptability	Prepares the transport system to adapt to future challenges, including environmental changes and population growth.	Future users, city planners, and the environment.
11		Accessibility and Inclusivity	Ensures that the transport system is usable by all, regardless of physical ability or socio-economic status.	People with disabilities, low-income groups, and other marginalised communities.
12		Education and Awareness	Cultivates a culture of sustainable transport use and awareness of smart transport options.	New and existing users of the transport system, particularly young and impressionable community members.

City planning transcends mere roads and buildings to envision a comprehensive ecosystem where living, working, and recreation converge efficiently and sustainably. Traffic, Mobility, and Accessibility focus together frame a vision for vibrant, inclusive, and progressive urban environments. Figure 5 illustrates how Accessibility, the Transport System, and Mobility – along with their sub-elements – integrate within George's transport network, guiding the creation of a CITP. This integration lays the groundwork for developing essential policies, strategies, frameworks, and plans (e.g., Roads Master Plan, NMT Plan, Freight Plan) across the transport system's various functional areas.

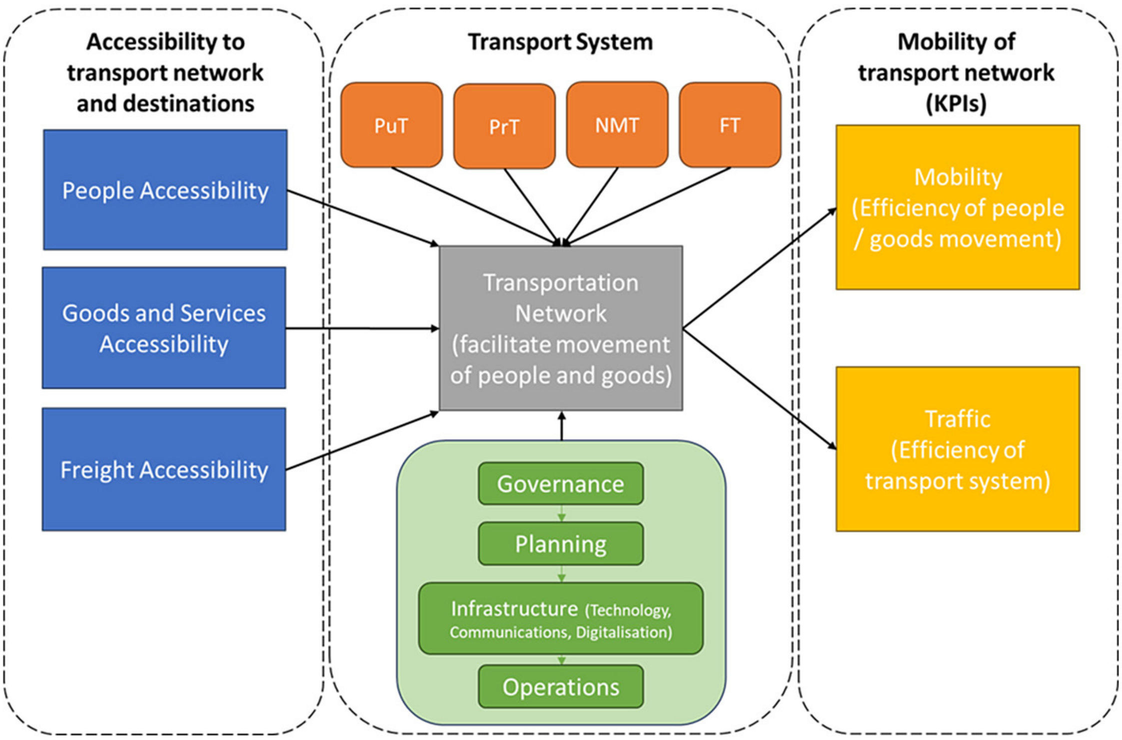


Figure 5: Components of the Integrated Transport for George

4.3 How the MSDF was Utilised as Input to the Model and CITP

The George Municipality Spatial Development Framework (GMSDF) must be regarded as a guide for future development and should not be considered to be a set of predetermined development proposals. In addition, the GMSDF does not prescribe what the exact nature and form of future development should be but rather guides potential development proposals. The GMSDF intends to guide where investment will be prioritised and involving the private sector in such decisions is considered to be important for establishing partnerships in development. Additionally, the land use data, the data of the MSDF, recent traffic impact assessments of new developments and the knowledge of the project team's town planner concerning time horizons, market forces at work, and land use projects and the uptake of rights were incorporated into the model. These types of data may be updated continually as new data or updates become available, thereby making this model relevant even though situations and circumstances are ever changing.

4.4 Applications of George's Transport Model for Input to the CITP

The application of the dynamic transport model has far-reaching implications for George's CITP. By providing a nuanced understanding of traffic operations and travel behaviour, the model supports informed decision-making on a range of issues, from infrastructure investment to policy development. It enables the identification of critical network bottlenecks, informs the design of public transport services, and guides the implementation of sustainable mobility solutions. Moreover, the model's flexibility allows for the evaluation of future land use changes, demographic shifts, and technological innovations, ensuring George's transport system remains resilient and adaptive. One of the examples of using this model was to aid in updating the George Roads Master Plan by evaluating the various scenarios and potential new road links, determining the effect that the various scenarios would have on the entire road network, and with this iterative approach ensuring that the future congestion problems are reduced at the critical bottlenecks for the base year, 5-year and 20-year modelled horizons. Some of the model outputs that were utilised in this process are shown in Figures 6 and 7.

5. DISCUSSION

5.1 Advantages of the New Model

Adopting a dynamic assignment model enables GM to develop a transport plan that is responsive to the actual needs of its residents. It allows for a more sophisticated analysis of potential infrastructure and policy interventions, ensuring that the proposed solutions are both effective and sustainable. By accurately modelling peak period traffic flows, the CITP can identify critical bottlenecks and prioritize investments that will have the most significant impact on improving mobility and accessibility within the municipality.

This shift towards dynamic modelling in George's CITP represents a significant advancement in transport planning methodologies, offering a template for other municipalities aiming to enhance their transport systems' efficiency and resilience. By embracing the complexity of traffic dynamics, GM sets a new standard for informed, data-driven decision-making in urban transport planning. Another advantage is the ability of the model to create high-quality visual outputs that provides decision makers with intuitive tools for transportation planning, as mentioned in Section 4.4.

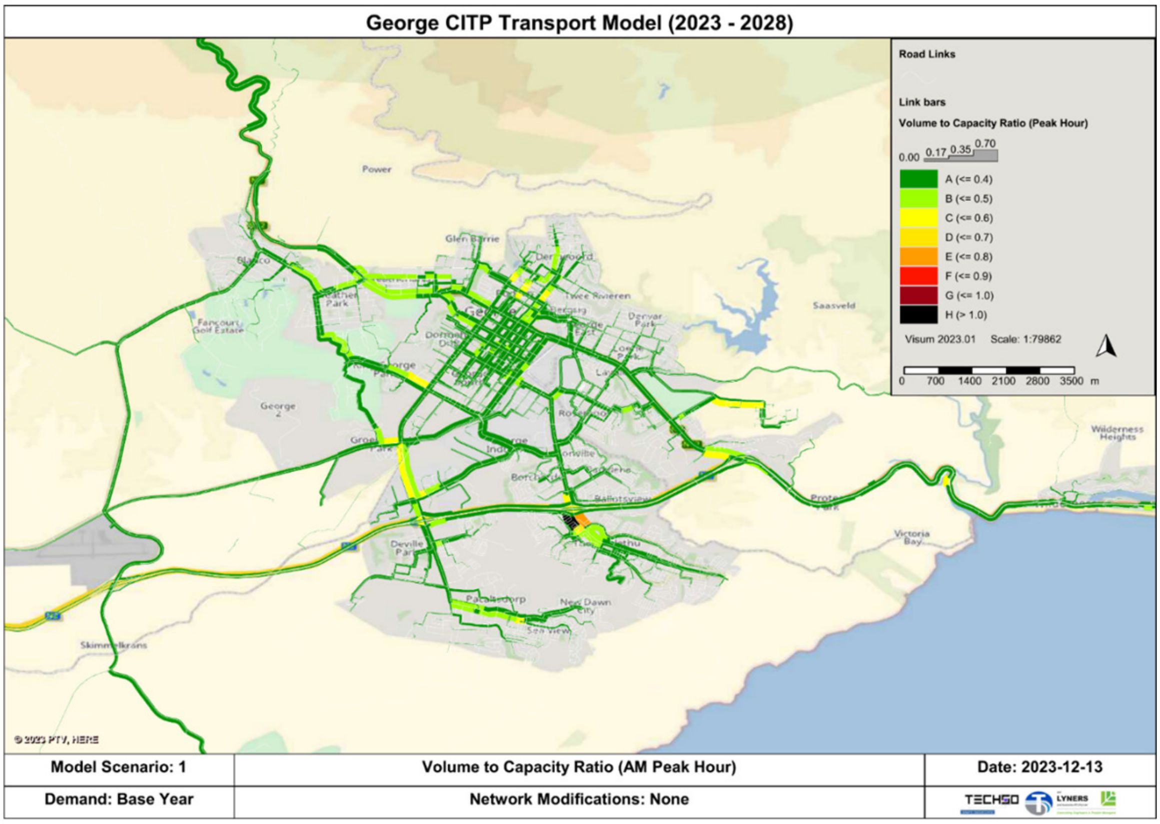


Figure 6: The modelled Volume to Capacity Ratio of vehicle on the road for the AM Peak Hour

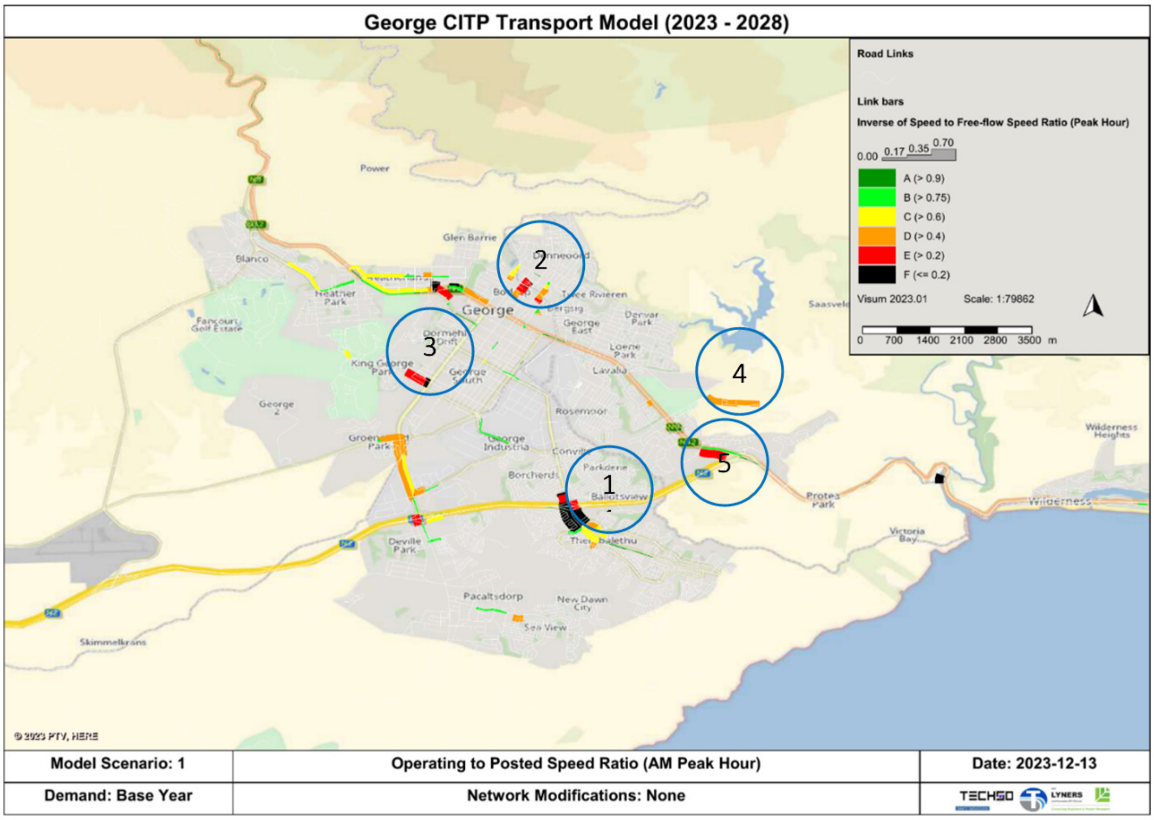


Figure 7: The modelled Operating to Posted Speed Ratio for the AM Peak Hour, with the top congestion problems highlighted

5.2 Utilisation by Other Municipalities

The scalability and flexibility inherent in dynamic transport models underscore their potential applicability across diverse urban settings. By adopting a similar data-driven approach, other municipalities can benefit from enhanced urban planning and mobility management capabilities. These types of models can assist in land use applications analyses for determining whether they should be approved or not, and the potential impact. Furthermore, these types of models can be used for determining traffic impact assessments by using the model as a starting point. Various network and road infrastructure improvement options may be explored through the scenario management capabilities of the model and the effect they could have. Additionally, PuT planning may be done by creating scenarios of different routes and utilisation rates of PuT, and even modal shift implications.

Other Geographical Information System-based databases and layers (for example the power grid, waste and landfill grid, and municipal services like sewage) can be integrated with the model, allowing for novel applications and use-cases. Lastly, the model can be used for emergency and disaster planning where different scenarios can be tested and evaluated, from a safety and evacuation time perspective. If these types of models are adopter, they could become a key building block as a municipal planning tool which can be utilised to develop future MSDF’s, IDP’s input to budget process, etc.

5.3 Challenges

Despite the clear advantages, the adoption of dynamic modelling poses several challenges, including the need for ongoing data collection, software proficiency, and model maintenance. These factors necessitate significant resource investment for local municipalities and underscore the importance of building internal capacity at an ongoing basis to manage and utilise these complex modelling tools effectively. Policies and guidelines with regard to data standards and formats are lacking, and therefore can pose a challenge for easy integration and ensuring clean and usable data. The lack of a digitised transport system may lead to more effort being put in than necessary to acquire and update models like these, for example PuT data which are not always readily available and require extensive counts to be done. Access to data is also often a challenge, and relying on more open data sources could be the answer. Ensuring regular updates to demand and supply model including land use can become cumbersome, but if done regularly and systematically could be of great benefit to a municipality.

5.4 Limitations and Recommendations

We knew that this model was set-up to launch a new paradigm of addressing the development of CITP’s as input into a new smart city planning era. As the advantages and benefits of the tool became evident, we also identified some limitations and recommendations that could enhance the tool and user experience. While the model sets a new benchmark, there is scope for improvement. Currently, the lack of real-time data feeds and user-friendly interfaces restricts its potential utility. Future iterations should transition from manual to automated data updates, noting that real-time data incorporation is different to the dynamic modelling simulation approach. Additionally, future versions should aim to automate the identification of problems and the generation of solutions, thereby enhancing the model's interactivity and incorporating live data feeds to accurately reflect real-time urban dynamics.

Furthermore, integrating additional municipal service layers such as the electrical grid, water, sewer, waste management, and evacuation routes would significantly enhance the tool's utility in incident and disaster planning. This integration would move the model one step closer to facilitating integrated smart city planning.

6. CONCLUSIONS

In conclusion, GM's adoption of a dynamic transport model represents a forward-looking approach to urban transport planning. By moving beyond the limitations of static models, George is positioned to tackle the complex challenges of urban mobility, aligning with the NLTSF vision for a smart, accessible, and sustainable transport system. This strategy not only enhances the municipality's capacity for data-driven decision-making but also sets a benchmark for other cities aiming to integrate advanced transport modelling techniques into their planning processes.

Here are some key applications that are made possible with this paper’s fresh perspective.

- Having an underpinning Transport Model (TM) enhances integrated planning by fostering collaboration among various inter-departmental teams, thereby improving teamwork.
- The TM serves as a dynamic tool that enables different departments and stakeholders to use it for their specific planning needs, thereby facilitating more informed decision-making. For example, Civil and Traffic Engineering departments can simulate various scenarios, including Traffic Impact Assessments and development proposals, to determine the best engineering designs, network development strategies, and cost models. Similarly, Land Use planners can explore different spatial development proposals to ascertain optimal land use allocations and distributions, which will inform future zoning schemes.
- The TM allows for the integration of models from other governmental spheres, such as provincial or district levels, enhancing the richness of the TM with specific tools like the provincial freight model.
- The TM offers an opportunity to evaluate the effectiveness and impacts of integrated plans, considering aspects such as transport efficiency, user satisfaction, and environmental consequences.
- Furthermore, the TM provides a comprehensive overview of all Intelligent Transport System (ITS) components associated with the transport network. This integration supports enhanced planning and operations for safety, security, and law enforcement.

6.1 Summary of Contributions

The Smart City Framework presented in the GM CITP acts as a lens through which the transportation planning was done, ensuring that some of the usually overlooked vision, goals, and objectives from the NLTSF are met, with a specific focus on accessibility and mobility. Furthermore, the successful implementation of the dynamic transport model contributes significantly to George's transport planning and smart city initiatives. By providing a detailed and adaptive framework for managing urban mobility, the model enhances the municipality's ability to address both current and future transport needs, fostering a more sustainable and efficient urban environment.

6.2 Potential for Replication in other Municipalities

The model's potential for replication in other municipal contexts is a testament to its adaptability and effectiveness. Municipalities are encouraged to explore and consider dynamic modelling as a tool for improving urban transport planning, suggesting a collaborative approach to share insights and methodologies, thus fostering collective advancements in the field.

6.3 Future Updates and Improvements

Future model updates and improvements should include enhancements such as real-time data analytics, improved graphical user interfaces, and features that automate and streamline the planning process. Additionally, ongoing research into emerging transport technologies and their integration into the CITP will be essential for maintaining George's leadership in sustainable urban mobility.

6.4 Future Work

Future research should focus on the integration of dynamic transport models with other smart city components, evaluating their collective impact on urban sustainability, efficiency, and inclusivity. Studies investigating the long-term effects of such models on urban development, traffic management, and environmental sustainability will be crucial for informing future iterations of the CITP and similar initiatives worldwide. This structured approach to discussing and concluding the research findings and recommendations provides a comprehensive overview of the dynamic transport model's role within GM's CITP, highlighting its contributions to the field and outlining a path for future exploration and application.

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