Transporting South Africa's movers into the future

by Dorothy R Diedericks and Johan W Joubert

Transport is the heartbeat of the South African economy. It involves the movement of goods from the factory gate to the consumer. More importantly, transport is responsible for moving people, so that they can actively participate in the economy.

Previous political policies and the resulting urban planning, as well as extreme socio-economic imbalances, led to a disparate public transportation system in South Africa. The current public transportation system uses train, bus and minibus modes of transport. This system only captures 50% of the passenger transport market. It attempts to serve an extremely large low-income group that commutes from the outskirts of metropolitan areas to dispersed economic centres. A number of future events, including the 2010 Soccer World Cup, have emphasised the need to focus attention on redesigning the country's existing transport system.

The strategic public transport network has lagged behind other transport development initiatives. Planners often use obsolete models and policies based on international environments, without taking the South African context into account. A dynamic taxi network, for instance, serves more than half of the commuters in the country.

In traditional network design and optimisation, bus stops are considered fixed in a network. When a South African commuter uses the appropriate hand signal to communicate with a passing taxi, however, he/she becomes an immediate bus stop, anywhere, anytime.

In a research project on an integrated public transport system, a number of research efforts – traditionally considered in isolation – were integrated to address unique South African requirements. The more traditional transportation planning, as considered by Ortuzar & Willumsen (2001) and McNally (2000), was extended to cater for advancements such as the activity-based modelling of Recker et al. (1986a,b).

The autonomous decision-making of commuters was represented by pedestrian movement contributions and the mode choice models of Hickman and Bernstein (1997), but with any increase in model quality, the computational burden of running and solving the model becomes problematic.

Agent-based modelling addresses the complex and autonomous behaviour of commuters and public transport modes. Instead of designing a fixed transportation system and assigning travel behaviour patterns in a static manner, agent-based modelling allows for participation in a transport environment, thus allowing for the modelling of individual agent behaviour.

Commuters and transporters are represented as agents who interact with each other and the environment in which they participate. A more realistic, scalable modelling approach can hence be used to support decision-making without increasing the model complexity excessively.

The methodology is described in four stages. Firstly, the transportation environment uses existing and known attributes, such as demographics obtained from census results and the physical transportation infrastructure. The modes of transport, including their difference in modal behaviour, are then described. These differences include schedules, infrastructure required and available routes. Thirdly, the commuters are described as "intelligent" agents, using an approach adapted from the contribution by Dia (2002). The agent is described as a function of attributes such as residential location, income and activities generating transport demand. The behavioural aspects such as mode choice and route assignment models are imbedded in the agent's decision framework. The final stage integrates the various agents with their environment.

An example

Consider City A. Fairly accurate census data exists for all political wards, indicating the population of each ward and descriptions of the inhabitants. A geographic information system (GIS) represents the area on a layered map. The agents are duplicated and "scattered" across the wards, based on the inhabitant counts. When an agent is assigned to an area, he/she assumes certain characteristics, based on the demographic description for that area. Modes are assigned to their networks, which are also represented on the map using existing data. Agents representing modes of transport "participate" by travelling on the network according to the route assignments.

Agents representing commuters have activities in which they participate, such as going to work and dropping children at school. As a result they make transport mode and route choices, based on their unique destinations. Being autonomous, each agent can make decisions based on available income and time. Since agents can interact with one another, it becomes possible for commuters to signal passing taxis. If the destination coincides with the destination of the taxi, and the latter has capacity, the taxi will stop and collect the commuter. Once the commuter arrives at the destination, the taxi is signalled again and the commuter can disembark. Buses and trains follow more formal routes and schedules with commuters embarking and disembarking at specific stops.

Having the ability to reliably model and simulate an urban transport environment means that a number of benefits are achieved. It makes it possible, for instance, to evaluate what the impact of a proposed bus route change would be on commuter travel time across a metropolitan area. This is achieved by changing the bus routes in the GIS system and simulating the resulting environment, continuously tracking attributes such as total travel time and travel cost.

Using agent-based modelling, one can establish the influence of electronic fare collection without embarking on costly demonstration projects, and one can evaluate fleet utilisation. It also provides an adequate environment to model the dynamic behaviour of the para-transit taxi system, something that has not been achieved in the past.

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Rail systems of the future – lighter, smarter, faster

A recent study by Siemens shows that rail traffic will increase substantially all over the world. The reason is that the number of large cities and urban areas will grow dramatically, and track infrastructure forms an important base for the economic prosperity of a region. Forecasts suggest that by 2025 passenger rail traffic will increase by more than 30% worldwide, and freight traffic will grow by over 65%. Passengers will benefit from shorter waiting times, better service and more attractive and more comfortable vehicles. The trains — often fully automated — will no longer stay a specified distance apart, but will instead maintain spacing in accordance with their relative speeds. This will lead to major savings in time and energy.

High-speed passenger trains operating at speeds of up to 450 km/h will shorten travel times between major cities. In addition, separate corridors will be established for freight traffic. This will lead to improved transportation capacity as well as to faster passenger traffic, as slower freight traffic will run on its own tracks. In China and India, for example, double-decker container cars could run on newly constructed roadbeds. Driverless freight cars could operate along selected routes. The customer specifies the destination; the car hooks itself into the traffic flow and reaches its destination completely on its own.

Of course, demand will not be the same everywhere. Priorities vary from region to region, focusing either on expanding local transport services (the USA, Europe, China, India), the targeted expansion of long-distance passenger and freight traffic (China, India) or modernising existing railroad systems (Russia).

In all of these areas, environmental protection will have very high priority. In 2025, trains will be lighter in weight and their drive systems will use less energy. Experts have high hopes concerning wheel hub motors. In this technology, the wheel, motor, and brake are combined into a single unit, and an electric drive is located directly in the wheel. Transmissions and drive shafts are thus obviated, along with associated losses in power transmission.

One option for non-electrified lines is the use of trains that are powered by fuel cells that would be refuelled at hydrogen filling stations along the railway line. All of the energy would be generated directly on board the train and without producing any harmful emissions. And thanks to the combination of lightweight construction and onboard energy storage for braking energy, trams may be able to manage without any overhead lines in inner cities. Moreover, lightweight train design will reduce wear and tear on rails and thus also cut maintenance costs.

Researchers expect that by 2025 materials will have been developed that, in case of fire, are either self-extinguishing or non-flammable. These materials will utilise nanoparticles incorporated in metals, ceramics, and polymers, in the form of an oil or a gel, for example. Thanks to precise location identification, the European satellite navigation system "Galileo" will make it possible to reduce the distances between trains. In this way, it will be possible to transport many times more traffic volume over the same railroad infrastructure than is possible today.

The report finds that improved mobility of freight and passengers will in particular be facilitated by the intelligent networking of transportation systems and the integration of all modes of transport. Thanks to telematics, standardised communication systems, and uniform interfaces, all of the various transportation modes will be optimally harmonised with one another and associated information will be interlinked — whether it's about individual or rail traffic, parking garages, train stations or airports. Passengers and motorists, for example, will have access to a wealth of information that relates to their own specific travel plans. A single ticket will then be valid for all transportation operators, and passengers will be able to travel in comfort from door to door by bus, train, plane, or subway.

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