Growing better transport solutions

by Dr Johan W Joubert and Pieter J Fourie

We have all contemplated a number of solutions on how we should address the increased congestion and traffic problems we face on the road. Some try to outsmart the other road users by investigating all possible alternative routes: sometimes it works, and sometimes the cleverness backfires!

It is not a good idea to experiment using a trial-and-error approach when making decisions about transport infrastructure. Decision-makers rely on models to help them evaluate how people might react when they decide to widen the Ben Schoeman highway, toll a length of road, or implement the proposed bus rapid transit systems.

The problem with state-of-practice models is that they do not intuitively reflect the way in which real people make decisions about commuting, yet they are supposed to assist in making decisions that will affect real people. The Optimisation Group at the University of Pretoria believes in improving the state of practice by developing and adapting state-of-the-art research solutions to fit the South African context.

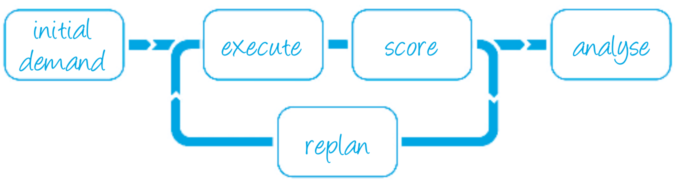
Commuters learn through experience when the best time is to leave for work, what route(s) to take, and when to return home again. Some have more flexible working hours, and some are more adventurous in trying new routes. No matter how hard one tries, some days the traffic flows, and other days it is a mess. Other people are probably also trying to improve their commuting times or are also contemplating a change in routine, and it may just happen that their collective decisions affect the traffic situation on a specific day.

Agent-based modelling is a relatively new approach to simulate scenarios where decision-making is involved. Each agent (or commuter) has autonomous decision-making ability. Due to a lot of clever work by other local and international researchers, one has a fair idea of how agents make decisions regarding their travel behaviour. With the Multi-agent Transport Simulation (MATSim) toolkit that is being developed with colleagues from Germany and Switzerland, the research group has been able to model large-scale transport scenarios for the whole of Gauteng.

The iterative process controlling the simulation is illustrated in Figure 1. Initial demand represents a population of commuters, each having a set of plans. A plan represents home, work and leisure activities, as well as the sequence, modes of transport and routes linking the various activities.

During the execution phase, each commuter selects a plan from memory – the more value the plan has for the commuter, the higher the likelihood of being selected – and the plans are executed simultaneously in a mobility situation. This simply means that commuters try to get from one location to the next in their plan, following their planned route on a network of roads. But since many agents execute their plans simultaneously on the same road network, congestion occurs.

The score phase of the cycle allows each commuter to evaluate the actual execution of the plan against the expected score of the plan. This is like sitting at home and deciding how good one's plan for that day was. The scoring not only takes into account the value one gets from performing the various activities for certain times, but also takes into account the actual



→ *1. The iterative controller guiding the Multi-agent Transport Simulator (MATSim).*

2. Transport simulation results for Gauteng. The two clusters, Greater Johannesburg and Tshwane, are clearly distinguishable.

travel time, and how early or late one has been arriving at work. Generally, it is not such a good plan, especially in the long run, to spend too much time at home, very little at work, and a lot in traffic, and on shopping and other leisurely activities. All these factors are taken into account in scoring the day's plan.

The chosen plans' scores are updated, and replanning occurs. A portion of the commuters may decide to alter one of the plans they have in memory: changing the departure time from home, one of the activities, or changing the route connecting two consecutive activities.

All commuters then select a new plan, again influenced by the expected score of their plans, and the process repeats itself. The evolutionary approach of learning through experience allows the whole transport system to eventually settle into a relaxed state. In real life, we are not really interested in an exact equilibrium: we can just look out of the window, or experience peak traffic in the morning to know that the transport system will never truly be in equilibrium.

The attractiveness of the agent-based approach is that one never explicitly tells the agents where to drive, when to leave for work, or what decisions to make. One merely develops the logic that they will use to make their own autonomous decisions. So, achieving the results in Figure 2 is in some sense quite weird, since the researchers never told anyone to congest downtown Johannesburg, the Buccleuch Interchange or the Fountains Circle in Pretoria – yet, they observe those congested areas in the results.

This emergent phenomenon is what the research group is after. A good model should be insightful: it should tell researchers something that they did not necessarily tell the model to tell them. To intuitively recognise the major congested areas in Gauteng is not sufficient to validate the model, though. Using existing traffic counting station data – obtained from the South African National Roads Agency Ltd (SANRAL) – allows the researchers to check where they are simulating too many, and where too few commuters. These provide flags that, in turn, allow them to refine the decision-making logic of the commuters.

"So what if one can simulate the status quo?" you may ask. Well, the researchers have not described the system, they have merely observed how the commuters react to the given system – and they do so in a manner that is similar to reality.

They can now impose an infinite number of different scenarios, such as increasing the number of lanes on a stretch of road, building a new road, or tolling the Ben Schoeman highway, and sit back and observe how the commuter agents change their travelling patterns and behaviour, based on the changed system that was presented to them. Since each agent is modelled individually, the research group obtains a much richer data set to work with.

As a first example, consider knowing what the travelling time for each commuter is. Performing detailed analyses for each simulated commuter may assist government decision-makers to improve the evaluation of the relevance and impact of a choice, say, to invest in more feeder networks for the Gautrain. Researchers can provide a new feeder layout in the simulation scenario and measure whether commuter travel times improve sufficiently to justify the investment in the new network. Since the agent population is generated from known demographic data, it is also possible to evaluate whether a government policy intervention has the desired result for a specific demographic group.

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