THE NEED FOR A PROVINCIAL LAND USE AND TRAVEL FORECASTING MODEL

WG ALLEN, Jr., PE[1] and D MARTHEZE[2]

[1]Bentley Systems, Inc., PO Box 390, Windsor, SC 29856 USA
Tel: +1 803 270-7114; Email: Bill.Allen@bentley.com
[2]Western Cape Department of Transport and Public Works, 9 Dorp St., Cape Town 8000; Tel: 083 641-5194; Email: Dru.Martheze@westerncape.gov.za

ABSTRACT

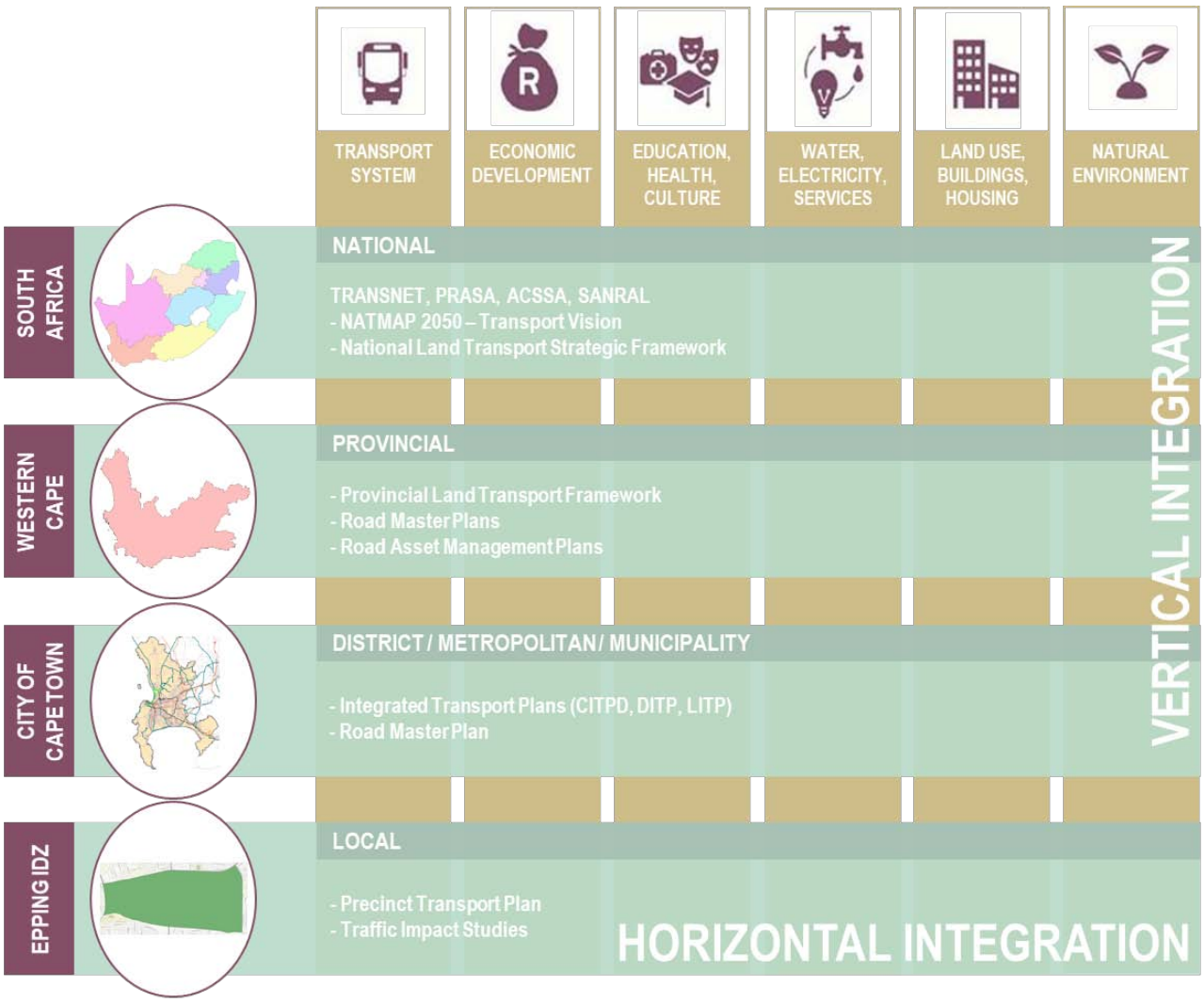
Western Cape has 6,2 million people and is one of the most diverse, progressive, and economically strong regions in the country. Although the City of Cape Town has two-thirds of the provincial population and employment, it is only 2% of the province's land area. Cape Town's status as a major port in southern Africa emphasises the importance of efficient goods movement for the region's economic health. Western Cape Government's role has increased in recent years, as part of the need for improved transport and land-use planning to stimulate and accommodate economic growth. Thus, the provincial Department of Transport and Public Works (DTPW) is expanding its role in infrastructure management and development and taking a more forward-looking approach to collaborative regional planning. In much of the world, transport decisions have historically been made based on political considerations, with little focus on the impact on system performance. But this is changing as governments learn how estimates of land-use and transport demand provide insights for sustainable design. Models of transport and land use provide information for decision-makers to achieve comprehensive and coordinated planning across sectors, on a continuous basis. DTPW decided to develop such a tool to support performance-based planning. This data will drive the development of policies, procedures, and methods that guide the province's future land-use and transport systems. This requires an integrated model system to forecast personal travel, goods movement, and land development together.

1 BACKGROUND

1.1 Historical Context

Western Cape is one of the largest regions in South Africa. The province includes Cape Town and 24 other municipalities that are home to three major universities and some of the most productive areas in the world for growing grapes for winemaking. The region has 6,2 million people and is one of the most diverse, progressive, and economically strong regions in the country.

Prior to 1994, the government of South Africa consisted of a top-down hierarchical structure, consisting of national and provincial authorities, divisional councils as the authorities to manage rural areas, and town councils acting as the local authority for urban areas. The new constitution of South Africa changed this structure from hierarchical to three spheres of government: *national*, *provincial* and *municipal*. Each are distinctive, interdependent, and interrelated. All spheres of government must observe and adhere to the principles in the Constitution and must conduct their activities under their jurisdiction (see Figure 1).



Source: WCG DTPW

Figure 1: Transport Infrastructure in RSA

The National Department of Transport, NDOT, is responsible for the national proclaimed roads, rail, ports, airports, etc. NDOT developed the transport master plan (NATMAP) for South Africa, a comprehensive, multimodal, integrated, and dynamic programme, and provides a sustainable framework not only for implementing transport but also for providing infrastructure and service. Most importantly, the plan seeks to develop continuously and improve the efficiency and effectiveness of a multimodal transport system – a transport system that is well regulated and well managed within a multisectoral sphere of effective coordination and cooperation between various government spheres, relevant private sectors, civil society partners and stakeholders up to 2050.

The South African roadway system now involves three road authorities: national, provincial, and municipal. The national presence is represented by the South African National Roads Agency Ltd (SANRAL), which is responsible for the management, maintenance and development of the national road network. SANRAL is part of NDOT.

At the provincial level, the Western Cape Government Department of Transport and Public Works (WCG DTPW) is the road authority responsible for the administration, planning, management, maintenance, and development of the provincial road network and traffic enforcement within Western Cape. Although the City of Cape Town accounts for almost two-thirds of the provincial population and employment, it is only 2% of the province's land area. In the past, the provincial governments have not played a major role in transport

operations or policy. However, that is starting to change as the different levels of government realise the need for increased cooperation and coordination, especially in the area of transportation. DTPW has seen its role and influence increase in recent years, as agencies become aware of the need for improved transport planning to both stimulate and accommodate economic growth. For example, the province provides bus subsidies and regulates operating licences for buses and taxis.

The municipalities are the authorities for roads in their municipal areas (consisting of towns and rural areas) and are responsible for the integrated transport planning for their municipal areas. The city's active agency, Transport of Cape Town (TCT), provides the MyCiti bus service and also coordinates with the national passenger rail agency (PRASA) and private sector transport providers that are responsible for managing bus service, including a sizable presence of "informal transit" – the minibus-taxis.

But there is concern within DTPW over the transport linkages between Cape Town and the surrounding towns, the ability of the current transport infrastructure to accommodate growth, and the economic necessity for roads that can adequately handle goods movement. In addition, the long-lasting effects of apartheid still have an impact on current and future development patterns. With these considerations in mind, DTPW has decided to expand its role in infrastructure management and development and to take a more forward-looking approach to transport planning. The Department has actually been trying to establish a system for strategic planning for at least 15 years. Early efforts focused on setting priorities for road projects, based on data from road and pavement information systems. In 2017 DTPW took a concrete step forward with the purchase of transport planning software and establishing a plan to create a process to forecast land use and travel demand.

1.2 Current Situation

The current transport system is under pressure from a number of social and economic factors. With mountainous areas and large nature reserves throughout the city, Cape Town is very constrained geographically. Although private vehicle ownership in Western Cape is the highest in South Africa, only 48% of households own vehicles. Internal population growth and migration could add more pressure to the system. Additionally, the public transport (PT) system is facing increased costs due to political unrest. Recent controversies over rail system management and acts of vandalism have affected a substantial share of the rail system's rolling stock. Similar unrest has to a lesser extent affected the privately-run bus service. This has caused an increase in auto traffic and minibus-taxi ridership.

On top of that, Western Cape has been suffering through one of the most significant droughts in years. The water shortage has put a large strain on the relationship between citizens and government, and this has severely impacted transportation-related decisions and investment strategies. Major water conservation programs have been implemented and are working, but the situation is still difficult and long-term relief is uncertain.

In many parts of the world, many transportation planning decisions have historically been made on the basis of political considerations. However, this has started to change in recent years as governments realise that it is in the best interests of their citizens to incorporate estimates of future system performance when considering both large and small changes in transport infrastructure and services. This includes the technical analysis of costs and benefits, comprehensive planning across multiple projects and travel modes,

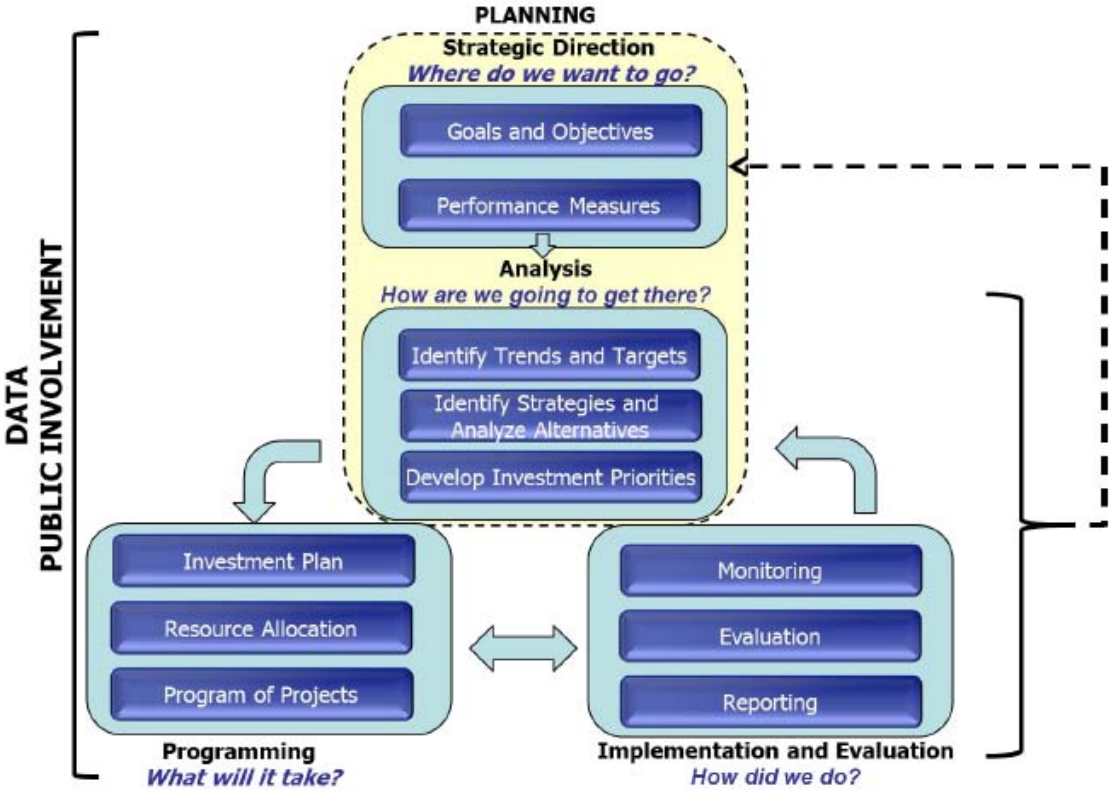
and coordinated planning between transport and other sectors, all done on continuous basis as an explicit government function.

In most regions, it takes a period of many years for public agencies to gradually realise the value of this kind of planning. Once it is recognised, a process is put into place to provide the necessary analytical tools to answer the questions of the decision-makers. One such tool is a comprehensive travel demand model that can provide estimates of the effects of transport decisions (1,2).

1.3 WCG's Approach

However, at DTPW, the process was pursued somewhat differently. This agency decided to create an analytical tool as an early step and then use the data that it generates to demonstrate the value of performance-based planning throughout the agency (1). Such a tool would provide a valuable picture of existing operations and services as well as objective information that could be used to support rational decision-making about the future of the transport infrastructure (see Figure 2). This figure illustrates the concepts behind performance-based planning and highlights the role of analysis in the process. The idea was that having such information at hand would enable managers to evaluate different possible actions and make choices that they could more clearly demonstrate were in the public interest. This would then act as a catalyst to drive the creation of internal policies, procedures, and methods that are used to guide the development of the province's transport system in the years ahead.

It is a principal purpose of this paper to explain why the Western Cape Government chose to act at this time and to articulate their desired objectives.



Source: The Transportation Planning Process Briefing Book (1).

Figure 2: Performance-Based Planning

2. THE PROGRAMME

2.1 DTPW's Vision

The Department did some analysis of travel modelling and decided that they wanted a comprehensive, integrated model system: one that would estimate personal travel, commercial (goods) travel, and land use development. This recognises that transportation and land use are interconnected and should be forecasted together. Land use forecasting is especially important in an environment that is still evolving, some 26 years after the end of apartheid. As noted above, the entire region is growing and the recent disruptions in PT service have put extreme pressure on the roadway system. There is a greater need than ever to understand modal shifts as the PT system recovers, private vehicle ownership grows, and new modes such as Transport Network Companies (Uber, Bolt) emerge. Although the City is the major economic engine of the region, the linkages between the City and the region are important, especially regarding the PT system. Cape Town's status as a major port emphasises the importance of efficient goods movement to the region's economic health.

2.2 Data Development

Developing a brand new travel model system from a "clean sheet" is always a challenge, as these models typically require significant levels of specific types of data on demographic attributes and existing travel behaviour. This kind of information is largely unavailable in South Africa, meaning that the models need to be crafted from a combination of local information and behavioural patterns transferred from other urban areas. In addition, there is little background in South Africa for data sharing among public agencies, and since a large component of the PT system is privately run, some of the operators are reluctant to provide data on services and ridership.

Fortunately, there is a growing number of private sector data companies selling information on demographics and elements of the transport system. The national statistics agency, Statistics South Africa (Stats SA), was helpful in providing both demographic data and the 2011 Nationwide Household Travel Survey (NHTS). That survey was a useful source of travel statistics. Transport of Cape Town also contributed substantial data for the development of both the transportation and land use models.

The year 2016 was established as the base time period for model development. Data from Stats SA and WCG was used to determine the characteristics of the Western Cape population. This focused on attributes that are known to influence travel demand, such as household size, income, vehicle ownership, and household life cycle (which includes the presence of children and the elderly). This is an essential step to ensure that the transport model reflects local conditions. Roadway data was obtained from HERE, which maintains a comprehensive worldwide database of road conditions, including attributes such as number of lanes, roadway type, usage restrictions, and speed. The availability of data on PT services varied widely. TCT and PRASA provided data on the MyCiti bus system and the rail services. But much of the bus service is provided by a private company, Golden Arrow Bus System (GABS). Although GABS is subsidised by WCG and its operating data is collected by a sister department within the WCG, that data was not made available. GABS schedule data was obtained from on-line sources and other data collected by DTPW. The minibus-taxi (MBT) system was a special challenge, as this service is provided by hundreds of operators, many of whom are quite suspicious of government intervention of any kind. Reliable data on actual PT ridership has been extremely difficult

to obtain, especially as it has fluctuated widely with the recent system vandalism. Although WCG provides operating licences to MBT operators, it is estimated that half of the current MBT fleet is operating without a valid operating licence.

The land use model presented an even greater challenge, as it requires *considerable* data on the characteristics of households and employers, detailed data on land usage, and extensive local data on building rents, housing costs, and construction costs. In addition, Western Cape has a significant level of "informal" development, including backyard dwellings, structures that are unknown to any public agency, and a substantial underground economy. All of this informal land use occupies space and generates travel demand, but it is quite difficult to obtain accurate data that describes this activity.

Data consistency has also been a major issue. There are many cases where data is available, but it represents different years and/or different levels of geography and/or slightly different definitions between agencies. Sorting all of this out, in order to create a suitably accurate, consistent picture of 2016 transport and land use conditions, required much more time and effort than originally envisioned. Future work should focus more effort on developing consistent, stable, comprehensive data for model development.

2.3 Software

At the start of this effort, DTPW was becoming familiar with the process of forecasting travel demand and the use of software to accomplish that goal. The staff then consulted with TCT, which had been engaged in model development work for several years. In addition, DTPW was an existing user of ArcGIS and had a relationship with the local distributor, Esri South Africa. Through Esri, DTPW discovered Citilabs, who provides the Cube suite of integrated software. DTPW retained Citilabs and Esri SA to develop a new integrated travel/land use model system, train DTPW staff, and create local expertise by working with WCG, TCT, local consultants, and University of Cape Town staff during a three-year development process beginning in February 2018. In October 2019, Bentley Systems acquired Citilabs.

2.4 The Model System

Cube is a software platform for travel modelling. Cube originated in 2001 as a merger of several existing packages: MINUTP, TP+, Tranplan, and TRIPS. Over the years, these programs have been combined into a comprehensive, integrated suite of software to model person travel (Voyager), goods movement (Cargo), land use development (Land), traffic simulation (Avenue, Dynasim), and accessibility (Sugar). The Cube Base platform provides both the user interface for all of these tools as well as the process for editing model scripts, data files, and roadway and PT networks (3).

The Western Cape Land Use/Transport Integrated model system (WCLUTI) is a unique planning tool, with the following elements:

- Tour-based person travel model: Instead of the conventional four-step aggregate approach, the person travel model uses the new generation of disaggregate tour-based structures. This models every round-trip tour as a discrete entity, simulating the various travel choices using Monte Carlo simulation.

- Commodity-flow model: Goods movement is modelled through a true commodity flow model that estimates the multimodal transfer of goods by industry type at the national and provincial levels. Truck trips (both short-haul and long-distance) are assigned to the roadway network along with the auto trips.
- Land use model: The land use model uses a sophisticated bid-rent system to provide true equilibration between the supply, demand, and price of land. It includes specific steps to represent the informal housing and businesses that occur throughout the province.
- Model integration: the transport and land use components are integrated into a single application package with a simplified interface that allows the user to apply the entire model (in iterative form) or only certain parts of the model, to save run time.

The model system was developed using a combination of local data, calibration of some components to observed data, and transfer of other components from US cities (e.g., Charlotte, North Carolina [4]), with appropriate adjustment to local conditions. The results were validated to the available observed data, including counts of traffic by link and PT ridership.

The model system produces a wide variety of outputs, including weekday traffic volumes by link by four time periods and daily, PT ridership volumes by route, and MBT ridership by traffic analysis zone (TAZ). It also estimates vehicle-kilometres and vehicle-hours of travel, which can be subsequently used to calculate many different impacts, including traffic congestion delay, greenhouse gas emissions, traffic accidents, and energy usage. The travel time matrices can be used to calculate accessibility, which can then be used to evaluate how roadway and PT improvements affect general mobility by geographic area. Finally, the model produces a database of every round-trip person tour in the province, with associated demographic data and travel information and this can be used to produce a variety of summaries to estimate how system changes affect different demographic groups and/or different geographic areas.

The integrated nature of the WCLUTI process is that it estimates the impacts of both transport and land use changes on the transport system and development patterns. It is well known that a major transport project can affect the accessibility of land parcels, changing the usage of those parcels, modifying the demand for travel, which in turn affects the transport project. Few regional models are able to handle this interaction in the same manner as the WCLUTI.

One of the more interesting uses of a travel model is to develop “story maps” that provide information on the impacts of transport improvement projects. Esri software can be used to display Cube outputs in a web-based environment that makes travel model results easily accessible to the public.

2.5 Support for Planning

The principal value of travel and land use modelling is that it serves as a “digital twin” of the actual transport and land use system. This allows decision-makers to quickly, easily, and inexpensively test out a wide variety of hypothetical improvements to determine how they might perform, before implementing them in the real world. This information is invaluable in the planning process and provides the kind of information needed to support performance-based planning (2). This is a paradigm in which key infrastructure decisions are made with a clear, detailed understanding of how those decisions will affect the public. This leads to improved, more transparent decision-making that is better understood by the

public and can be more easily communicated to all stakeholders. This is the long-term goal that DTPW is trying to achieve.

2.6 Schedule

As of this writing, the initial versions of all model components are in place (5). The modelling team is now in year 3 of the development process, with this year being largely devoted to model enhancements, improved validation, continued training, documentation, and formal hand-off of the process to DTPW staff. This is illustrated in Figure 3. Recently, a fourth year of project activities has been approved (2021-22), which will focus on additional model features, training, and example applications of the model to real-world scenarios.

Model / Year	**Year 1 (2018-2019)**	**Year 2 (2019-2020)**	**Year 3 (2020-2021)**
WCTM (Western Cape Transport Model) Person Travel Model – Cube Voyager	v1.0	v2.0 Model refinement and applications	v3.0 Model refinement and applications
WCLM (Western Cape Land Model) Land Use Model – Cube Land	v1.1 (Nov 2019)	v2.0 Model refinement	v3.0 Model refinement and applications
WCFM (Western Cape Freight Model) Freight Model – Cube Cargo	v1.0	v2.0 Model refinement	v3.0 Model refinement and applications
WCLUTI Model (Integration)	V1.0	v2.0 Model refinement	v3.0 Model refinement and applications

Source: Bentley Systems.

Figure 3: Project Schedule

3. CONCLUSIONS

At the outset of this project, there were some uncertainties, all of which have been resolved.

Question 1: What is the role of a travel demand model in an agency that does not have much experience in transport planning?

An agency can use the data generated by a model as a catalyst to motivate itself to commit to performance-based planning, resulting in more efficient and effective delivery of projects and services to its constituency.

Question 2: Is it feasible to transfer a travel model across continents to a different environment?

The results that have been achieved, including the satisfactory match to existing vehicle traffic counts, confirm the validity of the theory that a discrete model set can, with care and expertise, be transferred between different urban areas.

Question 3: Is it possible to create a fully integrated land use/transport interaction model set in a setting that had no model infrastructure at the start?

The selection of the Cube and Esri software platforms, including a very experienced consulting team with travel modelling, data, and GIS expertise, ensured that a complete modelling package would be put into place, along with adequate training, support, and documentation. DTPW's staff have undergone extensive training and are actively applying the model in support of the Department's planning initiatives. This is expected to bring an improved quality of infrastructure to the residents of Western Cape.

4. REFERENCES

Cube Voyager Reference Guide, version 6.4.5, Bentley Systems, June 2019.

Development of a Tour-Based Model, prepared for Charlotte Department of Transportation by William G. Allen, Jr., PE, December 2014 (unpublished).

Scoping and Conducting Data-Driven 21st Century Transportation System Analyses, US Department of Transportation, (fhwahep16072), January 2017.

The Transportation Planning Process Briefing Book, US Department of Transportation, (fhwahep18015), 2017.

WCLUTI: Western Cape Land Use & Transport Interaction Model, Documentation & Reference Guide, Version 1.1, prepared for Western Cape Government by Bentley Systems and Esri South Africa, December 2019 (unpublished).