1. Introduction

1.1 BACKGROUND AND PURPOSE

Over 60 years ago, urban transportation was first subjected to systematic investigation, perhaps appropriately, in Detroit. The Detroit area study became the forerunner of transportation planning studies conducted in most large cities and countless other urban areas throughout the world. At the heart of this process were forecasts of personal travel and goods movement for evaluating alternative plans and policies. Significant planning decisions concerning transportation infrastructure investment and travel demand management policies, as well as major land use changes, have relied on the methods, techniques and ideas that emerged in this field over these six decades.

The aim of this book is to describe the major developments in urban travel forecasting models and methods of analysis that were first established in the US and Canada in the 1950s and 1960s, transferred to the UK and other countries, and then extensively advanced and refined through research and practice. We trace the major technical and theoretical developments, with periodic hints of revolution, and their selective absorption into planning practice. We consider the ‘drivers of innovation’ over the years, in particular: (a) the increasing range of transportation policies considered; (b) the widening evaluation frameworks; (c) the means of analysing data; (d) burgeoning computing power; and (e) the role of simple intellectual curiosity.

From travel forecasting’s roots in operations research, transportation engineering and urban planning, we explore the widening perspectives of various academic traditions. In particular, contributions from economics, psychology, geography and regional science have provided insights and improved representations of the travel and location behaviour of individuals, households and firms as a basis for urban travel forecasts. We also discuss the different policies and projects that attempted to influence that behaviour and how their impacts were analysed.

As participants in our field of study, we are all extremely fortunate. Each of us comes to the subject of urban travel with different views and expectations. Each of us is a participant in the systems we study, often
with strong views about the travel behaviour of ourselves and others, how the transportation system should perform, or how its shortcomings should be addressed. How we construct a framework to identify and address urban transportation problems matters greatly to the lives of citizens, whether they reside in the urban areas of the highly industrialised world or the rapidly developing cities of Asia, Latin America and Africa.

From meagre beginnings, research and applications in this field expanded to such an extent that vast published and unpublished materials have accumulated over the past 60 years. The synthesis and presentation of this material presented a daunting challenge for selection and emphasis. We approached the task of describing and interpreting the historical record by identifying what we saw as important ‘themes’ in the development of urban travel forecasting models and methods of analysis. As will become apparent, we adopted a sympathetic view of innovations and considered them against the background of approaches existing at the time. We resisted the temptation to compare the past unfavourably with the present. Indeed, there is little reason to believe that current approaches will seem particularly enlightened or sophisticated when assessed a few decades from now.

1.2 NATURE OF MODELS AND FORECASTS

Before introducing the themes and the questions they raise, a few words on the nature of travel forecasting models may be helpful. The questions faced by the pioneers of the field can be summarised as follows:

1. What will be the pattern of flows in the transportation networks in 20 or 30 years under changes in population, car ownership and decentralisation of land uses?
2. What will happen in the future if specific changes are made to the transportation networks?

Faced with scant historical data on the use of urban transportation systems, as well as rapidly rising levels of car ownership, early urban transportation studies performed ‘base-year’ surveys of (a) personal travel by individuals and households, and (b) goods movement by firms and other organisations. Using these ‘cross-sectional’ data, analysts fitted empirical relationships between the demand for travel and what were identified as its determining factors in the survey year.¹

Their objective was to apply these relationships in forecasting future travel or assessing changes in travel resulting from proposed policies.
or projects. In this approach forecasting travel involves: (a) attempting to understand the nature, extent and cause of variations in travel behaviour among different population groups, including variations over geographic space, as a basis for assessing changes under policies and projects; and (b) making statements about the future, conditional on assumptions about improvements in transportation facilities and services.

Travel demand is expressed in terms of demographic, social, economic and activity location (land use) variables, together with monetary costs (fares, parking charges, fuel purchases, etc.) and level-of-service variables (e.g., travel time along a road or a public transport line, waiting and transfer times), collectively referred to as the ‘generalised costs of travel’. We often refer to these quantities simply as ‘costs’, with the understanding that they embody several components, each with different units: time, money and so on.

Generally, the amount of travel is observed to decrease in response to increasing generalised costs. In turn, travel costs usually increase with the amount of travel, and are also dependent on the capacities and regulations governing movements in networks. Travel and its costs, and the functions relating them, therefore, are simplified representations of reality, embodying our understanding of these relationships.

We emphasise, in agreement with leading scholars, that travel forecasting is not directly concerned with determining transportation supply, such as the configuration and capacities of a road system, the network of bus services or pricing arrangements for a toll road, with its connotations of an agent actively managing the capacity of services and network regulations. Therefore we avoid reference to what is sometimes referred to as a ‘supply function’ in discussing the mutual interdependencies between travel demand and the various costs and levels-of-service on the transportation networks. Travel forecasting is often used indirectly in conjunction with an evaluation framework as a basis for the design of transportation systems and the supply of services that they provide; we shall refer to this design process only occasionally.

Let us summarise these two sets of relations as follows:

1. A demand function: travel demand depends on a set of external factors and generalised costs. The external, sometimes called ‘exogenous’, factors, such as demographic and land use characteristics, are outside the immediate influence of planners, but may change over time.
2. A cost function: generalised costs on network links depend on link flows for given capacities and regulations.
These deceptively simple relations, expressed in mathematical form, conceal a great deal of complexity in the representation of the real world and are subject to a number of important extensions. One of the most interesting and complex is that the land use system itself is dependent on the transportation system and will in general be influenced by changes in the costs of travel. To incorporate this mutual interdependency between the land use and transportation systems leads us into the development of what are called integrated land use–transportation models. We shall have much to say about these at various stages of our story.

The numerical solution of these interdependent travel demand and cost functions under specified conditions and assumptions to prepare a forecast typically requires the determination of the values of millions of variables, usually by some iterative procedure. This solution determines the equilibrium flows and costs over (a) the transportation networks and (b) the associated personal travel or goods movement between different locations by various modes. This problem has proven to be as fascinating as it is challenging, and is of the utmost practical importance.

Forecasting has the popular connotation of projection over time, much as a weather forecast indicates the likelihood of rainfall at some future time. Although forecasting travel at some future point(s) in time, perhaps a few years or even decades ahead, is certainly part of our story, this book is also centrally concerned with forecasting the impact of plans and policies. The possibility of such forecasts rests on the expression of policies and projects in terms of changes in the variables (e.g., the times and costs of travel) that influence behaviour. Models have evolved considerably to embrace the following planning contexts expressed at various levels of spatial detail:

1. alternative arrangements of activity locations (land use);
2. investments in new roads and capacity expansion of existing roads;
3. investments in public transport systems, as well as changes to levels-of-service and fares;
4. traffic management, such as one-way street systems and allocation of lanes to particular users;
5. demand management, such as parking restrictions and road user charges;
6. applications of computer and information systems to operate and control transportation systems more intelligently.

In this book we are largely concerned with forecasting the response to plans and policies belonging to categories 1–5 at future points in time. We do not focus on operational issues, such as setting or adaptive control of signals.
From a technical point of view, forecasting and/or the analysis of policies require:

1. a ‘base-year analysis’ establishing analytical relationships between the travel demand and cost functions, and their respective sets of variables, from data obtained for that year and possibly for earlier years;
2. a ‘reference state’ analysis to determine the future levels of certain variables, such as land use, population, car ownership and employment;
3. impact analyses of policies or plans through their representation as measurable changes in prices and levels-of-service;
4. evaluation of changes from the reference state arising from the policies or plans.

1.3 THEMES IN MODEL DEVELOPMENT AND APPLICATION

From our present vantage point, we looked back and identified certain themes that proved relevant to developing models, to understanding the differences among them and in charting their progression to the present states of theory and practice. The themes with which we are concerned relate to: (a) the changing contexts of models development; (b) the ways in which demand and cost functions were specified, their parameters estimated, the mathematical relations solved, and travel forecasts obtained; and (c) our views on the validity of the whole enterprise. Many of the following themes are strongly intertwined and presented as such in the different eras considered. We describe them here for emphasis and clarity.

The first theme is the role of institutions in developing, sponsoring or promoting models. While academics and practitioners, separately or in combination, were often the ‘drivers of innovation’, a variety of institutions had a major impact on the funding, development, promotion or ratification of models. We refer to institutions in the broadest sense, ranging from national and local governments and, more particularly, public agencies charged with responsibilities for transportation systems, to research institutions, expert committees and funding agencies, whose pronouncements were particularly influential in the promotion of key ideas and sometimes set the agenda for model improvements. Legislatures sometimes also made pronouncements on appropriate model forms or modelling practices. We describe ways that institutions influenced or attempted to standardise the process of modelling, promote innovations, and disseminate material relating to models.

The second theme is planning contexts of the development and
application of models. For 60 years forecasting models served an important role in transportation planning for the purpose of evaluation and informing choices among alternative plans and policies. This book does not concern the urban transportation planning process or how it changed over the years. It is sometimes necessary, however, to identify the role of models and technical methods within this process and how the objectives and evaluation framework were influential in determining the nature of models, the information that was sought and the precision of solutions required.

At the outset of the urban transportation planning field in the 1950s, travel and traffic forecasts were often provided in the context of a formal transportation study with a well-defined scope and duration. The terms of reference for such studies changed greatly over the years, with major implications for the development and application of models. Three aspects are particularly important: (a) the particular purposes or role for which model(s) were assembled; (b) the range of policies, projects or plans to which models were applied; and (c) the information required by evaluation frameworks for identifying problems and assessing the relative merits of alternative policies or plans for ameliorating these problems. We describe many innovations over the years to improve the design of forecasting models themselves and make them, in the modern jargon, ‘fit for purpose’.

The third theme is the role and relevance of theory. The behaviour of land use – transportation systems is the outcome of many decisions by governments and by millions of behavioural units – individuals, households and firms – constituting the urban or regional systems of interest. Information about the behaviour of distinct groups of individuals or firms, perhaps identified by a zoning system and/or socio-economic characteristics, under conditions of change is necessary for the forecasting and evaluation processes.

The models we portray which seek to describe, explain and forecast system behaviour are simplified theoretical statements, invariably expressed mathematically, governing the relationship among many key variables of interest. What concerns us as we move through six decades of model applications is the successive conceptual frameworks and specific theoretical constructs for organising our assumptions about the current and future behaviour of personal travel and goods movement. Whether old theories or assumptions are discarded, or continue to stand alongside the new, is a matter of considerable interest in judging the theoretical maturity of the field and the requirements of practice.

Much has been written about the nature of mathematical models in the social sciences, and in economics in particular; and the similarities and differences between model developments in the natural sciences are often
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noted. We do not pursue these general issues here, but note a few key features that will accompany our discussion. At the heart of model development is the process of simplification. As Paul Samuelson [1915–2009] reminded us long ago:3

Even if we had more and better data, it would still be necessary – as in every science – to simplify, to abstract from the infinite mass of detail. . . . All analysis involves abstraction. It is always necessary to idealise, to omit detail, to set up simple hypotheses and patterns by which the facts can be related, to set up the right questions before going out to look at the world as it is. Every theory whether in the physical or biological or social sciences, distorts reality in that it over-simplifies. But if it is a good theory, what is omitted is outweighed by the beam of illumination and understanding that is thrown over the diverse empirical data. . . . But recall again this important point. . . . how we perceive the observed facts depends on the theoretical spectacles we wear (Samuelson, 1970, 8–9, italics from the original text).

We encountered several conceptual frameworks which differ in the nature of the explanations they offer about travel behaviour, some having different implications for forecasting, evaluation of projects and formulation of policies. Some theories of urban travel will, in Richard Lipsey’s words, ‘allow us to comprehend reality in new and different ways’ (Lipsey, 1989).4

The fourth theme is data requirements. Urban travel forecasting models are traditionally extremely heavy users of data relating to land use and transportation networks and services, the travel of persons and the movement of goods. Early transportation studies were characterised by very large household surveys. Over time important innovations occurred in the way that data were acquired, and used in establishing and testing hypotheses and in forecasting travel behaviour. As our story unfolds, we depict issues bearing on the relationship between models and data.

The fifth theme is solution of models. The outputs of forecasting models may be conditioned by the evaluation framework adopted in a transportation study. Typically these outputs include travel demands, vehicle flows on network links, and user costs associated with a given equilibrium state. The differences in these quantities between the equilibrium states associated with a specific plan or project are usually required. The necessity to determine such differences, which are often small, imposes a level of precision on the solution of equilibrium states associated with the forecasting model. Whatever are the merits or demerits of a particular model, some requirements on its solution are usually implied to secure sufficiently precise information. At various points in the historical development of the field, theoreticians and practitioners confronted important technical questions about the efficiency, precision and computational burden
involved in solving equilibrium models. Specifically, three questions are relevant: (a) Do solutions actually exist for the demand and cost functions specified? (b) What are the mathematical means for determining these solutions? (c) Are the solutions determined to the precision required for the comparisons sought?

The sixth theme is validation and performance of models. How theoreticians and practitioners have developed criteria for accepting particular models for their intended purposes will emerge as an important theme of our discussion. In turn these criteria will be influential in determining the accuracy of forecasts. Forecasting travel one, five, ten or 20 years into the future poses special problems and may involve a multitude of potential errors. These may arise from a number of sources, such as: (a) our understanding of the demand and cost relationships; (b) the forecasting assumptions for variables such as land use and population, which represent the future state of the city or region; (c) errors in data; and (d) human error. In our discussions of developments and innovation, we shall be concerned with the framework for assessing the validity of models and how models performed in relation to outcomes.

The seventh theme is practical compromises in model development. Some models and methods that we describe are much more complex than others, in both the representation of behaviour and the resulting system of equations. Throughout the last 60 years, more sophisticated models were generally presumed to be more accurate, and therefore preferred over more simplified ones. Yet, with some exceptions which we describe, complex models are apparently not widely sought after or used by planners. We can anticipate some of the reasons, so we wish to alert readers new to the field that to judge a model or method solely on the basis of its technical or behavioural sophistication would be to miss an important point. Planners often find themselves in that awkward position of having to make and justify their decisions on the basis of limited data, uncertain knowledge and limited resources, particularly money, manpower and time (Shepherd et al, 2006a). Only if this point is appreciated can we hope to understand the gap that has emerged between the cutting edge of theory and the world of planning practice.

As already noted, an essential feature of travel modelling for the purpose of forecasting is simplification. In the complex systems of equations that represent the behaviour of personal and goods vehicle flows in the land use and transportation systems, what simplifications are justified? What are the implications of alternative assumptions for forecasts and policy decisions which rest on them? These are questions that lie at the heart of applications of travel forecasting models.
1.4 SCOPE OF OUR WORK

The contexts of urban travel forecasting are now very wide-ranging, and include: (a) projects undertaken for private companies, as well as those proposed and financed by public agencies; (b) various spatial environments from massive, densely populated urban areas or conurbations with rich travel options to relatively small towns in extensive rural hinterlands; (c) strategic considerations as well as specific scheme-based impact studies; (d) the initial sifting of alternative plans through to testing final detailed designs; (e) area-wide, corridor-based and specific local applications; (f) the investigation of the long-range impact of large, expensive projects as well as the short- and medium-term appraisal of much more modest schemes; (g) those projects for which the knowledge base of traveller behaviour is reasonably secure or, at least, largely uncontested, and those for which there may be very little available evidence. In this book we exploit the common features of many travel forecasting models used with the cross-sectional approach, rather than consider each of these cases individually. We did, however, set some limits on the scope of our discussion based on model types, policies and spatial contexts:

1. Application to world cities. Although the approaches that we describe had their genesis in the cities of North America and Western Europe, they were over the years applied with relatively minor modifications to the large majority of major cities and urban areas in the world. In some contexts, particularly on the periphery of some cities in the developing world, data collection and model building are highly problematic. Discussion of these cases is outside the scope of this book.

2. Operational applications. We generally exclude operational issues, such as those relating to traffic control systems, although on occasion we do refer to some models used for such purposes.

3. Policy and project evaluation and design. We are almost exclusively concerned with what are sometimes referred to as ‘positive’ issues – investigations of ‘how the world works’ and how people do behave under given conditions, rather than ‘normative’ issues of how people should behave and the means by which they may be induced so to do. We consider the policies and plans to be given rather than address either how they are formed or normative issues relating to the formulation of ‘optimal’ plans for the supply of transportation facilities and services. As noted in section 1.2, when used in conjunction with an evaluation framework, these forecasting models are widely used in the design of policies and projects.
1.5 LIMITATIONS OF OUR APPROACH

This book is about the evolution, influence and application of ideas in urban travel forecasting over 60 years. Although we fervently hope that it will add to an understanding of the subject, we do not view our work to be a definitive history of the subject. Any history is conditioned by the personal experience, knowledge, interpretation and social context of its authors, and we are even more aware of this fact now than we were at the outset. Just as we did not always accept certain early accounts in their entirety, others may judge ours as incomplete or subject to qualification. It will be for them to fill in the gaps, amend a viewpoint here and there and perhaps correct some bias. We are aware that our account, particularly its breadth and the depth in particular areas, has been influenced by several factors, which imposed limitations on our approach. We mention the following:

1. In assessing and synthesising material from thousands of articles published in our field, and the large number of transportation studies conducted over this period, we attempted to identify the main forms of model development, bring out the key ideas, and give credit to their originators. In synthesising this vast range of material, the possibility of omissions or inaccuracies is always present. Our own research experience has been confined to only a part of what is now an extremely broad and deep subject covering several academic traditions including mathematics, engineering, operations research, psychology, economics, geography, regional science and urban planning. We do not claim to have delved into all sub-specialities let alone possess expert knowledge in each. Others from different backgrounds or research experience would without doubt identify different themes for their discussion and emphasis. To partly compensate for this situation, we have sought the views of many experts, and in several places we point the reader to specialist texts and manuals where more details can be found. In an extensive and rapidly developing field we hope to have achieved sufficient perspective to identify the main issues, themes and developments; however, omissions are inevitable and we invite comments where these are considered significant.

2. In most cases, identification of innovations and their originators presents few problems. In the case of the significance of innovations, we sometimes resorted to existing papers, texts or reviews, sought the insight of experts, and drew on our own experience. Where attribution of ideas was in doubt, we returned to the historical record, reread relevant articles, consulted colleagues and relevant experts in the field,
and then came to a personal view. In some cases we were informed through correspondence that standard accounts are inaccurate, and we revised or revisited these. It is unlikely that we found them all.

3. While it is relatively straightforward to consult the international literature and conference reports to assess the contributions of academics and consultants, access to transportation study reports, particularly those subject to commercial confidentiality, is more problematic. New models with catchy acronyms emerge regularly, although few are highly innovative. While we are confident that our views are broadly representative of practice, we were unable to scrutinise the full range of applications. Important innovations arising in practical studies quickly tend to find their way into the international literature and, in turn, are disseminated back into future practice. In various discussions and correspondence, we were directed to unpublished work that is often of great interest and significance. Sometimes that work was published in less visible journals and perhaps covered later in more popular or widely disseminated accounts, and the original work is forgotten, as was pointed out to us on a number of occasions. We imply no malpractice here. Sometimes it just happens.

4. Even in a largely technical subject, the history as seen through North American eyes is rather different from that seen through European eyes; we tried to blend our two perspectives. Furthermore, we are well aware that reporting of innovations in this field is overwhelmingly in the English language, and through historical circumstances and by sheer weight of research capacity over the years this in turn is US dominated. Even less likely would be a knowledge of the French, German, Russian, Spanish, Japanese or Chinese experience both then and today. We were not able to do justice to many articles published in other languages or papers that were not presented at international conferences or published in the international literature. We had some help with important work published in other languages, especially German, French and Spanish, but this dilemma remains a major challenge for our field at a time when the research output of Asian countries is expanding rapidly.

5. Finally, since our intention is to present ideas to a wide audience, recording developments in one of the most highly analytical fields of public policy analysis poses particular challenges in how to deal with its formal language – mathematics. Often both the language and the techniques (such as calculus and statistical analysis) are central to the expression and solution of theoretical and technical problems. As both authors have mathematical backgrounds, we know well how their use in a highly technical field has been vital to establishing
logically coherent arguments and contributing to knowledge – even if it sometimes failed to achieve the level of knowledge creation and precision sometimes claimed. But the benefits of formal developments are often exaggerated when it comes to the discussion of principles and ideas, particularly when issues in the real world are ‘staring us in the face’.

We therefore adopted a dual approach: the main text is free of mathematical analysis. However, where we felt that it would contribute significantly to the discussion, we added mathematical endnotes. References to specialised discussion are also included. Others will judge whether this approach has been successful. Even with the substitution of words for symbols, many parts of the discussion may prove difficult to newcomers. As noted in the Preface, we feel that it will be appropriate to read this book in conjunction with a technical textbook on travel forecasting and a formal course in order to augment the discussion and fill in the gaps.

1.6 NAVIGATING THE TERMINOLOGY AND ACRONYMS

Experienced readers of American and British transportation literature are well aware of differences in terminology between these two major branches of the English language. A few words of explanation may be helpful. We adopted British spelling throughout, except in quotations, where the original spelling is retained. The noun ‘transportation’ is mainly used in American English, whereas ‘transport’ is the preferred noun in British English. We agreed to use ‘transportation’ in this book, except in proper titles and quotations. In British English, ‘public transport’ is the noun used to refer to public transportation systems and services. In American English, ‘transit’, ‘mass transit’ and ‘public transit’ are all used. We decided to use ‘public transport’ to refer to these systems in all countries.

In the UK and some other places, the term ‘transport model’ is a convenient shorthand used to refer to travel forecasting methodology. We do not use this term here, except occasionally in the UK context, in order to avoid possible confusion for readers unacquainted with it.

In an effort to be concise and improve the flow of the text, we introduced a number of commonly used acronyms. Although they are defined when introduced, an overview and some explanation may be warranted.

Throughout the book, we abbreviate the United States of America (US) and the United Kingdom (UK). Names of governmental agen-
cies at the national level are always preceded by these initials. The US Department of Transportation (US DoT) was created in 1967. Prior to that event, the federal highway agency, the Bureau of Public Roads (BPR), resided in the US Department of Commerce (US DoC). At some point shortly after the establishment of US DoT, BPR was transferred and renamed the Federal Highway Administration (FHWA), the acronym ‘FHA’ having already been used to designate the Federal Housing Agency. In 1964 responsibility for public transport was assigned to the newly created US Department of Housing and Urban Development (US HUD). Subsequently, this responsibility was transferred to US DoT, where the agency responsible for public transport was named the Urban Mass Transportation Administration (UMTA). Finally, in 1970 the US Environmental Protection Agency (US EPA) was established. In a few cases ‘DoT’ is also used to designate a state department of transportation.

The UK Ministry of Transport (UK MoT) was established in 1919, and continued in some form until 1970. At that time transportation matters were transferred to the newly formed UK Department of the Environment (UK DoE). From 1976 to 1995, the UK Department of Transport (UK DoT) by and large had responsibility for transport problems. Following several name changes during 1997–2001, the UK Department for Transport (UK DfT) was created.

Cross-references are inserted at many places to connect one topic to a related discussion in another section. Often these cross-references state only the word ‘section’ followed by the section number. Transition and connecting phrases are omitted in the interest of brevity.

Finally, for historical interest, we give the birth and death dates of deceased contributors to our field and related fields. Living contributors are not so designated. In the Notes, we also cite Wikipedia web pages of many individuals for whom such pages have been posted. We have inevitably missed some, and others may be added in the future, so we ask readers to refer to Wikipedia for more information about contributors to our field.

1.7 CONTENTS OF THE BOOK

Writing about our field would be considerably easier had it developed from a single point in a generally agreed direction to an identifiable, unambiguous and unchallenged ‘state of the art’ where the world of practice harmonises neatly with that of theory. But that was not to be. The field developed in a rather complex way with theoretical advances intertwined with practical developments, the latter first moving ahead of,
but later lagging behind, the former. The ‘mainstream’ of practice has also revealed significant variations over time, among various countries and in different planning contexts. This situation has prompted many questions about the distinct alternatives available for travel forecasting at any particular time and their relative merits for different applications.

We consider this rather irregular and sometimes disjointed evolution of theory and practice by developing a broadly chronological account of overlapping periods, where significant ‘break-points’ were suggested by either innovation in methods or policy development. Some have suggested that these correspond to changing paradigms, when one set of ideas and world view for interpreting issues is, by power of explanation or force of relevance to planning problems addressed, traded for another. (We shall later argue that this represents an oversimplified view of the realities of planning practice over the years.) We sometimes follow particular ideas up to the present day. We also backtrack to pick up various themes and, on occasion, to address what we consider to be missed opportunities where alternatives to the ‘mainstream’ appeared and only much later were seen to be of considerable value to forecasting practice.

In Chapter 2 we chart the rise of the field and the establishment of what became variously described as the traditional, conventional, classical, four-step or sequential approach to travel forecasting. This account is confined to developments in the US, and Canada, where the challenge of the motor age was first confronted with a ‘systems approach’. This review takes us up to the early 1970s when political and economic imperatives (e.g., the grass-roots freeway revolts in the US and the first oil crisis) led to more emphasis on transportation system management and public transport.

During this period the ‘systems approach’ to transportation planning was exported to other countries, such as the UK, which also took up the challenge in the early 1960s of planning for mass motorisation. Chapter 3 addresses the transfer and application of the techniques and the innovations in travel forecasting that occurred up until the early 1970s, in part owing to their adaptation to local requirements. Departing from a largely common approach being applied in the US, we describe significant innovations in forecasting models, which led to major changes in the way that forecasts were prepared.

We then turn to a discussion of what some called the ‘disaggregate behavioural’ revolution, which emerged in the early 1970s. We describe a theoretical approach, with its roots in the statistical study of modal choice a decade earlier, based on the rational choices of individuals over discrete sets of alternatives, such as the choice between several transportation modes. Within this framework we show how the motivation and
actions of decision makers (individuals and households) in a wide range of urban travel situations was described, explained and forecast, based on assumptions of economic rationality. This micro-behavioural approach, founded on what became known as the random utility maximising theory of discrete choice, provided an appealing and enduring approach to travel forecasting. Gradually it established itself as a practical alternative, and a complement to the traditional forecasting approach in urban transportation. It also enabled a theoretical reinterpretation and reformulation of the traditional four-step procedure.

In view of the extent and importance of this micro-behavioural approach, we present it in two chapters. Chapter 4 concerns those theoretical and practical innovations that occurred in a short but formative period in the early 1970s. These were largely associated with the theory and application of a particular model form, the multinomial logit model, but also included important early research on the relationship between the basic structure of models and hypotheses about travel-related decisions. Chapter 5 introduces a large number of innovations in model specification, parameter estimation and applications. In particular, Chapter 5 describes how theoretical arguments led to the development of new models and methods for analysis and forecasting of travel behaviour, which allowed a number of problems with conventional models to be addressed.

The micro-behavioural approach was greatly enriched in the late 1970s and 1980s by examining the wider context of individual and household decision making and impact of transportation policy at the micro-level. This development began an era of ‘behavioural realism’ in which many assumptions of the past were scrutinised and refined. By representing the demand for travel as derived from the need to conduct activities separated in space and time, activity-travel models offered an innovative approach. With their inherent emphases on constraints and interdependencies among trips and household members, they were initially presented as a distinct alternative and a possible rival to both the traditional and the micro-economic approach. Now they may be seen as part of a grand behavioural synthesis, their practical contribution being expressed first through the development of ‘tour-based’ forecasting models in the early 1980s and, subsequently, to ‘schedule-based’ analysis of travel behaviour in time and space. This framework and the models that evolved from it are the subject of Chapter 6.

In Chapter 7 we reflect on what we see as a missed opportunity. In the mid-1950s, concurrent with the origins of the traditional approach, an intellectually demanding book appeared (Beckmann et al., 1956) that proposed a conceptual framework, which might have been used to interpret and address some of the technical and theoretical problems confronting
travel forecasting. We examine the contrasts between the traditional approach to specifying and solving the sequential procedure and what later became known as the combined model approach. We offer some views of why the latter was not recognised for 20 years and discuss its significance.

In Chapters 8 and 9, we consider the world of practice in more detail. Taking the US and UK as important examples, we examine developments of the traditional trip-based travel forecasting models as well as more advanced approaches. In addition, we record the innovations and practical application of models which incorporate the interdependency between the land use and transportation systems and goods movement. While drawing on the legacy of earlier times, we focus on the last two decades. In the early 1990s in the US, new legislation had profound implications for the specification and solution of travel forecasting models, as well as launching a major attempt to reform the way that travel forecasts were made. Important innovations also occurred in the UK in this period; however, here the emphasis was on the adaptation of traditional methods to address a broader range of policies.

From its beginnings in the early 1950s, urban transportation planning generally, and travel forecasting in particular, was closely associated with the development and use of digital computers. In Chapter 10 we take a step back and trace the history of these ambitious efforts from the early mainframe applications on through to the current use of personal computers, and associated developments in travel forecasting software. In particular, we note how changes in computing power had profound implications for the specification and solution of these models. We also trace the evolution of the principal software systems for urban travel forecasting.

In Chapters 11 and 12 we draw our story to a conclusion. In the former we consider the achievements and current challenges and offer some views on the future prospects for the field. Drawing on our themes we summarise the major developments in the theory, methods and practice of urban travel forecasting over a period of 60 years and reflect on the innovations that occurred to provide more satisfactory ways of undertaking existing tasks, to answer critical concerns and to address new requirements. We consider the longevity of the traditional approach, the hitherto limited application of alternatives, and the multiple ‘states of the art’ which characterise contemporary practice. We consider some views on current challenges faced and, without being prescriptive, discuss some questions and issues which might guide the future development of the field. In Chapter 12 we return to the context of urban travel forecasting and ask how innovative ideas emerged. Finally, we offer comments for those approaching urban travel forecasting as a field of study for the first time.
Introduction

We are about to take the reader back to a time quite different from the modern age, not only in the nature and scale of the problems faced and the approaches to their resolution but also in the technology of analysis and what is sometimes referred to as the ‘culture of research’ in our field. In 1950 many countries were still recovering from the Second World War. The transistor had only recently been invented (1947), while the advent of the laser was a decade in the future (1958). Computers were extremely primitive by modern standards and practically unavailable for civilian use. The inventions of the now ubiquitous internet and World Wide Web\(^6\) were decades away. The problems of dealing with large amounts of data from surveys of urban transportation were enormous. Indeed, many of the mathematical, statistical and data analysis tools that are now taken for granted were then being invented.

In those early days there was no ‘culture of research’ in our field. Transportation was not an academic discipline. There were no research institutes devoted to its development, few conferences devoted to the subject, minimal published material, no dedicated journals to serve the advances in the subject, and no automated way to conduct searches of what little literature was available. The modern age is as different and in some aspects unimaginable to those of 1950 as the world will be in perhaps 30 years for the citizen of today.

We are now ready to tell our story.

NOTES

1. For a definition of cross-sectional data, see en.wikipedia.org/wiki/Cross-sectional_data (accessed 9 May 2014).