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Erratum

The publisher regrets that the following "Introduction" did not appear in the special issue of *Networks and Spatial Economics*, vol. 3, no. 3, which is titled "Dynamic Traffic Assignment II" and guest edited by Malachy Carey and David Watling.

Introduction to a Special Issue of Networks and Spatial Economics on dynamic traffic assignment

This is a second special issue on dynamic assignment for traffic networks (DTA), the first being Issue 3/4 in Volume 1, 2001, edited by Srinivas Peeta and Athanasios Ziliaskopoulos. That issue contained a lengthy introductory article by the editors on dynamic traffic assignment, past, present and future, hence we will not embark on such a survey here. The papers in the present issue are diverse in their coverage of issues and approach to DTA, which reflects the diversity of issues and approaches in DTA in general.

With static traffic assignment a relatively 'simple' widely accepted set of models was developed, including models for user equilibrium and system optimum, with origin-destination demands being either fixed or price elastic, and with multiple origins, destinations and traffic types. In the early days of DTA it seems to have been expected that an analogous set of simple classic models would be developed for DTA. However, efforts to extend the static network models to time-varying traffic have found this to be a much greater challenge than anticipated, in terms of both technical complexity and the range of issues that are raised. It is instructive to here note some of the reasons for these difficulties. In doing this, we assume that, as with static assignment, the problem is to be formulated as an optimisation problem, or complementarity problem, or variational inequality problem, or some such approach in which the assignment of each user is determined not just by local conditions but by conditions and costs over all routes open to the user. These approaches are sometimes referred to as 'analytical' approaches, in contrast to simulation approaches, though the term is not very satisfactory. We briefly comment later on simulation approaches.

First, even without introducing any new features, capturing road traffic flows over time as well as space on a network has proven difficult. For example, the link travel times can not be stated as a simple function of link flow, as in static assignment, since the link inflow and outflow per unit time differ: if they are the same, we have a static model. Also, it might seem that a natural approach would be to formulate the problem as a space-time extended network, and use the extensive literature on dynamic transportation models. However, if link travel times depend on link usage, then the link travel times are endogenous to the problem, hence the time-lengths of the time-space links are endogenous, so that a time-space network can not be constructed in advance but would have to be repeatedly revised in the course of a solution process. To retain tractability, most DTA modelling has retained a spatial network (but not a temporal network) and, to model traffic flow on each link of the network, has used a simple ‘whole-link’ model, treating the link travel time or exit flow rate as a function of the number of vehicles on the link. This is an approximation since, when flows are varying over time, the link travel time and exit rate must in reality depend on the flow and density varying all along the link but, as noted, that has usually been excluded in the interest of tractability. This in turn has led to various criticisms of the ‘whole link’ approach. A further difficulty often arises in ensuring that traffic exits from a link or path in the time order in which it entered (FIFO), which by definition is not an issue in static models. In some models FIFO requires restrictions that would not be otherwise desirable, and has often been difficult to prove or analyse. Incidentally, the reason for enforcing FIFO is sometimes misunderstood. It is introduced to prevent a model from generating trafffic overtaking and passing (FIFO violation) that is not related to any real world behaviour of traffic: overtaking and passing behaviour would need to be explicitly and properly modelled. For example, if with time-varying flows we (unrealistically) let the travel time on a link be an increasing function of only the inflow rate, then a sudden fall in the inflow rate will cause a sudden fall in travel time, so that traffic now entering may exit before traffic that entered earlier, hence violating FIFO, though this is certainly not how real traffic would respond to a fall in the inflow rate.

A second set of reasons why extending from static to dynamic assignment raised difficulties is that formulating a DTA model immediately suggested trying to capture other features of traffic (as well as time-varying flow) that had not been not possible in static models, for example, choice of departure and/or arrival times, traffic controls, time-varying queues and spillback. All of these inherently involve variation over time and hence were unknown in purely static traffic assignment. For example, in the static case, if route choice is fixed, the remaining problem is simple, whereas in the dynamic case, even with route choice and departure times fixed, the problem reduces to the so-called dynamic network loading problem, which has attracted much research and is still a substantial problem. A second example is that in reality queues involve spill back, which shortens the travel part of the link and may spill back to prior links. To avoid this complexity, queues are often represented as vertical or point queues, which is not always satisfactory for road traffic. A further important feature in purely static assignment models is that the link travel time is assumed to be a nondecreasing function of the link flow, thus excluding a ‘backward bending’ travel time function or a downward sloping flow-density function. That is reasonable in a static equilibrium context, but in a dynamic context it excludes what is usually referred to in traffic engineering and traffic flow theory as congested traffic, and is referred to in the economics literature as hypercongested traffic.

A third set of reasons why extending from static to dynamic assignment raised difficulties is that, at about the same time DTA models were being developed, there arose a range of new issues and problems to which DTA models could be applied, and which indeed seem to demand DTA modelling. For example, advances in electronics and communications made possible various forms of on-board driver information, route guidance, navigation systems and IVHS (intelligent vehicle and highway systems). These, require real time forecasts of traffic distribution hence real-time DTA models. The complex behavioural responses that may be elicited from such information systems has in turn led to serious challenges to the whole equilibrium philosophy upon which traditional static and dynamic network modeling has been based. These have led to an increasing interest in dynamics not just of a within-day nature, but also those that occur between days, such as drivers learning behaviour over time, habitual decisions, day-to-day adjustment, disequilibrium behaviour, and the notion that even ‘stable’ networks exhibit daily fluctuations in flows and travel time. This in turn has led to an interest in applying the theories of deterministic dynamical systems and stochastic processes to transportation network problems.

In the preceding three paragraphs the focus has not been on simulation type models for DTA. In recent years there have been dozens of microsimulation models developed for traffic flows. Most of these are concerned with single links, freeways, roundabouts or intersections, and only a minority are concerned with traffic assignment on a network. The latter encounter most of the difficulties outlined in preceding paragraphs, with the following qualifications. Microsimulation models can usually handle nonlinearities, nonconvexities, discontinuities, feedback, etc., relatively easily, hence have advantages when very detailed modelling of vehicle interactions is desired. In contrast, in so-called analytic models these features can cause computational or analytical difficulties or cause the model to lose its desirable properties. On the other hand, analytic models usually have important advantages in proving existence or uniqueness of solutions, and in determining properties of solutions, such as user equilibrium or system optimum, hence in obtaining optimal congestion prices, optimal controls, etc.: all of these tend to be more difficult or impossible for simulation models.

In response to the above challenges and difficulties in DTA, a range of models and approaches have been developed, depending on the problems, issues or environments addressed, the level of detail needed and the assumptions made. The diversity seems to be increasing, in contrast to the ‘one size fits all’ or unified models that had been expected in the earlier days of DTA modelling. This is perhaps not surprising, having also occurred in other fields in natural and social sciences and engineering. The five papers in this issue reflect this diversity of research in DTA.

The paper by Ennio Cascetta and Pierluigi Coppola outlines and classifies the range of network models for DTA that have been proposed in the last two decades, focusing on continuous, nonscheduled, services such as road traffic. The models are reviewed and classified according to assumptions on the flow structure (continuous or discrete) and representation of time (continuous or discrete). They present a general modeling framework that embraces most of the existing specifications both for the discrete-time, discrete-flow and continuous time, continuous flow cases.

The paper by Nicholas Taylor, gives an up-to-date exposition of the CONTRAM model or modelling system for DTA. It is of particular interest since it appears to be the longest standing model for dynamic traffic assignment and has been regularly extended and developed for more than twenty years and is in use in several countries. Its distinctive approach is to combine a form of microscopic simulation of traffic quanta, called ‘packets’ by analogy with communications networks, with a macroscopic time-dependent traffic model.

The paper by William Lam and Hai-Jun Huang argues that to understand and predict travel demand and traffic flow it is necessary to explicitly include the various activities for which people travel, and how these relate to the spatial and institutional organization of an urban area. They develop two models, one for longer term planning and one for shorter term traffic management, with the latter including equilibrium activity location, route and departure time choices in queuing networks. The proposed activity related approaches suggest one of the directions for development of DTA.

The paper by David Watling and Martin Hazelton focuses on the modeling of day-to-day dynamics in a within-day static environment. In particular, it presents a simple introduction to dynamical systems of route adjustment, and explains the conceptual issues that arise in the transition from a traditional framework of static equilibrium. The review ranges over perturbation approaches to equilibria, deterministic dynamical systems, and stochastic processes.

The paper by Yurii Nesterov and Andre de Palma introduces a class of models that they interpret as the stationary regimes of dynamic processes. These models, which they refer to as 'stable dynamics' models, lie between the widely used static assignment models on the one hand and the recently developed dynamic assignment models on the other. They describe this stable dynamics approach for a general network and use it to give a dynamic explanation of the static solutions.

We hope that this special issue will be useful to new entrants to the field as well as to those currently involved in DTA research.

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