THE USE OF ‘EMERGENT BEHAVIOUR SYSTEMS’ TO OPTIMISE ROAD NETWORKS FOR PEDESTRIAN AND CYCLING

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Abstract

Traditional traffic control systems tend to use a top down, hierarchical approach that can be effective in controlling motor vehicle traffic, but such approaches can be somewhat deficient when it comes to the management of the comparatively unpredictable behaviour of pedestrians and to a lesser extent, cyclists. The concept of ‘emergent behaviour systems’ (Johnson, 2002) uses the collective intelligence of individual members of a system to provide an overall ‘idealised’ demand management response. Using the City of Adelaide in Australia as a case study, the city centre for a modestly sized metropolis of 1.1 million people, this paper examines what changes to the local road system and local traffic monitoring would be needed to better provide for the needs of pedestrians and cyclists. Ultimately, the application of this new approach could be of substantial value to urban and transport planners in helping car dependent urban areas make the transition towards more environmentally sustainable modes of transport such as walking and cycling.

Keywords: emergent behaviour systems, pedestrians, cyclists, road networks, demand management
The use of ‘emergent behaviour systems’ to optimise road networks for pedestrian and cycling.

1 INTRODUCTION
Traffic engineering has well established research processes and modelling methodologies in place for anticipating future traffic demand and predicting the likely supply of transport infrastructure needed to cope with the related level of demand. The road network patterns of modern western cities such as Adelaide, the state capital of the state of South Australia in Australia and home to approximately 1.1 million people, clearly reflects the application of quantitative and positivist oriented research paradigms.

Roads are dimensioned with sufficient lanes to accommodate the traffic demand generated by Adelaide’s urban area and traffic control systems (predominantly in the form of signalised intersections) regulate and optimise intersecting and multi-directional traffic flows. Because of the volume of motor vehicle transport and the fact that motor vehicles travel at high speed (relative to other land surface modes of transport in urban areas such as cycling and walking), the design and provision of road infrastructure for them tends to assume maximum priority in the metropolitan transport task for Adelaide. This is despite the rhetoric expressed in strategic planning documents such as Adelaide’s Draft Strategic Transport Strategy and the city’s Planning Strategy that suggests that public transport, cycling and walking are the significant and appropriate transport modes to promote. Modern road networks are able to accurately measure and record traffic demand along through roads through road loop sensors and video. Moreover, on toll roads where vehicles have to be fitted with transponders that register their presence when passing through gantry sensors along the roadway which levy the toll, such as in Melbourne’s City Link toll system, the actual trip routing of individual vehicles can be determined. Global Positioning Satellite (GPS) Technology also has the potential to accurately plot individual vehicle trips, not just on toll roads, but on every road, regardless of its location. Nevertheless, although transport engineering and planning has all of the apparent accoutrements of a reliable, replicable scientific approach to problem solving, ultimately, traffic generation is a social phenomenon, which does introduce a measure of unpredictability in the process, particularly when it comes to the issue of discretionary travel for recreational trips. For example, higher fuel prices, a major social event or weather can influence social behaviour markedly in the way that people choose to take a trip, when to take it, how they take it, the routes chosen, or indeed whether they take a trip at all.

When it comes to predicting the travel routing, trip attraction and trip generation rates for pedestrians and to a lesser extent, cyclists, the quantitative methodologies that work well with dealing with fast flowing motor vehicles tend to be somewhat dysfunctional. This is because pedestrians
only move at 3-6 km/h and are able to cope with less specialised transport infrastructure for their needs, apart from being constrained with obvious barriers posed by walls, ditches or fast flowing unbroken traffic. Similarly, cyclists are not theoretically restricted to roads and they have a ‘go anywhere’ capability akin to pedestrians. For traffic planners and engineers, catering for pedestrians and cyclists in the city up to now has been more of a safety consideration than any real attempt at seriously evaluating their travel desires and practices in the city, with a view to optimising the efficiency of their travel patterns.

The unpredictability of pedestrian and cycling activity in city environments stems partly from behavioural considerations (ie why people make a trip at all and why they choose a particular route) and the fact that there is little effort or measurement capacity to quantify just how many pedestrians and cyclists are moving about the city in real time in the way that is done for motor vehicles on through traffic routes in metropolitan Adelaide. The upshot for this is that pedestrians and cyclists are largely left to their own wits to find their way around the city and they have to adapt to the nature of the infrastructure in which they find themselves in, which they obviously do. But why people choose particular routes to their destinations is a matter of some mystery to traffic engineers and planners and largely eludes conventional traffic engineering methodologies. Urban designers attempt to cater to pedestrians at least, by creating people activity points and a design aesthetic which includes architecturally appealing structures and landscaped open spaces that draws people into or along certain areas of the city. This suggests that control or at least influence over how pedestrians move in the city is viewed by urban designers as being a social and psychological phenomenon.

One way of attempting to rectify the short-comings associated with traditional traffic engineering and planning approaches in catering to the needs of pedestrians and cyclists, is the concept of ‘emergent behaviour networks’. The concept of ‘emergent behaviour systems’ is defined and its application to optimising pedestrian and cyclist urban transport networks is examined. A methodology based on ‘emergent behaviour systems’ is discussed in terms of how it would be used to provide better transport networks for pedestrians and cyclists. The paper concludes with discussion about the implications for planning policy and strategy, using the city of Adelaide as an example, of adapting ‘emergent behaviour systems’ in the research and design of pedestrian and cycling networks.

1 TRADITIONAL TRANSPORT MODELLING APPROACHES

Traditional transport modelling (Roess et. al., 2004) approaches usually attempt to determine traffic volumes, speeds, travel times and travel delays, traffic densities, traffic accidents, freight movements and pedestrian volumes. It is interesting to note that Roess et. al. (2004) in their Traffic Engineering handbook pose the issue of pedestrians as being part of the traffic system that traffic engineers manage, largely as it relates to their interaction with the
road system which is designed for motor vehicle traffic. Moreover, few traffic engineering textbooks devote much specific attention with regard to viewing the pedestrian and cyclist as having equal rights to motorists. It is perhaps not surprising, that in many cities, the transport network arrangements for pedestrians and cyclists appear to constitute an afterthought. Indeed, much Australian planning literature has lamented the negative externalities associated with excessive car usage in Australian cities, in particular, through landmark publications such as ‘Cities and Automobile Dependence’ (Newman & Kenworthy, 1989) and ‘Towards An Eco-City: Calming the Traffic’ (Engwicht, 1992).

Some transport modelling views the city’s transport systems and land use in an integrated manner, such as Tranus (De La Barra, 2001), which at least theoretically makes provision for a wide range of factors that contribute to trip activity to be taken into account, such as office employment, incomes, floor spaces of various activities, residences, trip modes and transport options. Tranus also has the capacity to predict various parameters of urban growth such as floor space, population, land requirements and energy usage by transport and buildings. It could be argued that with the appropriate input data from surveys of community travel behaviours, traditional modelling approaches should have the capacity to provide functional outcomes that are similar to the normal expectations of computerised transport models like Paramics which provide 3D simulations of alternative transport scenarios which are easily understood by the layperson. What existing modelling approaches do not do, with regard to pedestrians and cyclists, is in developing an understanding of how the aggregate and incremental travel decisions over time in a city’s population crystallise into defined and well travelled routes. A transport methodology that could do this would be much more responsive to the needs of pedestrians and cyclists and even users of other transport systems such as roads and public transit. Moreover, with appropriate planning and design approaches using this methodology, it could encourage more people to walk and cycle in our cities in preference to using environmentally harmful mechanised means of transport.

2 EMERGENT BEHAVIOUR SYSTEMS

Cities are excellent examples of emergent behaviour systems. Holland (1995) comments that:

“Cities have no central planning commissions that solve the problems of purchasing and distributing supplies….

How do these cities avoid the devastating swings between shortage and glut, year after year, decade after decade? The mystery deepens when we observe the kaleidoscopic nature of large cities. Buyers, sellers, administrations, streets, bridges, and buildings are always changing, so that a city’s coherence is somehow imposed on a perpetual flux of people and
structures. Like the standing wave in front of a rock in a fast-moving stream, a city is a pattern in time.”

In planning literature, Jane Jacobs’ (1961) ‘The Death and Life of Great American Cities’ recognised the value of ‘Emergent Behaviour Systems’, although it was not described as such in her lexicon. Jacobs focus was on the role of cities that she considered successful in facilitating and promoting community interactions on the street that created ever more complex behaviours that seemed to reinforce each other. Jacobs (1961) comments on how the city collectively manages to make the city safer:

“Under the seeming disorder of the old city, wherever the old city is working successfully, is a marvellous order for maintaining the safety of the streets and the freedom of the city. It is a complex order. Its essence is intimacy of sidewalk use, bringing with it a constant succession of eyes. This order is all composed of movement and change…The ballet of the good city sidewalk never repeats itself from place to place to place, and in any one place is always replete with new improvisations.”

Some of the characteristics of emergent behaviour systems are the notion that there is a complex system to begin with and that they are self organising. The local system has an intrinsic intelligence with feedback loops that create new behaviours or what might be termed ‘emergent behaviours’ (Johnson, 2001). An ant colony is a good metaphor for explaining the operation of such a system. In searching out food for the colony, individual ants leave pheromone trails for other ants to detect. These trails provide a feedback loop which indicates to other members of the colony where the optimum routes to a food supply are and this becomes part of the colony’s collective intelligence. Modern computer search engines such as Google are examples of computer software technology that apply the concept of ‘emergent behaviour systems where collective knowledge is used to map the quickest and most direct electronic pathway to a website, based on the previous behaviours of web users accessing the website in question.

With regard to travel behaviour, each person does not make a trip in isolation because at any one time, they share a transport network with hundreds, even tens of thousands of other travellers. The interconnected nature of a city’s transport network means that as trip densities rise on the network, the character of a trip will be influenced by the character of other travellers’ trips. For example, as congestion rises, all travellers using the transport network are affected by each new traveller using the network. Some individual travellers already using the transport network will respond to the externalities of other travellers joining the network with various adaptive behaviours. Some travellers will choose not to use a car next time and walk, cycle or take public transport. Others may decide to leave at a later time when congestion is less. Others may re-evaluate their trip purpose and choose alternative trips or not
travel at all. Still others with apparently little flexibility about travelling time, mode or travel destination may instead decide to car pool or improve the comfort of the journey with a better car. These collective coping strategies in the population lead to an optimisation of the operation of the transport network, at least within the existing personal constraints of travellers, society and the transport network. Admittedly, however, sometimes even this is not enough because the road networks in many large conurbations are still grid-locked with traffic.

The triggering events for major collective change in the travel behaviour of the population could be a dangerous or unpleasant situation such as being stuck on a freeway attempting to access a congested freeway off-ramp or it could be a well documented accident. The challenge for computer modelling is in attempting to predict why some individuals will modify their behaviour in response to environmental stresses whilst others are content to accept them. A further complication is in attempting to predict how people that are prepared to modify their behaviour in response to environmental stresses, is the manner in which they will respond. For example, in response to extreme congestion in morning rush hour traffic, will a motorist simply commute at an earlier time or will they catch the bus instead? Ultimately too, modellers will be concerned with how lasting the modified behaviour will be. Do travellers who switch to an alternative travel regime actually adapt to the different set of circumstances associated with an alternative travel scenario and then consciously and continually weigh up whether the travel experience is an improvement (aside from just the time and cost of the trip)? If the experience worsens, do they revisit the original travel arrangements? Adelaide City Council conducted an unintentional experiment with parking in 2004 by increasing on-street full day parking charges on the city centre fringe to a premium level higher than that of city centre parking stations. Commuters stayed away in droves, but even though the Council had reduced prices to a more acceptable commercial level, a year later, few commuters have returned. This anecdotal evidence suggests that whilst adaptive behaviour is a significant force, there can be substantial inertia in such systems.

The concept of emergent behaviour systems is detailed in equation 1, with equation (1) being a summary formula that describes the iterative nature of behaviour modification in each new trip over time that is made by a ‘traveller’ on a particular route for a transport network. Modern computing power would have the potential, assuming that appropriate input data is available, to show how transport network behaviour changes because of the increasing collective intelligence of the population of ‘travellers’ using the network with respect to time.

\[
TD = \sum R(1-n) \left[ \sum T(1-n) \left\{ \sum P(1-n) \right\} \right]
\] (1)
In equation (1), TD is a summation of total trip densities for all route segments R in a transport network; P represents each person in the population making a trip on the route segment in question; t (see equation (2)) is a function of various trips being made according to the range of probabilities contributing to a trip being made (as expressed in equations (3), (4) and (5)) with 1 being the maximum probability value for t; and T is the singular occurrence in time for each set of trips being made for each route segment.

\[
t = f\left(\sum p(PCT) + \sum p(PT) + \sum p(SPT))/3\right)
\]

In equation (2), PCT represents each ‘traveller’s’ trip planning considerations, such as when to travel, the destination, the mode, the speed to travel at, the trip purpose and route choice in the transport network.

\[
p(PCT)=\text{Set of probabilities for trip planning considerations} \tag{3}
\]

\[
p(PCT)=\text{Set of probabilities for past trip experiences contributing to a repeat trip} \tag{4}
\]

\[
p(PCT)=\text{Set of probabilities of total population’s past trip experiences contributing to a repeat trip} \tag{5}
\]

Indirectly, current transport demand management practices (ie for signal optimisation, public transit and freight tasks) and examples of intelligent transportation systems (network optimisation, in vehicle dynamic routing, electronic tolling, congestion pricing, incident detection and traffic enforcement), adopt feedback loops to reinforce what would result in optimal operation of the transport network, at least within the capacity, infrastructural and user constraints afforded by the transport network. In vehicle information systems and electronic message boards on highways are already in use around the world with a view to modifying the collective behaviour to change toward more optimal travel behaviour. The limitations of these systems, however, apart from there being obvious infrastructural constraints such as there only being one practical route between two locations, is that the traveller may have less than perfect knowledge to be able to make an informed judgment about whether modifying their travel behaviour will optimise their trip compared to not making any changes. However, if vehicle positions can be accurately positioned instantaneously using GPS and the road network is equipped with sufficient sensors to indicate the true state of traffic in the network, in-vehicle navigation computers can theoretically present the traveller with accurate information about the merits of various travel options (ie alternative routes), in terms of time, fuel usage, accident risk and trip smoothness (ie minimised stop-start travel). If every traveller is linked into a central computer coordinating traffic in the road network, then the
arrangement becomes an example of a sophisticated emergent behaviour network.

3 APPLYING EMERGENT BEHAVIOUR SYSTEMS TO NETWORKS FOR CYCLING AND WALKING

In the previous section, the concept of emergent behaviour systems was presented. It seems relatively easy to explain in a qualitative sense how emergent behaviour networks result in complex behaviours in an urban setting. Jacobs’ (1961) work draws attention to the liveliness of a successful urban street being that the unpredictability of people’s movements creates a unique experience in every instant of time. If a street can be dynamic like this, then people will revisit it time and time again, possibly adding new vitality on every occasion, the novelty of which encourages people to come back again and again.

Attempting to manipulate these feedback loops takes one into the realms of the social sciences and arts, because it becomes difficult to manage and monitor people’s walking and cycling activities, although employment, education and some organised activities do have some degree of predictability in their likelihood of trip generation, even for pedestrians and cyclists. Urban design theorists such as Lynch (1991), Jacobs (1961), Cullen (1990), Lozano (1990) and Gehl (2002), had a clear sense of what urban design principles and practices were likely to engender pedestrian activity in the city, but their ideas are in practice canny ‘rule of thumb’ insights derived from perceptive and imaginative observations of what seems to work and what doesn't work in cities. Sometimes this is backed up with empirical studies that show what people like or dislike about the city, but there is a lack of deep understanding with regard to how positive and negative feedback loops modify pedestrians’ travel behaviour as they move through a city’s pedestrian network in a real time context. Similarly, the same comments can be said to apply to cyclists. In other words, we quite often know the outcomes (i.e. where pedestrians seem to be), but not the processes and factors which seemed to have shaped pedestrian trips. It could be argued that for trips without a specific purpose, then attempting to predict the happenstance wanderings of pedestrians at leisure in search of serendipitous urban experiences could potentially be a somewhat daunting, if not impossible task.

Notwithstanding this, the transport network for pedestrians and cyclists is largely circumscribed, particularly in cities with car dominated transport infrastructure. In cities with mass public transit systems, pedestrian densities are monitored. Most cities are now also using video surveillance systems, ostensibly for personal security reasons in their public areas, which could conceivably also be modified to determine pedestrian densities and monitor pedestrian activity. The above and below ground pedestrian networks in many of the world’s larger cities which have been built either as public thoroughfares or to facilitate greater control of retailing activity (as is typical in the enclosed ‘Big Box’ shopping centres so favoured by the Westfield group of
Australia and the United States), are designed to constrain and channelise pedestrians. The exception to this is where the transport network becomes more of a fine grid where mixed land uses proliferate which offers a diverse range of urban experiences that encourages pedestrians to explore and seek out new experiences.

The equations defined in section 4 (1 to 5), equally apply to pedestrians and cyclists as they do to motor vehicle trips. What differs is the potential complexity and unpredictability of each pedestrian trip. Notwithstanding this, if some overriding principles are applied, such as that no matter what trip is made, that there is a trip purpose, a trip beginning and a trip destination, and there are land uses or activities which are trip generators, then all trips can be predicted. The challenge is in developing a methodology that can identify the data needs of such an approach (or at least derive suitable proxies) and in determining how feedback mechanisms provide either positive or negative reinforcement to pedestrian and cycling travel behaviour in an urban environment.

It would be tempting to suggest that modern GPS technology and the power of centralised computing could be applied to managing pedestrian and cycling activity in much the same way as the potential exists for motorised traffic to be controlled. Mobile phone technology, if combined with GPS technology, could theoretically position every pedestrian and cyclist in the city (assuming that they had this technology), which would allow feedback loops from each ‘traveller’ which can tap into the wider community consciousness about what was interesting or worth seeing in the city. Furthermore, such technology has the potential to allow pedestrians and cyclists to activate signalised crossing points at intersections to better respond to their needs. If more pedestrians are waiting to cross than motorists at a particular intersection, then the traffic management system could give priority to pedestrians. However, getting the general populace to accept such an imposition without tangible benefits to compensate for the resulting intrusion on personal privacy could prove to be an almost insurmountable challenge.

An alternative, but admittedly inferior technical solution is to adapt video surveillance capacity in a city environment, which at a crude level would respond to increased pedestrian densities and allow modification of the phasing of signalised intersections where pedestrians have to cross to better suit the needs of pedestrians. Video surveillance and entry sensors to retail areas would also allow activities or trip attractors to be identified which would assist planners in determining where better facilities are needed to adequately cater to pedestrians and/or cyclists. Admittedly, in the absence of any worthwhile trip attractor, pedestrians and cyclists will not appear. Hence, the use of emergent behaviour systems will not necessarily point planners and urban design professionals to what needs to be provided in a transport dysfunctional city environment. Nevertheless, the application of such an approach can provide powerful clues as to what works and what doesn’t work
in the city for pedestrians and cyclists, simply due to their presence or lack of presence in various parts of the transport network and by various land uses.

4 TOWARD A METHODOLOGY FOR OPTIMISING CITY TRANSPORT NETWORKS FOR CYCLING AND WALKING

In the case of Adelaide’s city centre, the study ‘Public Spaces and Public Life-City of Adelaide: 2002’ (Gehl, 2002) adopted conventional survey research methodologies to firstly provide an inventory of what facilities were available for pedestrians and cyclists and secondly, what their usage of these facilities were. Whilst useful, the approach is somewhat static and until a subsequent review is done which could be 5-10 years in the future, there is very little likelihood of a response to parts of the city’s transport network that in time are underperforming because there is not mechanism for feedback loops from pedestrians and cyclists. The exception is Adelaide’s central city retail area (figure 1), where a 600m long pedestrianised street known as Rundle Mall, utilises security video surveillance to coordinate police response to public disorder events and crime (figure 2). Interestingly, North Terrace, the main cultural boulevard for the City which is parallel with Rundle Mall one block to the north of it, lacks video surveillance, although informal surveillance is provided by passing motorists and waiting public bus passengers (figure 3). The concept of the approach described in the previous two sections of emergent behaviour systems does provide for dynamic and virtually instantaneous feedback from the users of the city’s transport network, which would allow for similarly rapid responses in managing traffic signals to optimise the safety and convenience for pedestrians.

Figure 1 Aerial view of Adelaide City Centre, looking south.
Figure 2 Rundle Mall, Adelaide, Australia (Source: Gehl, 2002)

Figure 3 North Terrace, Adelaide, Australia.
The aims driving the application of the ‘emergent behaviour concept’ are essentially twofold. Firstly, it can be viewed as a management tool designed to monitor current pedestrian and cycling activities and optimise traffic signal phasing where necessary to suit the needs of these groups. Secondly, over the longer term, the dynamic nature of this methodology would allow better strategic decisions to be made about the current provision of infrastructure in the city through long term observational studies about how people actually use the transport network.

The first step in making this happen would be to install video surveillance cameras at all signalised intersections where pedestrians cross. Ideally, every link of the transport network used by pedestrians or cyclists would have some form of video surveillance. A centralised computer would monitor pedestrian flows and densities throughout the transport network using the camera inputs from strategic locations such as at all signalised intersections. Computer software capable of monitoring pedestrian densities and movement would then be used to coordinate signal phasing to optimise accessibility for pedestrians.

Figure 4: Traffic and pedestrian activity with pedestrian crossing points for City of Adelaide, Australia
The use of GPS technology would require a targeted sample of survey participants over a sufficient period of time to see whether regular walking and cycling habits change over time. This may also need to be done in conjunction with a diary to highlight why a change in behaviour occurs, for example for trips between an office and a regular lunch venue. Over time, perhaps a period of a month, a survey participant’s particular trips (by type, such as the journey to work from the bus-stop to the office), would be mapped which would be followed up with interviews at the conclusion of the survey period to determine why the travel behaviour was modified for the particular route concerned. This could be compared with other survey participants in the sample to see whether there was a common or ‘emergent behaviour’ emerging. Interviews may also need to ask survey participants whether their modified behaviour related to the perceived behaviours and or experiences of other people who used the same area to walk or cycle in.

5 RECOMMENDATIONS FOR PLANNING AND DESIGN IN THE CITY

The Gehl Report for the City of Adelaide (Gehl, 2002) had as its focus the need to physically improve the city’s public spaces with particular emphasis on creating a better city for walking and for encouraging people to stay. The suggested recommendations included:

- Creating good walking routes;
- Creating pedestrian priority streets;
- Develop an integrated pedestrian network with a variety of pedestrian routes;
- Improve the ground floor frontages of buildings;
- Improve the north-south connections;
- Improve footpaths;
- Manage the acoustic environment;
- Improve the city’s squares;
- Link the city’s squares in with its pedestrian networks;
- Integrate functional and recreational pedestrian activities;
- Improve seating and resting opportunities; and
- Improve the play spaces for children.

As insightful and useful in its stock-take of pedestrian activity and city infrastructure as the Gehl report was, it only provides a snapshot of the City of Adelaide as it appeared in 2002. A ‘smart’ city for pedestrians and cyclists would have a traffic network management system that dynamically responds to the needs of pedestrians and cyclists in real time. It would also provide urban designers and transport planners with the tools to rapidly respond with infrastructure initiatives without the extra lead time that is usually required in conducting a new research study. This would require real time data input about the instantaneous positions of pedestrians every few seconds. Every link in the pedestrian and cycling network, particularly intersections, would be
monitored using video surveillance which would be linked to a central computer.

Over time, a database would emerge which would illustrate successful and less successful parts of the city from the perspective of pedestrian and cycling usage and traffic conflict incidents. Software automation could be used to generate automatic reports that indicate pedestrian and cycling activity, which the planning system would be required to take into account every time the City’s Development Plan is reviewed (usually every three years).

6 CONCLUSIONS

‘Emergent behaviour systems’ (EBS) as a methodology has the potential to improve our understanding of why people do or don’t use a transport system in real time. When combined with the use of intelligent transport systems technology which includes ‘in-vehicle’ driver communication systems, feedback loops from the users of the transport network allows even greater optimisation of a transport network to be achieved.

Similarly, the application of the concept of EBS to walking and cycling would allow dynamic mapping of how pedestrians and cyclists are actually using a city’s transport networks and allow urban and transport planners to identify which urban spaces and travel routes require remedial action. When EBS is combined with qualitative targeted surveys, thereby allowing feedback loops from pedestrians and cyclists to be tapped into, the tool becomes even more powerful in identifying particular strengths and weaknesses in the transport network. The use of EBS to manage an integrated approach to the optimal travel needs of both motor vehicle traffic and pedestrians and cyclists moves from the current notions of static planning and management strategies (which is particularly the case for pedestrians), to a dynamic planning and management strategy which exploits the enormous processing power of modern computers to simultaneously provide both the travellers and the transport network managers a greater sense of choice and control over the travel task, at least within the overall infrastructural constraints of the system.

The potential of EBS to produce continuous data streams of travel activity and the factors that influence travel choice every second for an indefinite period, means that the research lead time for the data procurement and analysis for new transport network projects can be kept to a minimum, thereby allowing urban and transport planners, urban designers and traffic engineers the opportunity to focus their energies on the design and implementation of new transport projects.
REFERENCES


Cullen, G. (1990), *The Concise Townscape*, Butterworth Architecture, Essex, United Kingdom


Engwicht, D. (1992), *Towards an Eco-City: Calming the Traffic*, Envirobook, Sydney, Australia


Quadstone, *Paramics* (Software Company), Edinburgh, United Kingdom
