Why are traffic models necessary?

Increasing road traffic and urban congestion is one of the main challenges facing societies in the developed world. A fundamental understanding of traffic, including public transport and pedestrians, is key to finding the root causes of congestion and the mechanisms to avoid or recover from it. From a practical perspective, performing field trials of proposed modifications to road infrastructure is expensive, and there is also the real possibility of adverse consequences, both in terms of cost and safety, if the proposed modification does not perform as expected. It is therefore crucial to carry out careful modelling of any proposed changes to the arterial network.

Could you outline your approach to modelling large urban transport networks using stochastic cellular automata?

In brief, we model cars as particles moving along links and through intersections of a network. The model is discrete in both time and space, making it easy and effective to implement on a computer. We leave out irrelevant details but include essential features such as realistic traffic signals at intersections. Our model can easily include new scenarios such as changing tram stops, new bicycle lanes and altered parking restrictions. It therefore provides a predictive tool that can inform urban planners.

What advantages does your model hold over the microsimulation packages currently available?

We view the model as a ‘mesoscopic’ model, which is deliberately less detailed than a microscopic model. A microsimulation model is designed to provide detailed predictions of the flows through a specific and carefully calibrated (small) subset of a road network. By contrast, our mesoscopic model is tailored to studying strategic network-wide questions. Such questions would relate to generic properties of whole classes of networks, and to understanding how the behaviour of these networks can change as the various parameters (turning rates, input/output volumes) change. This perspective is very much in tune with statistical mechanics; rather than focusing on a single set of parameter values that are considered to represent the current state of a particular network, we study the possible behaviours of the network for a whole range of parameter values.

How do you translate your mathematical models into practical uses for traffic systems?

We work closely with engineers at the Roads Corporation of Victoria (VicRoads) and Victoria’s Department of Economic Development, Jobs, Transport and Resources to model the effect of specific proposed modifications to the tram network in the northern suburbs of Melbourne, and also to model the effect of introducing continuous flow intersections on Hoddle Street, which is one of Melbourne’s largest and busiest arterial roads.

Can you elaborate on some of the biggest challenges your team has faced in its investigations? How have you overcome these difficulties?

There are many significant challenges when one attempts to translate insights from theoretical models to practice. From a scientific point of view, these can be overcome by teamwork, through which we benefit from each other’s strengths, patience and good working relationships between academic researchers and people in industry. From a funding perspective, we have been able to find long-term support from the Australian Research Council (ARC) within the recently awarded Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS).

In which direction do you hope to develop your research in the future?

As our model becomes more and more sophisticated and mature, we intend to increase its use as a predictive tool used by road authorities as a first step in deciding whether or not field trials of proposed modifications will be worth considering. Moreover, as a research community, our understanding of traffic flows on networks is still very much in its infancy. There are a huge range of questions, from fundamental/theoretical to practical/pragmatic, which we intend to study with our model over many years to come.
The trouble with traffic

An urban transport network model, grounded in statistical mechanics and developed by experts from the University of Melbourne, Monash University and VicRoads in Australia, is pioneering the predictive testing of potential modifications to the traffic network system.

If urban planners are to successfully manage road traffic in the upcoming years then effective models are needed to identify and pinpoint solutions for the predominant causes of congestion. Although there are a number of microsimulation packages already available on the market, their usefulness is hampered by two major limitations. First, they are time-consuming to set up, as each scenario requires a large amount of input data that is both extremely detailed and accurate. Second, they can only simulate relatively small traffic networks – larger networks, such as arterial road networks in a city, cannot be successfully modelled.

A novel type of model that has the computational power required to deal with such large-scale traffic networks is therefore required as a matter of increasing urgency. This is where a project involving experts from the Australian Research Council (ARC) Centre of Excellence for Mathematical and Statistical Frontiers at the University of Melbourne and Monash University, and the Roads Corporation of Victoria (VicRoads) comes in. At the centre of this highly collaborative project are three statistical mechanics researchers: Dr Tim Garoni, Professor Jan de Gier and Dr Lele (Joyce) Zhang.

STOCHASTIC CELLULAR AUTOMATA

Developing a traffic model based on statistical mechanics is an approach that has been successful for freeway traffic. Within such a system, cars are modelled as moving and interacting particles. Applying these techniques from mathematical physics to network traffic is, in itself, a fairly innovative approach, as most of the other models currently available have been developed based on techniques taken from branches of applied mathematics or engineering. Even more innovative is the model’s pioneering use of stochastic cellular automata for the study of the impact of realistic traffic lights on urban traffic networks.

The resulting model, named Cellular Automata Simulator for Arterial Roads (CEASAR), is both easy to implement, as it only requires the most essential basic information (such as traffic signal data), and simple to update in the event of a changing scenario (such as the introduction of new bicycle lanes or a sudden road closure). This approach, treating the network as an interacting particle system, allows us to use advanced techniques developed in fundamental...
CLOSE COLLABORATION

It was Dr Tim Garoni and Professor Jan de Gier who first forged a collaborative research relationship with VicRoads in 2008, while Garoni was based at the ARC Centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS) at the University of Melbourne. Dr Lele Joyce Zhang joined the team in 2011, and has played a leading role in the collaboration ever since.

Although Garoni and Zhang have since moved to Monash University, they continue to work closely with de Gier, and also more recently with Dr Andrea Bedini at the University of Melbourne, as well as with VicRoads. Their research is now co-funded by both VicRoads and the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS).

research, and thus provides a tool capable of simulating traffic through large road networks, which is computationally fast and requires only minimal input data and calibration,” de Gier elucidates.

REAL-WORLD USES

In addition, the CEASAR model can implement realistic traffic signal systems, improving its ability to bring about real-world benefits. For example, CEASAR includes an accurate model of the Sydney Coordinated Adaptive Traffic System (SCATS). SCATS is a control system used in many cities around the world, in which traffic signal parameters such as green times and cycle lengths respond to current levels of congestion.

As an example of a recent study performed with CEASAR, the researchers studied the effects that using different adaptive signal systems have on an arterial network’s macroscopic fundamental diagram (MFD). MFDs plot information relating to flow verses density within a road network, and enable the effective comparison of traffic flow under different conditions. The ability to simulate various network performance metrics such as MFDs, combined with the ability of this model to operate on a citywide scale, in a way that incorporates realistic traffic signal systems and includes diverse modes of transport, is what makes it so useful to urban planners and transport policy makers. Indeed the research team behind CEASAR is one of just a handful of groups worldwide who have achieved such a high level of functionality.

MAKING A DIFFERENCE IN MELBOURNE

To date, the CEASAR team has produced a number of interesting findings, which have led to the publication of three peer-reviewed papers as well as multiple technical reports. From 2012-14 alone, under the ARC Linkage Project entitled ‘Modelling large urban transport networks using stochastic cellular automata’, the researchers used the model to study the Melbourne road traffic network. Overall, they investigated the effect of temporary traffic incidents on network performance and of using real-time data to divert traffic away from the incident; studied the impact of different levels of kerbside parking on network performance; performed a preliminary comparison of absolute versus conditional tram priority; analysed the impact of allowing cyclists to use bus lanes; refined their SCATS model to enable the comparison of a variety of alternative SCATS implementations; considered the effect of increasing SCATS’ maximum cycle length; examined the impact of several clearway policies on tram routes; and looked at the consequences of relocating a number of tram stops and detectors.

The insights generated by this research have already been used to inform a number of policy decisions and, by continuing to work closely with local government, the CEASAR team hopes to further utilise their model for the predictive testing of the impact of potential road network modifications. In addition to this, the group is also working in collaboration with Dr Andrea Bedini at the University of Melbourne to develop their model’s online visualisation tool (which can currently be accessed online via Google Chrome at http://ceasar.acems.org.au). Last but not least, the team plans to carry out theoretical research on the generic behaviour of road traffic networks over the upcoming years – work that is likely to bring about significant practical applications in the future.

If urban planners are to successfully manage road traffic in the upcoming years then effective models are needed to identify and pinpoint solutions for the predominant causes of congestion.