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Paper title: **The role of pedestrian modelling in planning for special events**

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Abstract (200 words):

Special events, such as sporting events and street festivals, are an important part of community life. These events involve a large number of pedestrians converging on an area for a relatively short amount of time. The issues for event planners include effective and safe crowd control, whether to provide temporary or permanent infrastructure, and consideration of the placement of attractions, as their location will influence the movements of pedestrians. The Commonwealth Games (Melbourne 2006) are an example of a large special event where pedestrian modelling is currently being used to understand the effects of potential scenarios. The Sports and Entertainment Precinct, where most of the events will be held, has been modelled using PAXPORT, a pedestrian modelling package developed by Halcrow. The results of the models developed to date have significantly informed the planning process, in particular by demonstrating problem areas and showing the impacts of different infrastructure designs.

Introduction

Special events are commonplace in today's society. These include sporting events (such as Olympic and Commonwealth Games, Grand Prix events, tennis tournaments and world championship events) and smaller events such as street festivals and parades.

These events attract many spectators, the majority of which are on foot. This produces a need for an analysis of the event area to determine:

- whether the infrastructure is capable of handling the demand;
- whether temporary infrastructure is required to control crowds; and
- where stands and attractions should be placed to avoid congestion but also to attract spectators.

The demand characteristics of special events are very different to normal day-to-day demand in the event area. Usually a large amount of pedestrians converge on the area, sometimes over a short period of time. Areas normally available might be blocked off or altered. For example, the parkland surrounding the Melbourne Cricket Ground (MCG) is normally available for visitors to enjoy, however during MCG events it becomes a car park and therefore impedes normal pedestrian behaviour.

Historic demand data is either limited or unavailable for special events, as they are usually one-off events or held infrequently. Traditional validation techniques are not usually applicable. This makes realistically modelling the event area more difficult than, say, a shopping strip or shopping centre under normal daily conditions.

This paper describes techniques for pedestrian modelling for special events, and uses some of the modelling undertaken for the 2006 Commonwealth Games as an example. Past and current pedestrian modelling techniques are presented. A scenario from the Commonwealth Games modelling is then demonstrated, including a discussion of validation techniques and how the results influenced the decision-making process. Finally, a discussion on the future of pedestrian modelling is presented.

Past and current pedestrian modelling techniques

There are many approaches to modelling pedestrian behaviour, which can be divided into two schools. The first school is the "civil engineering" approach. This is concerned with forecasting demand so that decisions can be made about provision of new infrastructure. The main outputs of these models are values of people travelling along various routes and the algorithms used are frequently based on traditional vehicle modelling algorithms. They are generally macroscopic models, where the smallest detail of a pedestrian's movement is the locations they visited and the paths they used to get there.

The second school is the "architecture/urban geography" approach. This group is interested in how people move around areas, in particular how design and location of certain attractions influence their movements. These models are usually microscopic, in that they model a pedestrian's path in more detail, usually in terms of steps or small grid squares. They are usually developed for small areas only, however some have been expanded to cover entire cities. However, some models combine both approaches and as a result are very flexible regarding what type of areas they can model.

A large amount of work in pedestrian modelling and planning is based upon Fruin's work in the 1970s. Fruin (1971) developed a level-of-service measurement, again based on vehicle modelling principles, that showed how congested certain areas are based on the density of people in that area. Different areas, such as open space, lifts, and stairs, have different density values for each level from A to F, where A is "free flow" and F is severely congested.

A very simple technique for measuring the adequacy of an area to handle large flows is to calculate the Fruin level-of-service for that area. However, this does not take into account the origin and destination of pedestrians, just how many are passing a particular point.

Mathematical models, such as regression models and Markov models, have also been used to model pedestrian behaviour (Harney 2002). Regression models estimate the number of pedestrians that will visit a certain area, based on elements such as retail floorspace and parking spaces. Markov models are useful as they can take into account where pedestrians have visited most recently, as this will have an effect on where they go next, and are most useful for trip-chaining analysis. Both approaches are severely limited due to their simplicity.

Physical models have also been used to model pedestrians. Helbing (as described in Harney (2002)) used the notion of attraction and repulsion to model microscopic behaviour.

Space Syntax (2004) is an example of the architectural viewpoint. It looks at how space is used by pedestrians and has evolved into several models ranging from rooms and buildings to entire cities. The technique used is visibility graph analysis, in which a set of locations is defined and the visibility of each point from each other point (or line of sight) is determined. This is combined with socio-economic analysis to determine the attractability of each location. It does not involve simulation.

PAXPORT is a pedestrian modelling software package developed by Halcrow, a global consulting company based in the United Kingdom. The software was initially developed for modelling train stations and airport terminals, but has also been used for stadiums. It uses traditional traffic assignment methods to calculate the paths of each pedestrian, but does not show individual paths of pedestrians. The network is represented by a block structure and uses Fruin's work on pedestrian densities and speeds to determine levels of service in an aggregate manner. PAXPORT consists of five main programs: the network builder, simulation package, graphics package, and two data analysis packages.

Modelling the Sports and Entertainment Precinct

The Commonwealth Games are to be held in Melbourne in March 2006. 4,500 athletes are expected to compete, with almost 3,000 officials, 3,000 VIPs and sponsors, 3,000 media representatives, 20,000 employees and volunteers plus tens of thousands of spectators expected to attend (Melbourne 2006 (2004)).

The location of most of the events is the Sports and Entertainment Precinct, just southeast of the Melbourne CBD. The precinct contains three arenas (MCG, Rod Laver Arena (RLA), and Vodafone Arena (VFA)) and also contains extensive parkland known as Yarra Park (Figure 1). A new park area, Birrarung Marr, lies to the west and the Yarra River is to the south of the precinct.

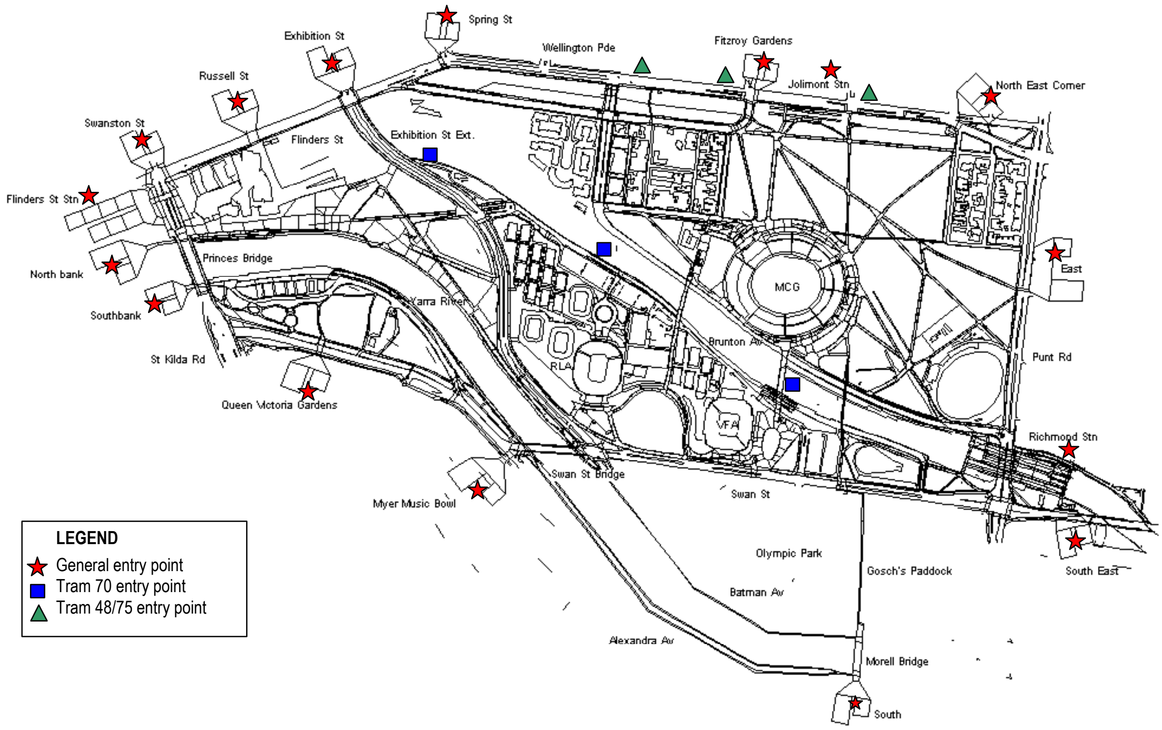

Figure 1 Overview of precinct, showing PAXPORT's block structure over a CAD drawing

The Sports and Entertainment Precinct is located close to three train stations. Richmond Station is one of the largest stations in Melbourne's rail network with 10 platforms, and all trains going to the southern or eastern suburbs stop here. Jolimont is a smaller station serving the north-eastern suburbs, and is located just north of the MCG. Flinders St Station, Melbourne's main train interchange, is also located within walking distance of the precinct. A tram line also runs through the precinct, stopping near the Tennis Centre and the MCG. During special events, such as the Australian Open tennis, dedicated trams run every minute or so from the CBD.

In order to gain a better understanding of the pedestrian behaviour in the precinct under expected conditions and for different scenarios, Sinclair Knight Merz have been constructing pedestrian models of the precinct using PAXPORT.

Several models have been developed so far, starting with a base model using events from a sample day. This model has been modified and extended to create:

- A model of the AFL grand final held annually at the MCG, for validation purposes;
- Models testing various bridge designs and widths for a new pedestrian link from the MCG to Birrarung Marr; and
- Models testing various cultural event scenarios on top of scheduled sporting events.

This paper will describe the second of the above extensions, focusing on the modelling process, validation techniques and final outcomes.

Scenario

In the infrastructure scenario, several bridge options were evaluated for their capacity and ability to reduce bottlenecks. An earlier model without a bridge has confirmed that a new bridge spanning from the west side of the MCG to Birrarung Marr was required, not so much for congestion reasons, but more for convenience. There is no 'straight line' path from the CBD to the precinct, and it was envisaged that a new bridge would encourage more people to travel to and from Birrarung Marr and the CBD. A secondary aim was to reduce some of the pressure on Richmond Station.

The two key aspects investigated were the width of the main span and the width and location of the stairs. Each design also incorporated a plaza above Batman Avenue.

Concept designs were developed during a consultation process that included stakeholders such as event operators, venue managers, police, traffic experts, local authorities and residents. Several options were rejected prior to the modelling phase, leaving two options to be evaluated further. These were:

- a bridge with a single walkway, and two staircases from ground level to plaza level on the south side of the plaza (Option 11a);
- a bridge with a different plaza design, and stairways on both the north and south sides of the plaza (Option 11b); and
- a bridge with an arched superstructure, dividing the eastern span into two walkways, with north and south stairs to the plaza (Option 12). This option was tested with two different span widths. One span width was also tested with an alternative location for the north stairway and two different stair widths, making six design options in all.

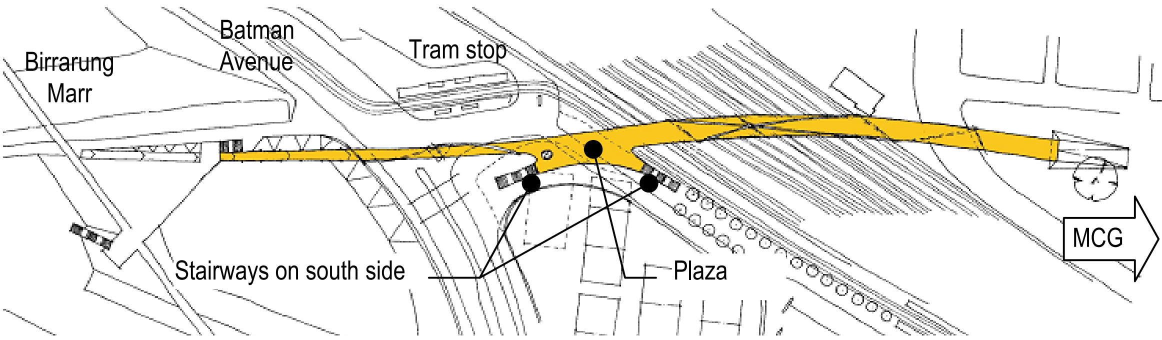

Figure 2 Option 11a design

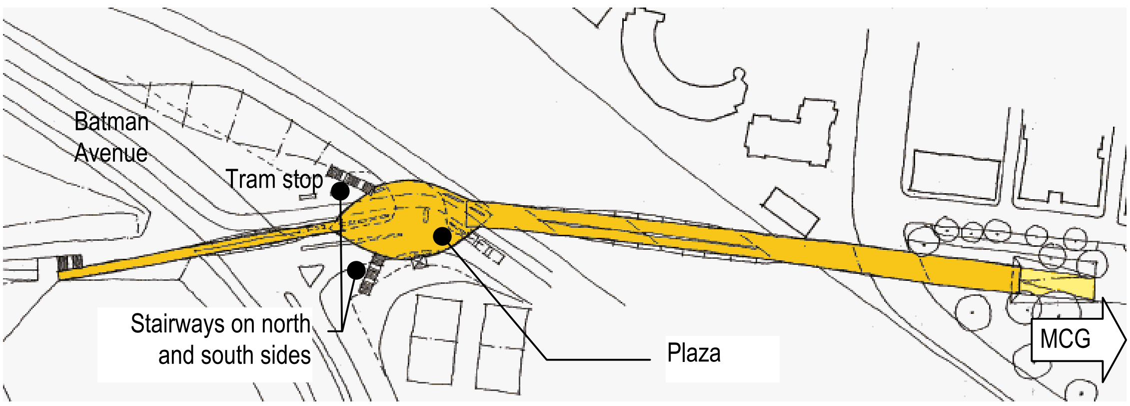

Figure 3 Option 11b design

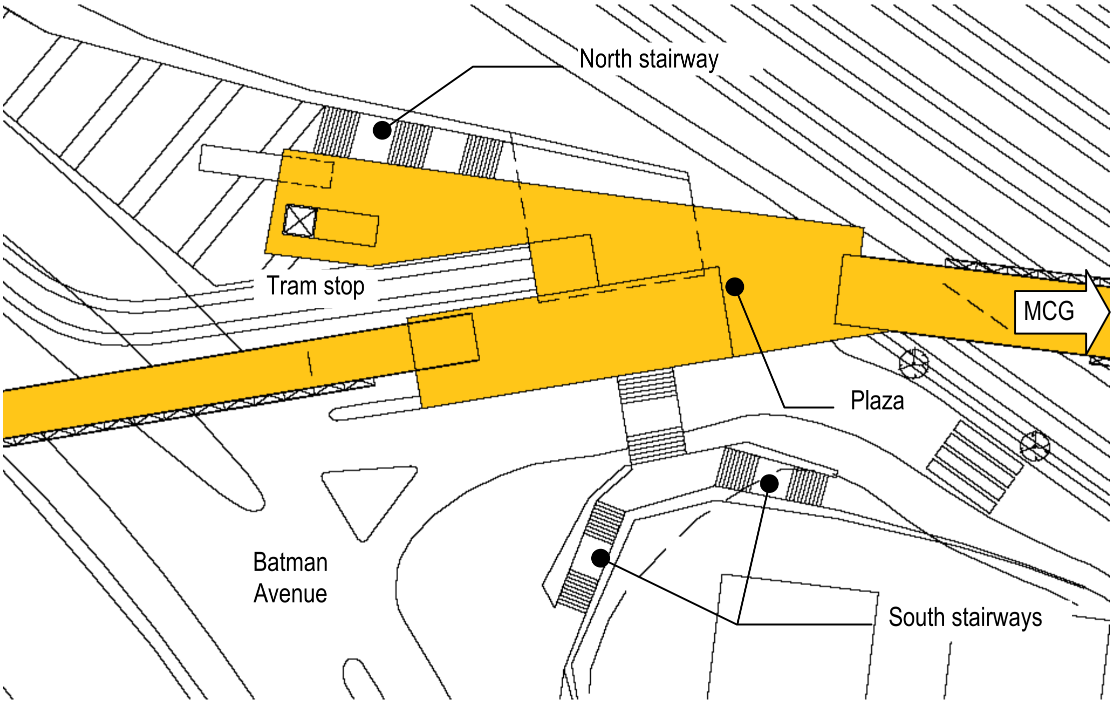

Figure 4 Option 12: close up of plaza

Two demand scenarios were used: an AFL Grand Final scenario with 91,400 pedestrians travelling to the MCG, and an Australian Open tennis tournament scenario with 12,375 pedestrians visiting Melbourne Park.

Modelling process

The modelling process consists of several steps:

- Constructing the network;
- Defining the events and demand;
- Defining person types; and
- Running the model.

Network construction: Constructing the network in PAXPORT is a time-consuming process. Networks consist of blocks, that specify where people can walk, and links, that specify which blocks are joined. Several different types of blocks are available, which specify the behaviours pedestrians will exhibit in that block. For example, paths would be coded as passageways, which allow pedestrians to walk freely. A shop or park area would be coded as a service block, as people tend to dwell and linger in these areas for a set amount of time.

A CAD file is used to guide the modeller in drawing the blocks. The links are formed automatically as the blocks are created. Once this is complete, locations need to be specified. Locations are important blocks that are likely to be a destination for a pedestrian, such as the train station, ticket stand, arena, or cultural event area.

Defining events: Pedestrians require at least one location to visit at a specified time as a driver, therefore the next step is to specify the events. For each event, the location, expected demand, and start and end times are required.

PAXPORT can also handle people who enter the precinct but do not attend any events. For the Commonwealth Games, these people may be interested in soaking up the atmosphere. They can be defined by specifying the time they enter the model, rather than the time of the event. Normal pedestrian movements, such as people travelling to and from work, were not included in the models as PAXPORT cannot easily handle people walking through the model from entry to exit without stopping somewhere.

Defining person types: PAXPORT allows 64 different person types to be specified. This means the model can create pedestrians who walk faster, pedestrians who arrive early, and pedestrians who have already bought a ticket. This contributes some realism to the model. We have used the person types to specify arrival profiles (when people are likely to arrive for an event) and event profiles (for those attending two or more events in a day).

Running the model: A run file is required to specify the model parameters, such as input/output files, block type properties and whether dynamic routing is used. The models produced output for a simulated day (7am to 8pm) and each model took around 30 minutes to run.

Outputs

PAXPORT can generate various outputs, including level-of-service (LOS) plots and graphs, density and flow calculations.

Figure 5 shows a level-of-service plot for the Option 11b bridge at 6:30pm. The blue areas are LOS A, which is “free-flow”. The bridge spans, however, are yellow or LOS D, which is acceptable but becoming congested. These plots give an overview of the congestion at each point in time and are quite effective when played as an animation.

Figure 6 shows a level-of-service graph, which concentrates on a single block and shows how many pedestrians are experiencing which level-of-service at a particular period of time. From this we can see that the span is fine for most of the day, except when crowds leave the MCG around 5:30pm when some congestion begins to occur and persists for about an hour. Above the graph, the amount of time spent in each LOS is displayed, which is useful when comparing the effects of two different infrastructure scenarios.

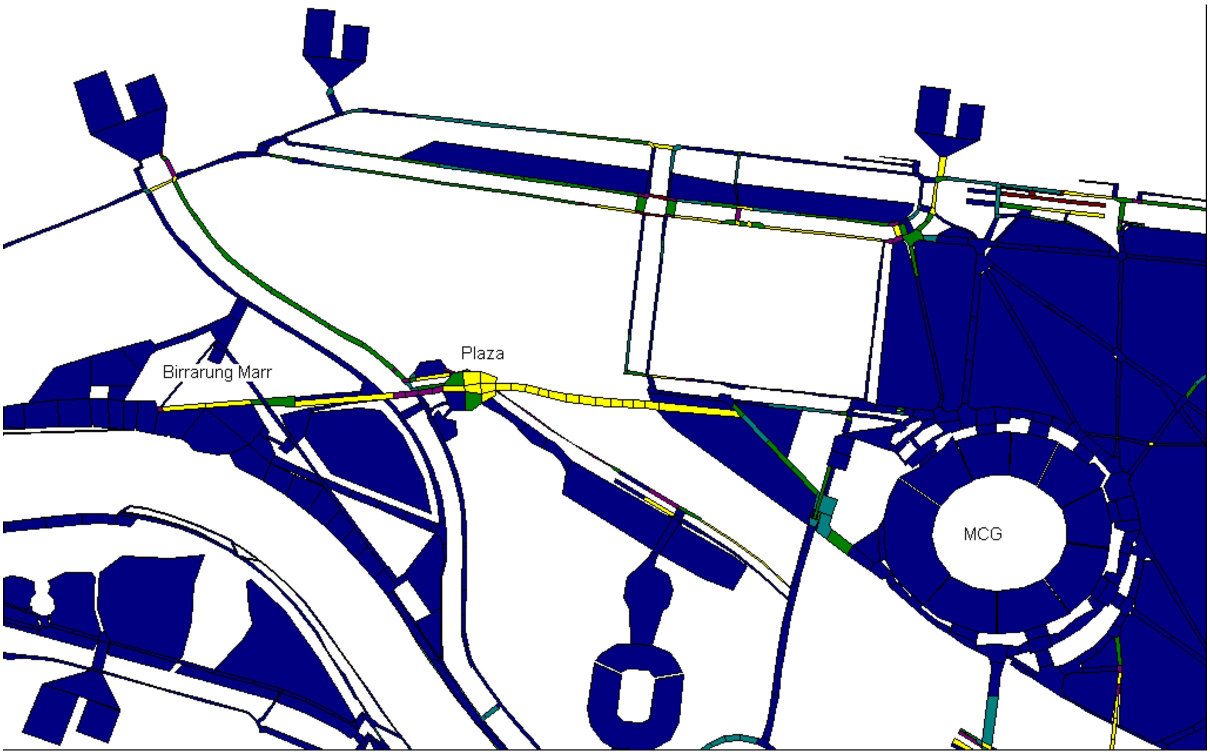

Figure 5 Level of service snapshot at 6:30pm for the Option 11b design

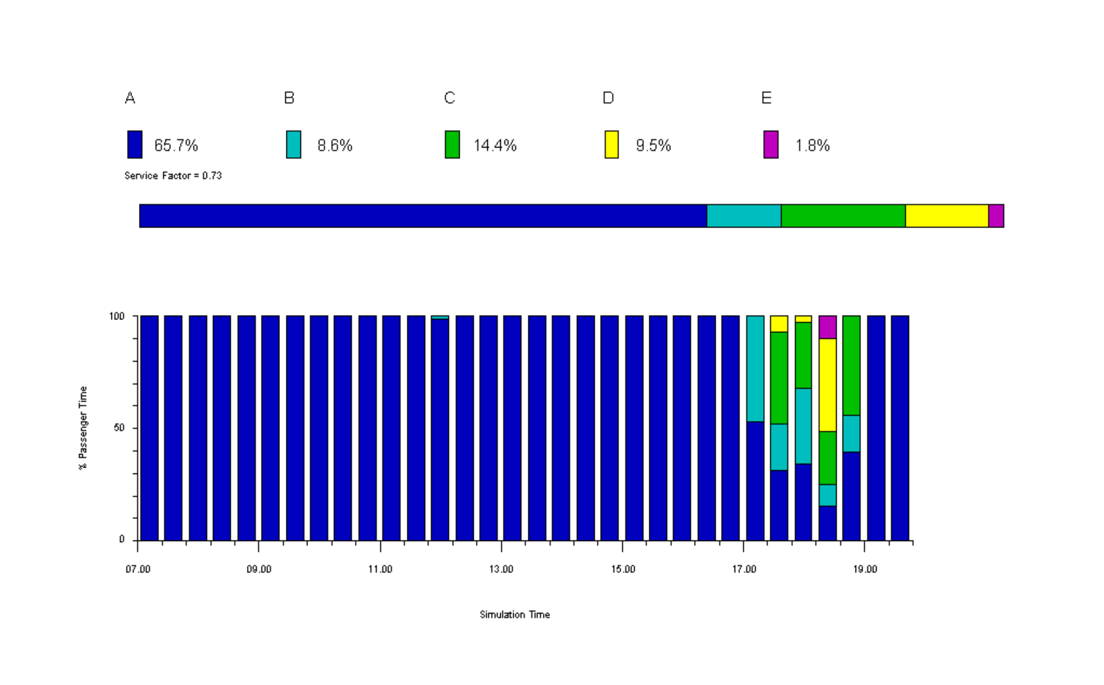

Figure 6 Level of service plot for west bridge span (Option 11b)

Validation techniques

Pedestrian models of special events are hard to validate, as in most cases there is little or no historic demand available. As the Commonwealth Games is a one-off event, no historic demand is available. For annual events such as the Grand Prix or Australian Open, previous demand data is available, however demand could fluctuate quite significantly from year to year, due to weather and also the interest in the event.

For the Commonwealth Games models, we have used several validation techniques to ensure that the results are sensible.

The first technique is a visual walkthrough of the model in operation. This was shown to an audience including experts in pedestrian movement who were not overly familiar with the configuration of the Sports and Entertainment Precinct and also people who were very familiar with the Precinct and the events schedule. This led to discussions regarding which behaviours were realistic for the Commonwealth Games environment. Videos of patrons going to and leaving the Australian Open tennis were also used in the validation.

The second technique was to model a smaller event from the Sports and Entertainment Precinct for which validation data was available. A model of an Australian Football League Grand Final was modelled and the arrival and departure profiles were validated against known data. The use of data from smaller and more frequent events was useful in showing that the modelling approach can produce realistic results.

Influence on planning process

The models demonstrated that a bridge was effective in encouraging pedestrians to travel to the CBD and reducing some load at Richmond Station. The different configurations assisted in choosing between very similar designs, along with consultation from other stakeholders in the area. The final choice was Option 12 and construction will begin in late 2004 (Melbourne 2006 (2004)).

Modelling was only one part of the planning process, however it played an important role by being able to provide some numerical indication of the effects on pedestrians of each scenario.

The future of pedestrian modelling

As the notion of “green” and environmentally sustainable travel becomes popular, more emphasis is being placed on providing better infrastructure and facilities for pedestrians. However, the only method of testing whether new infrastructure or facilities are going to be useful and economical is by using pedestrian models to test scenarios. Current models are sufficient, however some are lacking in some areas and some new methodologies may provide solutions to these problems.

Considerable research is being undertaken into realistically modelling pedestrian behaviours, especially in Europe. Special event modelling is often the driver of such research and special event scenarios are frequently used as demonstrations. This research will hopefully lead to models with more realism, flexibility and capability.

Issues with current models

Current modelling packages are sufficient for most models, however there are some basic and also far-fetched improvements that could be made.

- For traditional simulations, the number of people stopping at a food stall etc. is required as an input to the model. However there are times when this is either too specific or a stab in the dark.
- Some stakeholders were curious whether PAXPORT could tell us where the best place for a food stall etc. would be, however it cannot predict which areas would be more attractive than others.

Individual-based models

One method for representing the network is by using grids or cellular automata. Cellular automata (CA) have been used for investigating micro-level behaviours, such as crowd behaviour and single link flows. The cell-based nature of CAs produces good results for these small models, however in reality people move in a vector-like fashion, so this approach is rather limited. The software PedGo, used primarily for evacuation analysis and crowd behaviour, also uses a cellular automata approach (TraffGo 2004). Recent work on propagation of "forces" in crowds also used a cell-based approach (Henein and White 2004).

Agent-based models

Agent-based models use an agent as their basic unit. An agent is a software entity that is "situated" in an environment, where it can sense happenings and act accordingly. Agents act autonomously and can communicate with each other. This unit represents human behaviour quite well, in particular our decision-making skills. Several research projects have used agent-based modelling to model pedestrian behaviour with some success.

Haklay, O'Sullivan, Thurstain-Goodwin and Schelhorn (2001) are interested in pedestrian movement from a geography and urban planning viewpoint. This group created a model combining the agent modelling language SWARM with GIS, concentrating on movement in urban spaces. The model involves two stages, a pre-model stage where all the parameters are set and the actual model stage, and it models both microscopic and macroscopic behaviours. It makes use of socio-economic data to set up each person's characteristics and determine which locations they would be most likely to visit. An application of this model was a street festival in London, where one of the tasks was to evaluate ideas for a parade route choice.

Legion (2004) is proprietary software specialising in modelling crowd behaviour.
It treats each person as a "virtual person" who senses their environment and makes decisions about where to move accordingly. Applications include train stations, sporting events and evacuation scenarios. Legion was first developed by Still (2000) as a model of ingress and egress of crowds from events.

Kerridge, Hine, and Wigan (2001) use a time-based and agent-based simulation to investigate pedestrian behaviour. Each agent occupies a cell and decides where to move next based on where they are going and what they can see, so again both microscopic and macroscopic behaviours are modelled. Some advantages of this model are that it is based on a small set of parameters and a decision system which makes simulations easy to set up, it can model group behaviour and the outputs include both individual statistics as well as traditional model outputs.

Finally, Gloor, Cavens, Lange, Nagel, and Schmid (2003) describe a large-scale model that will be used to evaluate future scenarios in a tourist landscape. The techniques used include vision, arbitrary movement, and learning (ie. several pre-runs to build up knowledge). The issue of scalability is also discussed due to the large area covered by the model. This is a factor for special events modelling as the size of the area to be modelled can be quite large.

However, there are some issues with agent-based models:

- It is difficult to force agents to do things. For example, if we have a reasonable arrival profile that we want the model to match, as agents make their own decisions then it is difficult for the modellers to force the agents to arrive at a specified time.
- Due to their complexity, they are difficult to validate, difficult to debug and sometimes difficult to analyse.
- When modelling with agents, the modellers need to be especially clear about their assumptions, as they may end up inferring results that are incorrect and do not apply to the real-world system.

Conclusion

Special events, such as sporting events and carnivals, are an important part of today's society. They involve a large number of pedestrians converging on a sometimes small area for a short period of time, and therefore need to be planned carefully. Modelling is frequently used to test possible demand and infrastructure scenarios. The current state-of-the-art package is PAXPORT, which models macroscopic pedestrian movement.

This paper demonstrated the use of PAXPORT in modelling a special event, the Commonwealth Games in 2006. Once set up by experts, the model is easy to adapt, produces realistic results, and produces meaningful diagrams and plots that show exactly what is happening in the area. The results influence the planning decisions by giving indications of what may happen if certain scenarios arise or if new infrastructure is provided.

Further research into this area has identified agent-based modelling as a useful approach to pedestrian modelling, as agents have the capability to represent behaviours more realistically. The downside at this time is that the models are complex and difficult to validate.

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