

# Traffic microsimulation – dispelling the myths

By Steven Wood

Since its introduction in the 1990s microsimulation has changed the way traffic engineers approach modelling and test transport and traffic scenarios.

But despite its many advantages, microsimulation has also come under criticism in recent

years with a number of transport planners continue to regard microsimulation with suspicion, preferring to place their trust in conventional modelling systems that use more simplified, aggregate representations of flow and junction capacity.

One objection is that any attempt to model individual behaviour is flawed as we do not understand and cannot calibrate the controlling parameters. This paper considers this and other criticism alongside the progress of microsimulation since the 1990s.

## INTRODUCTION

When traffic microsimulation was first introduced commercially in the mid 1990s, it represented a significant advance in modelling. With its focus on vehicle behaviours and interactions on the network, and its ability to test scenarios and immediately see results through a virtual reality display, it was nothing short of a revolution.

Since that time traffic microsimulation (hereafter referred to as microsimulation) has advanced in leaps and bounds and has been used for a very wide variety of applications. It is used routinely to examine signalised roundabouts, bus priority, urban traffic control, ramp metering, traffic calming, wide area traffic management, road works design, car park location and control, pedestrian and cyclist interaction, traffic impact, incident management and traffic emissions. In short, it has been used in many circumstances where other modelling systems could not cope.

Few would dispute that microsimulation has transformed traffic modelling and revolutionised the way in which the results of modelling are presented to the outside world. To its proponents, the advantages of microsimulation are blindingly obvious, but microsimulation is not without its critics. The most fundamental objection is that any attempt to model individual behaviour is flawed as we do not understand and cannot calibrate the controlling parameters. To the adherents of traditional modelling, microsimulation models are perceived to be expensive, data hungry and almost impossible to validate.

This paper originated from the discussion on microsimulation modelling by the Transport Modellers Forum (TMF, formerly TraMPNet), the details of which were reported in the May 2012 edition of *Traffic Engineering and Control*. It addresses some of the most common criticisms that have been directed at microsimulation, both in terms of concept and application. By reference to a number of practical applications, this paper describes how microsimulation has been applied to tackle and confront issues that, due to their complexity, have been ignored by traditional modelling methods. It concludes by considering the need for better guidance for modellers, focusing on the purpose and application for which the model is required.

## WHAT IS MICROSIMULATION AND WHY USE IT?

Microsimulation differs from traditional highway assignment modelling methods in two distinct ways. Fundamentally, microsimulation models the actions and interactions of individual vehicles, in simulated time steps typically less than 1 second, as they travel through a road network. Traditional models on the other hand assign a matrix of trips to a network calculating average journey times across timeframes of 1 hour or more, using empirical relationships between flow and theoretical capacity. Through its focus on simulating individual vehicles, microsimulation is capable of providing a real time visual display, which represents the second key distinction compared to traditional models.

An underlying principle that underpins microsimulation is that the moving components in the system (i.e. the vehicles) perform according to their physical properties and constraints and the behavioural characteristics (aggression and awareness) of their drivers. In microsimulation the movement of individual vehicles is largely governed by three interacting models representing: vehicle following, gap acceptance and lane changing, The results of which vary according to the physical and behavioural attributes in each case.

By directly modelling the components of traffic flow instead of their mathematical proxy, microsimulation has provided a unified approach to traffic modelling that has opened up opportunities for modellers to tackle problems where conventional models were found wanting. Accordingly, microsimulation has been applied to a variety of applications ranging from the conventional to the more challenging. For example, microsimulation is ideally suited to model the characteristics of traffic flow on congested motorways, as this relies on an understanding of vehicle behaviour and interactions in order to replicate key flow characteristics such as flow breakdown and shock waves. Furthermore, microsimulation can portray the variable circumstances which lead to congestion in all types and sizes of road network.

The significant advances in the presentation and display of results through the provision of a real-time visual display and high resolution 3D graphics afforded by microsimulation has provided a powerful means to communicate the benefits of a scheme with stakeholders and the

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public. This contrasts with outputs from conventional models that take time to interpret and are often impenetrable to those outside the modelling profession. Furthermore, the interactive nature of microsimulation means that it is ideal for quick scenario testing and decision making, enabling the impacts of proposed design changes to be tested and the impacts visualised so that informed decisions can be made.

### MICROSIMULATION – WHAT THE CRITICS SAY

Over the past decade microsimulation has continued to develop and evolve and its application has spread significantly as transport planners have increasingly embraced it.

However, a number of transport planners continue to regard microsimulation with suspicion, preferring to place their trust in conventional modelling systems that use more simplified, aggregate representations of flow and junction capacity.

What lies behind the resistance to microsimulation? The main objections to microsimulation can be divided into two categories. The first relates to the concept of microsimulation. To these critics the principle of attempting to model individual vehicle dynamics is flawed and lacking in integrity. This line of argument contends that the factors influencing vehicle behaviour and dynamics are insufficiently understood, difficult to calibrate and cannot be reliably modelled. The second category covers a number of perceived practical issues in developing and applying microsimulation models. For example, these could include concerns over high model development costs or difficulties in model calibration.

What is, perhaps, revealing is the absence of any constructive and detailed critique of microsimulation beyond the verbal hearsay. While researching this article the author was surprised to find very little in the way of published material on the trials and tribulations of microsimulation modelling. What is apparent though is that a number of misleading and false perceptions undoubtedly exist as many microsimulation modellers are likely to testify.

The charges levelled against microsimulation that are presented in this paper have been drawn from the author's experiences over the past 10 years or so in projects covering a range of microsimulation models and applications. The list is by no means exhaustive, but it is hoped that many of the topics raised will resonate with other practitioners as it is likely that similar experiences will have been encountered.

### MICROSIMULATION – WHAT'S WRONG WITH THE CONCEPT

In an article published in TEC in 1998 Stephen Druitt wryly observed

*If we never had had a system of traffic modelling, and were to start inventing something today, what would we come up with? It is difficult to imagine that this would not be centred on the modelling of individual vehicle movements as in contemporary microsimulation.*

Yet, some 14 years later, and after thousands of microsimulation models have been developed and applied to problems, including many that could only be solved using the principles of simulating individual vehicle movements, pockets of resistance remain.

To these critics the core issue relates to the acceptance of vehicle behaviours and dynamics as a basis for modelling. This objection is related to what they would regard as our poor understanding of these complex relationships, and stems from an absence of empirical evidence and pub-

lished research. These critics argue that the relationships that determine vehicle behaviour including driver awareness and aggression should be calibrated to local conditions for the models to have any validity. As this is unlikely ever to be practical, as it would impose such time and cost penalties, the implication is that we should abandon microsimulation and restore our faith in the tried and tested relationships between speed and flow and volume and capacity that have served us so well.

The distribution of levels of aggression and awareness are derived from national characteristics and can be varied in the simulation using local data if it is felt necessary to take account of specific circumstances. For example, local data could be desirable for locations where aggressive driving behaviour typically occurs, such as the M25 and may assist in the model calibration process. However, practical experience has shown that for the majority of models the use of default values for aggression and awareness is perfectly sufficient.

Even if we were to concede that the behavioural relationships that underpin microsimulation modelling are difficult to measure, should the next logical step be to ignore these behaviours completely? Just because they might not be capable of definition with infinite precision is no argument for denying their importance.

There seems to be double standards at work here. Take speed flow curves, so cherished by the traditionalists. True, speed flow relationships are intuitive and can be readily understood and since they have been in use since the dawn of transport modelling, have all too readily been accepted without challenge. While the form of the speed flow relationship used in the model will have a critical impact on the projected changes in future demand, in reality, there is no reason to assume that any of the "off the shelf" speed-flow curves will be capable of representing local observed conditions and there is no requirement for speed flow curves to be calibrated using local data.

Based on, often long-term historic, research that rarely, if ever, is subject to scrutiny, the deterministic methodologies employed by traditional traffic planning software provide little or no scope to accommodate the behavioural characteristics of congested networks. What sets microsimulation apart from conventional models is a focus on the representation of individual movements where behaviour is influenced by individuals' responses to the prevailing geometric layout and traffic conditions. This can understandably appear challenging or unnerving to traditionalists and accounts for the most frequently cited criticism that we do not know enough about these behaviours to be able to model them.

All models by definition are a simplification of reality, but microsimulation offers a unified approach to traffic modelling that models the detail directly. By doing so, it ensures higher standards of representation and integrity with results that are likely to be closer to reality.

### THE PRACTICAL OBJECTIONS

This section addresses some of the criticisms that have been directed at microsimulation that relate to its practical application. As noted, very often resistance to embracing microsimulation arises from a number of pre-conceptions rather than from direct experience of developing models. This section considers the factors that are most often cited as reasons for rejecting a microsimulation based approach.

#### Microsimulation Models Are Expensive To Build

The view that microsimulation models are more costly to develop than conventional models arises from a percep-

tion that microsimulation models are more complex and time consuming to develop than traditional models and data requirements are more onerous. This, it is assumed, results in higher staff and survey costs for a comparable non microsimulation based model.

When comparing costs between conventional and microsimulation models the importance of model purpose becomes paramount. There is no reason why the data and model development costs for microsimulation based models should not be similar to traditional models if they are developed to a common specification. The key issue here is as microsimulation is capable of supporting a higher level of detailed analysis than conventional models the specification for the model is likely to take advantage of the advanced features within microsimulation. For example, if a detailed analysis of flow is required (e.g. by lane or vehicle type) or 3D streetscaping is included, this is likely to incur additional costs. As these features are not generally supported by traditional models they should legitimately be considered as optional extras.

The use of flow profiles within microsimulation is often cited as a reason why microsimulation models are data hungry and costly to develop. Flow profiles provide a means of profiling the volume of vehicles released onto a network over a peak period and can be specified for each O/D pair and for short time intervals such as 5 minutes. They can be used to distinguish between different peak profiles within different parts of a study area that, in certain circumstances, could be critical in representing local flow characteristics, thereby improving the accuracy and reliability of the model.

Flow profiles are often considered to result in increased data collection costs, however, as flow profiles can be readily developed from ATC or MCC and queue data collected for model calibration/validation this should not normally result in additional data collection costs. Furthermore, by providing a more accurate representation of flow characteristics, it could reasonably be argued that adopting flow profiles reduces the time spent on model validation thereby contributing to a reduction in costs.

There is little by way of hard evidence to demonstrate the comparative costs of microsimulation based and conventional models. This may be largely due to commercial confidentiality, but is also compounded by the fact that microsimulation models are more typically applied to provide a more detailed analysis, so are developed to a higher specification, making a like for like comparison challenging.

### Microsimulation Models Are Impossible To Calibrate

The key determinant of a successful model calibration is having the observed data to support it. This applies equally to conventional models and microsimulation based models. If a microsimulation model is being used to support a highly complex application, for example, to model the merge/weave movements on a motorway, then observed data will be essential to provide an accurate representation of vehicle behaviour and hence to calibrate the model to local conditions.

This point is well illustrated by an S-Paramics microsimulation model developed to assess design options for Junction 15 of the M25 specifically for the M4 eastbound diverge and M25 northbound merge (illustrated in Figure 1).

To provide confidence in the detailed design required a very detailed model that included validation of the vehicle flows and speeds by lane. A comparison of the ob-



Figure 1 : M25 J15 Model Study Area

served and modelled flows and link speeds for the M4 eastbound flow approaching M25 J15 for Lane 1 (inside lane) is shown in Figures 2 and 3 respectively.

The modelling of vehicle behaviour was considered essential for this study in order to reflect "cause and effect" that produces the familiar shock wave phenomenon of congested motorways. This calibration was successfully achieved and demonstrated that microsimulation was the only modelling tool capable of meeting the exacting requirements for the project.

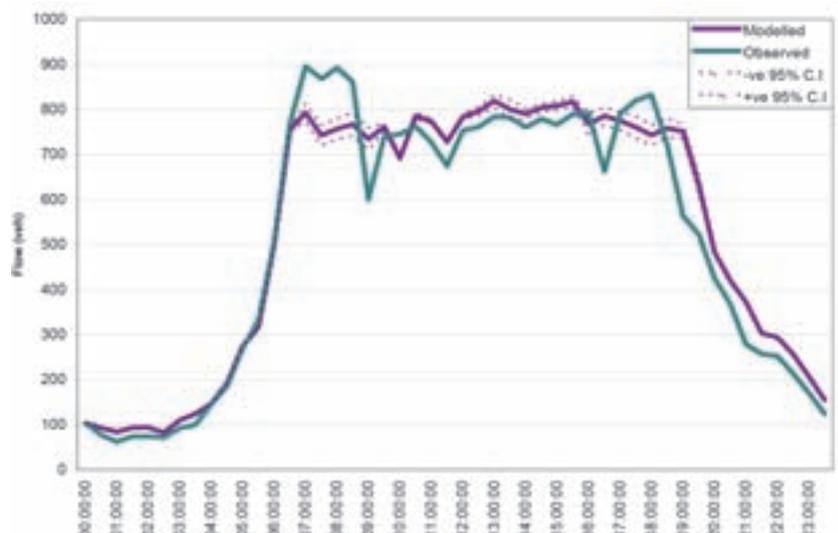
As noted, microsimulation is typically applied to test the more complex situations where the representation of vehicle behavioural characteristics and dynamics is vital. In these circumstances it is hardly surprising that calibration is often a challenging process, but made easier by data specifically tailored to meet the task.

In short, attempting to calibrate any model whether traditional or microsimulation based without the right data to support it is doomed to failure.

### Microsimulation Is Only For Single Junctions Or Small Corridors

The term "microsimulation" was originally conceived and applied to denote an attention to analytical detail. Regrettably, the term has often been misunderstood and taken to mean "simulation of a very small area only" and largely explains the misconception that microsimulation is un-

Figure 2 : Link Flow Validation M4 W of M25 (eastbound)



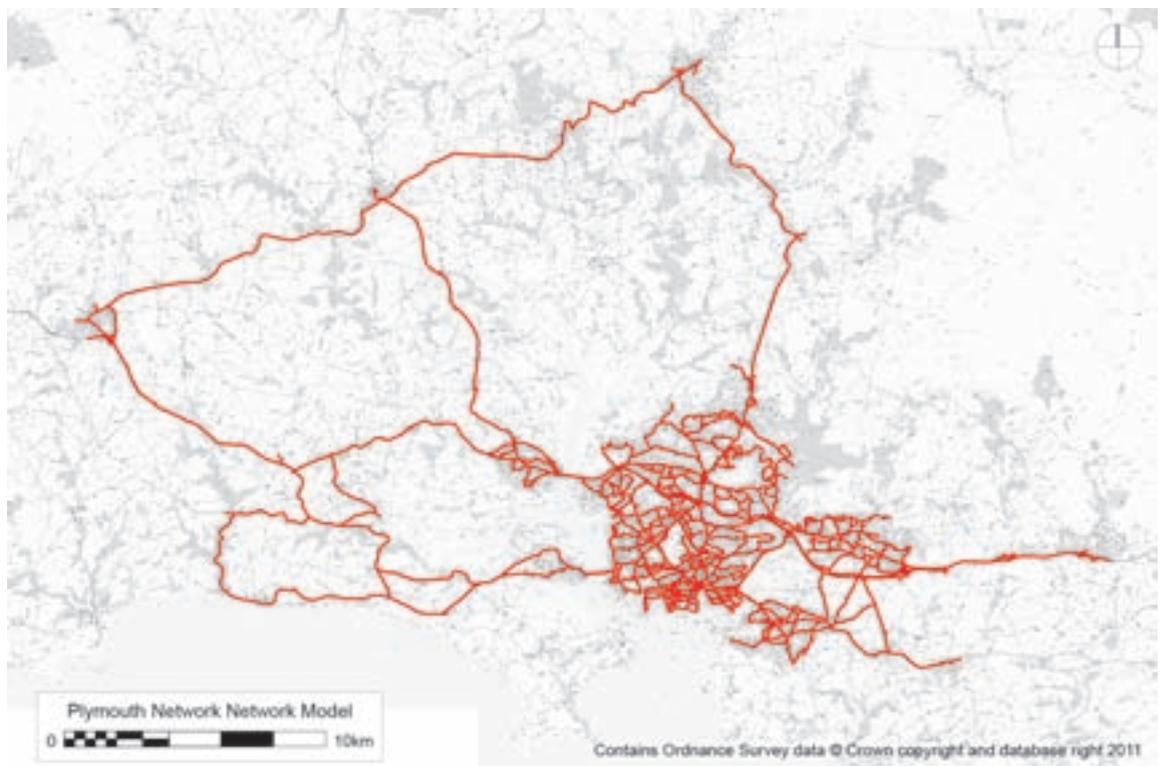


**Figure 3 : Link Speed Validation M4 W of M25 (eastbound)**

suitable for modelling anything larger than smaller networks of linked junctions or corridors.

From the very start of microsimulation being used on a commercial basis from the late 90s onwards, it has been applied for modelling the full spectrum of road networks ranging from individual junctions to wide area problems of rural and urban congestion. Its versatility is well demonstrated through its application on a wide range of projects including motorway management, wide area studies, emissions modelling, traffic management and event planning, economic appraisal, transport assessments and road scheme design.

The Plymouth Travel to Work Area model (TTWA) is an early example of microsimulation being applied on a wide area basis. Developed for Plymouth City Council (PCC) in 2002 to assess a number of major re-development proposals across the city, the model encompasses the whole of the city and extends to Liskeard, Tavistock and Ivybridge. The extent of the study area is shown in Figure 4.



**Figure 4 : Plymouth TTWA Model Study Area**

The trip matrices were initially derived from a strategic SATURN model, but were subsequently updated and the model re-validated to DMRB standards.

The TTWA model has enabled PCC to take a holistic approach towards traffic impact assessment and traffic management, bearing in mind that local evaluations undertaken for new developments can be of questionable value in congested road networks. It provided a means to assess developments within the entire area using a common framework, enabling the transport planning priorities, phasing, impacts and application of ameliorative measures, to be assessed and applied.

### Microsimulation Cannot Do Assignment

The belief that microsimulation did not have the capability to carry out an assignment is thankfully less prevalent than it once was. The assignment of traffic to a network has been a feature of some microsimulation software packages right from the start. In other microsimulation packages, assignment is undertaken by means of an interface with external software.

Microsimulation can typically undertake all-or-nothing, stochastic and dynamic methods of assignment and there is now a proven track record of such techniques being successfully employed in microsimulation for well over a decade. However, the fact that the concept of convergent equilibrium assignment is not necessarily adopted in microsimulation continues to concern some traditionalists. The fact that microsimulation recognises and embraces variability as opposed to seeking a precise mathematical solution remains one of the defining issues that distinguishes microsimulation from conventional modelling.

### Microsimulation Cannot Cope With Overcapacity

How often have you heard the claim “When I ran a 2030 scenario, microsimulation did not work?”... or words to similar effect? When demand is well in excess of the capacity of the network, microsimulation models may result in “gridlocked” networks and any attempt to try and analyse conditions becomes a fruitless exercise.

Where problems have arisen in attempting to model future growth scenarios with microsimulation, more often than not this has been the result of applying growth in line with NTEM or NRTF without question. When the model falls over the software is frequently assumed to be at fault.

Deterministic modes are far more forgiving than microsimulation when it comes to modelling congested networks. Conventional models typically assign traffic onto a congested network through multiple iterations. After each assignment iteration the link speeds and junction capacities are modified and then used for the next iteration. The model is then run for a number of further iterations until convergence is achieved. While this may conveniently produce a forecasting solution without “gridlocking” it is important that the modeller should not be lured into a false sense of security. In other words just because convergence has been achieved this should not be taken that you have best forecasting solution.

Furthermore, in conventional models link speeds and junction capacities are calculated from flows that represent an average in a pre-determined modelled time period, typically one hour for a peak period, as the calculated speeds and capacities are average values across the modelled time period. The main difficulty with using average values is that they do not take account of the variations in flows in a peak period, so do not reflect the important variations of link speeds and journey times that normally occur in congested urban networks. Most significantly, the peak journey times will not be reflected. This could for example be particularly important in representing school trips that tend to occur within a narrow time period, but can significantly increase flows.

It follows that while traditional models may provide a convenient solution to the over-capacity problem, this may ultimately prove very deceptive. In microsimulation, if the model gridlocks, this indicates that one or more of the assumptions are likely to be wrong. Better to review your growth rates, ask whether they are achievable and if not, decide whether the adoption of variable demand is the right thing to do. Without microsimulation, there may be no way of knowing that there was ever a problem!

### Microsimulation Models Produce Results That Are Too Variable

The charge that microsimulation models are volatile and can produce wide variations in flows between successive model runs is frequently made by advocates of deterministic models that they would claim provide a greater certainty of outcome.

Microsimulation accepts that traffic is by its nature variable and makes no attempt to conceal it. Modellers adopt microsimulation because they consider its representation of traffic flow and congestion are closer to real world conditions, and are not surprised when successive runs of the same model produce a range of results.

Microsimulation systems reflect the fact that traffic flow changes from day to day on the same journey and can report on the effects of a scheme taking into account these fluctuating conditions. For example, the time we leave home for work, can at best be stated to most likely fall within a ten minute window. A microsimulation model can accommodate this for every journey, and, along with many of the events which might happen on that journey, provide the ability to model a range of scenarios that could happen in reality. The variability across multiple model runs is an approximation to the variability that exists in the real world.

Variability is reflected through the use of random num-

bers that are used to determine the allocation of certain characteristics, including driver behaviour, to each vehicle and the exact time vehicles enter the road network. Each different random number seed will cause a different set of outputs to be produced so that every time the model is run, a unique stream of random numbers is used to govern events in that run.

Critics of microsimulation often mistake model variability for instability. For the purpose of definition, instability is taken to imply significant changes in costs between successive model runs that results in wide variations in flows and routes taken by vehicles on the network. It is true that in certain circumstances, microsimulation models can exhibit volatility, but volatility is often a feature of real life conditions. For example, in heavily congested conditions where the network is close to capacity there is often significant fluctuations in routeing. If the network is volatile then the model ought to reflect this and only microsimulation provides the means to do it.

It is recognised that where models are used to provide inputs to scheme evaluation, the importance of understanding the underlying variability of results is of particular importance. In order to help in assessing the significance of the variability within microsimulation model outputs, in term of the implications for scheme design and evaluation, a procedure has been developed that analyses the statistical significant of variability (How to reduce the gambling element in some transport planning decisions, Emily Seaman, TEC, June 2006). This is based on carrying out multiple runs of the simulation model to determine whether this provides enough data to determine whether we can be 95% confident that the true average journey time (or flow) lies between the calculated average (from the model runs) plus or minus 10%.

For heavily congested models, the variability across model runs is likely to be high and a large number of runs may be required to satisfy the criteria. Smaller models with less route choice will require a much lower number of runs.

Deterministic models tend to produce single number answers often based on convergent, iterative assignment procedures. Because it does not exist in reality, the concept of assignment convergence does not exist with microsimulation. Microsimulation is an inherently stable methodology, but the analysis of output variability gives the modeller the opportunity to compare this with observed data variability and hence arrive at a statistically sound conclusion in which there can be confidence in the model's validation and forecasts.

### A LEVEL PLAYING FIELD

Practitioners of microsimulation are likely to agree that the burden of proof required to demonstrate that a model is fit for purpose is generally higher for microsimulation based models. As such they tend to be subject to levels of scrutiny well beyond that demanded for conventional models. This is understandable in cases where microsimulation models have been developed to tackle more complex problems from which other models would tend to shy away, but standards should apply based upon the application, rather than the modelling software. This should result in the more specialised applications being subject to a more rigorous auditing process to demonstrate that the complex traffic behaviours and characteristics are being fully reflected.

A further reason for the higher burden of proof models stems from the absence of guidance available to auditors that is specifically tailored to microsimulation models. The guidance issued by the DfT through WebTAG is heavily biased towards deterministic models which emphasises the

importance of achieving equilibrium, however, the latest guidance on Highway Assignment Modelling contained in TAG Unit 3.19 (issued as a draft in May 2012) does at least acknowledge "the concepts of equilibrium and convergence are difficult under such conditions and stability becomes a more crucial concern for micro-simulation based assignments". Further guidance on what might constitute an acceptable measure of stability is eagerly awaited.

There is no doubt, that the development of smarter guidance, designed for use by auditors, that adequately reflects current best practice, will greatly assist in dispelling some of the misconceptions that have grown up around microsimulation. It is hoped that this will provide a more objective basis for determining "fitness for purpose".

### CONCLUSIONS

Microsimulation has transformed and revolutionised transport modelling over the past 15 years, setting new standards for the presentation and analysis of results. It has pushed back the frontiers of contemporary modelling and opened up opportunities for solving problems that were incapable of being tackled by modelling systems designed to address issues of an earlier age.

Yet, for all its achievements, microsimulation still struggles to win universal acceptance and continues to be viewed with suspicion and even hostility amongst loyal adherents of conventional modelling approaches.

There will always be the traditionalists who will remain stubbornly resistant to the advance of microsimulation. They will continue to place their faith in tried and tested deterministic approaches that provide a mathematically precise solution but one that conveniently ignores the un-

derlying variability that occurs in real life. It is unlikely that these will ever be won over.

There remains a number of misconceptions that have often resulted in an inaccurate representation and sometimes highly misleading impression of microsimulation that has not helped its cause. It is these issues that this paper has sought to address.

It is fair to say that the various practical objections to microsimulation that are addressed in this paper largely stem from a partial appreciation and limited experience of microsimulation. It is incumbent on experienced practitioners to spread good practice and to promote a better understanding of what microsimulation is all about and what it can do.

Most important, is a need to ensure that any guidance issued to assist either practitioner or auditor avoids any of these pitfalls. This will mean reflecting current best practice and keeping up with advances in microsimulation modelling that is constantly evolving.

There is no doubt that the misrepresentations that microsimulation has had to endure have been a source of continued frustration to those who have championed its cause, and it is right that the myths should be challenged. It is to these defenders of the faith that this paper is dedicated.

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