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The evolution of urban mobility: The interplay of academic and policy perspectives☆

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ABSTRACT

Urban mobility in Western countries has evolved substantially over the past fifty years, from an early interest in catering for growing car ownership and use through major road expansion, to the current emphasis on reducing car use and cutting back on road provision, encouraging sustainable travel and promoting liveable cities with a high quality of life. This can be observed in the changing patterns of car use in many European cities over time (i.e. a rapid increase followed by stabilisation and now decline). This evolution can be related to changes in the transport policy paradigm, which has been heavily influenced by the involvement of an increasing range of academic disciplines, many of which have contributed to modifying the supporting data collection, modelling and appraisal methodologies. The paper explores the varying interplay over time between academic/applied research and policy practice, and the methodological legacy left by earlier perspectives on urban mobility. It highlights a recent reinterpretation of mobility provided through taking a 'socio-technical perspective', and speculates on how policy thinking on urban mobility might further evolve over the next forty years.

1. Introduction

The evolution of urban mobility can be seen as the outcome of a complex and changing set of interactions. On the 'demand' side contributing factors include varying demographic patterns linked to economic growth and societal changes, resulting in new patterns of consumption; while on the supply side there have been major changes in transport infrastructure provision, often associated with advances in technology. Transport policy has also played a major role, not only by funding major transport investments, but also through the introduction of a broad range of physical, regulatory and pricing measures. Such measures have varied over time and have been introduced in response to a changing set of perceived concerns, policy objectives and priorities. (See Table 1.)

As part of this evolutionary process, it is argued that academic and applied research has had a major influence on the policy discourse, both through its contribution to the framing of the debate at a conceptual level, and through methodological advances in data collection methods, analysis and modelling techniques, and appraisal methods.

The paper addresses this thesis under five headings. First, in Section 2 it broadly reviews the evolution of urban transport policy perspectives and how they relate to changing conceptualisations of what urban mobility involves; and then provides some empirical evidence to demonstrate the travel consequences of this evolution in Section 3. Section 4 looks in more detail at the interplay between transport-related research and policy practices, and the resulting influences on policy formulation and on methodology. Section 5 broadens the perspective to look at wider technological and behavioural influences on travel behaviour, and Section 6 brings this information together to look to the future: how might urban mobility evolve in the coming decades? Finally, Section 7 draws out some implications and conclusions.

This is a wide-ranged paper intended to give a broad historical and prospective overview, and so it is not possible to investigate any individual issue in depth.

2. Evolving urban transport policy perspectives

Historically, there have been a number of transport revolutions in most countries, brought about by major advances in transport technologies [1]. The development of an inland canal system in many Western countries in the eighteenth century, coupled with advances in maritime shipping technology, greatly reduced costs of freight movement and stimulated the industrial revolution and the early stages of globalisation. Similarly, the development of railway networks starting in the nineteenth century further stimulated economic development, as well as further stimulating freight traffic, and enabled large numbers of

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people to move around their country relatively quickly and cheaply. In the twentieth century, it has been the advent of the motor vehicle and the building of fast, high capacity roads which has had the greatest influence on domestic travel, coupled with the development of the airline industry and its influence on international passenger and freight movements.

Urban scale and form have been greatly influenced since the late nineteenth century by the development of urban public transport systems, particularly rail-based [2]. But since the mid twentieth century it has been the explosive growth of motor vehicles in more advanced economies which has had the greatest influence on our towns and cities. It is this latter period – covering the last 40 to 50 years – which this paper focuses on.

During this latter period, in a number of larger cities such as London, New York, Paris, Tokyo and Vienna, we can observe an evolutionary development in transport policy, associated in particular with successive paradigm changes which have influenced problem identification and diagnosis and the kinds of solutions which are proposed.

Kuhn [3] introduced the concept of the 'paradigm shift', to explain major shifts in thinking. He postulated that scientific revolutions occur when scientists encounter sufficient anomalies, or questions that cannot be adequately answered within the current paradigm, which lead them to question accepted norms and to search for a new framework for discovery and analysis. This can lead to a major change in how the world is viewed, as in physics with the switch from a Newtonian to a Quantum Physics perspective. But, as in this example, where one paradigm did not entirely replace another, in the transport context it seems more appropriate to think of a paradigm enlargement rather than a paradigm replacement. This notion is alluded to in Heggie and Jones [4], who argued that there are different analytical and modelling 'domains' that are appropriate for tacking different kinds of issue.

Broadly speaking, we can characterise the evolution of urban transport policy over the past half century as a three stage process, summarised as follows [5].

2.1. Stage One: traffic growth policies — a vehicle-based perspective

Early stages of urban economic growth lead to a rapid increase in car ownership and use, and a resulting policy focus on meeting the 'inevitable' major growth in motor vehicle traffic, to avoid the city 'grinding to a halt'. This is often associated with the development or expansion of a domestic motor industry. The solution to this problem is seen very much in 'engineering' and scientific terms: as requiring investment in a major urban road building programme and measures to maximise vehicle capacity on existing urban streets, supported by large increases in parking provision, particularly at major trip destinations. In the process, public transport investment may be cut back, and road space taken away from street activities (e.g. market stalls), pedestrians and cyclists. Often too, extensive on-street tram systems are removed (e.g. as in London) to provide more capacity for motor vehicles.

This is often accompanied by land use policies designed to rationalise the use of urban space, through the introduction of zoning policies and non-traditional street patterns which favour car use over more sustainable transport modes. Many cities in this stage of development use North American cities as their role model. This vehicle-based paradigm is often widely supported by a range of groups in its early stages, not only by those in positions of power and wealth (who are the direct beneficiaries, as car owners), but also by the bulk of the population who aspire to car ownership and see road building as a positive sign of economic development, and may be directly employed in the motor industry and its associated industries.

This transport revolution requires a more strategic perspective than was necessary previously and usually involves major public sector investment; so it encourages the development of techniques which provide a more quantitative analysis of the relationships between transport and land use. This brings two new disciplinary views into the transport profession. First, mathematical skills to develop comprehensive vehicle trip origin–destination models, using gravity models, entropy maximising techniques and other tools from social physics; and, second, economists to develop formal appraisal methods that help to justify the large injection of public funds required to build major new urban road networks. The collective efforts of these various disciplines applied to large scale transportation studies led to the development of three-stage aggregate traffic forecasting models, combining vehicle trip generation, trip distribution and traffic assignment modules [6].

Quite soon, however, it becomes apparent that it is not possible to cater for unrestrained car use in larger urban areas with high to medium land development density — a car-centred city requires a lower density Los Angeles/Houston style city structure. In London, for example, even with proposals for an extensive urban motorway network, the three-stage traffic forecasting models were predicting demand levels several times greater than the proposed capacity [7]. And even that planned capacity could not be delivered: the construction of the first section of one of the proposed motorways in inner London led to such a public outcry that the conservative administration in the Greater London Council was voted out in 1973, and the incoming labour administration promised an end to major motorway construction in London, under the slogan 'homes before roads'.

In addition, the practical consequences of increasing levels of car use begin to become apparent, not only in terms of growing traffic congestion, but also through its effects on air pollution, traffic accidents and – more recently – concerns about rising CO_2 emissions. Such problems are currently being confronted in major Chinese cities such as Beijing and Shanghai, for example.

This leads to a policy impasse: how to cope with the pressures for traffic growth, if major road building is not an option? The major breakthrough comes by redefining the problem — the first paradigm change. Rather than catering for unlimited vehicle movement in urban areas, the primary objective switches to cater for growing person movement instead. This enables road traffic growth to be contained, while increasing overall levels of mobility.

2.2. Stage Two: Traffic containment policies — a person trip perspective

From a person trip perspective, the policy focus switches to one of moving people from their origin to destination, in the most efficient manner, so the mode by which this movement takes place becomes of secondary importance. Since public transport systems (buses, trams, trains, underground) use the limited available urban space much more efficiently than private cars, and can accommodate much higher numbers of people per unit area, the solution to the conundrum of how to cater for the rapid growth in vehicle demand in a physically constrained area is to switch much of this growth to other forms of transport. In practice, in the early stages of this policy transition, it has often been articulated in terms of accommodating as much car traffic as is manageable and then encouraging the rest to use other modes.

The switch in policy emphasis from providing additional road capacity to enhancing rail provision was given a strong boost by the publication of the 'Downs–Thompson paradox', based on empirical research in London and Paris [8]. This showed that average radial door-to-door speeds by car and rail are roughly the same, indicating paradoxically that the best way to increase average urban road network speeds is to raise average door-to-door speeds by rail – or by other sustainable transport modes. In much of western Europe and in Japan – and more recently in cities such as Beijing and Shanghai – there has been renewed interest and investment in rail-based public transport systems, while in South America the focus has been on building (cheaper) Bus Rapid Transit (BRT) systems, due to funding constraints. This shift in perspective has usually been coupled with increasing restrictions on car use, particularly parking controls in urban centres and access restrictions to counter high levels of air pollution, but without any major cutback

in provision for car use. Although in outer suburban areas, policies in support of car traffic growth may still prevail.

To model travel behaviour from a person trip perspective requires the addition of a modal split module [9], and this modelling expansion was associated with two major intellectual contributions from economists. First, the development of the concept of 'generalised cost' (i.e. the combining of various time and cost components of trips into a composite measure), which also facilitated the monetisation of time savings in the economic appraisal. And, second, the development of the theory and practice of random utility theory and disaggregate choice modelling [10], to more accurately capture mode choice processes.

However, as early as the mid-1970s, some academics were beginning to question whether the person trip perspective was providing a real understanding of why people travel, and of the travel choices which they make. Heggie [11], for example, in a study of the effect on behaviour of car restraint policies in Oxford, identified twelve forms of household adaptation, most of which could not be directly modelled within a trip-based perspective. At a practical level, some people also expressed concerns as to whether it would be possible or desirable to cater for unlimited growth in person trips in denser, growing urban areas, even if some of them could be switched to non-car modes.

Although this early disquiet has taken several decades to take firm root in urban transport policy discourses, it has recently become an issue of major concern given projected increases in city populations (e.g. in Copenhagen and London). This has been accompanied by a much greater recognition of the importance of cities as centres of economic, social and cultural activities. This, in turn, has led to a growing policy interest in providing a higher quality of urban life – coupled with increasing concerns about public health. This has stimulated the second paradigm change: an interest in city activities and liveability.

2.3. Stage Three: liveable cities — activities and quality of life perspectives

Now there becomes a much greater emphasis on cities as centres of activity and on associated urban quality of life issues. From this perspective, it is meeting people's activity participation requirements which is of primary concern, and movement is secondary — a means to an end, rather than an end in itself [12]. Within this enlarged perspective, it becomes possible to raise questions such as 'is your journey really necessary?'; to consider trade-offs between travel, other forms of communication and in-home vs. out-of-home activities; and to assess the wider impacts of transport policies on people's daily lives.

This has also been associated with a resurgence of interest in the role of cycling and walking in cities, as offering sustainable and healthy modes of transport, and in enhancing public space and providing footway space again for street activities. While economic theory has long recognised that travel is largely a derived demand, it is only within an activity-based perspective that this can begin to be operationalised.

Methodologically, the activity-based perspective has introduced new forms of data collection, both in terms of measuring behaviour (e.g. the use of activity-based and time use diaries) and in the types of data concerning provision that need to be collected (e.g. detailed information on the location of facilities and their opening hours, plus information on satisfaction and well-being). While the perspective has stimulated much detailed research into daily behaviour and has led to major advances in modelling techniques at the research level, until recently it has proved to be challenging to implement the activity-based approach in practical urban studies which rely on operational modelling and appraisal methods.

The activity-based perspective has facilitated a more fundamental debate about whether the primary aims of transport policy should be to cater for mobility or to provide enhanced accessibility to facilities (which may not require physical movement at all) — a debate that has grown in relevance in recent years with policy concerns about social inclusion and sustainable lifestyles. It has also provided policy makers with an enlarged set of policy instruments and perspectives. For example, it recognises that travel behaviour can be influenced by reducing constraints on the timing of activities (e.g. flexi-time at work to encourage peak spreading), or by encouraging home working and the use of internet services (e.g. internet shopping and home deliveries) as a substitute for personal travel.

The typical measures introduced as part of a 'Stage Three' city policy mix are wide ranging and are likely to include.

(i) Cutting back on space and capacity provision for cars and other motorised road traffic, by reallocating road space to sustainable transport modes and to street activities, as well as through congestion pricing.
(ii) Providing enhanced public transport provision and strong encouragement for increased walking and cycling, both through better facilities and better information and marketing; and
(iii) Promoting street activities and high quality public realm.

In the case of London, for example, this has led to a fundamental rethinking of the way in which urban streets are used [13]; here each street is currently being re-classified in terms of both its 'Movement' function (by all modes of transport) and also by its importance as a 'Place' – recognising streets as an important part of urban public space. In some other cities this shift in perspective has led to the demolition of some of the elevated highways and multi-storey car parks that were constructed several decades earlier during the 'Stage One' phase of urban transport development – e.g. in Portland, San Francisco and Seoul [14].

On the ground, Stage Three is often associated with relative and absolute reductions in car use (and sometimes car ownership), despite increasing incomes. Evidence of this counter-trend is investigated in the next section.

3. Empirical evidence of the effectiveness of policy shifts

When cities are in the early stages of facing a rapid growth in car ownership and use, it seems that such growth is inevitable and that there are no options other than to substantially increase road capacity until potential demand is fully satisfied. Yet, with the benefit of hindsight, we can see that it is possible through policy actions to achieve a levelling off in the growth of urban road traffic over time at well below 'saturation level' – and in many cities to experience a relative and absolute reduction in car use.

Some European cities, in particular, have shown that it is possible to decouple urban traffic growth from economic growth. Fig. 1 shows two 'Stage Three' European cities, Paris and Vienna, where it has proved possible to 'turn the tide' and reduce car modal share and absolute levels of use, despite increases in economic wealth. And so move to more sustainable transport systems that put less pressure on the road network and hence help to reduce congestion and air pollution, and at the same time improve transport efficiency and urban quality of life.

This is one illustration of a broader phenomenon recently referred to as 'peak car', which has been observed in national data sets in several more economically advanced countries in North West Europe, as well as in Australia, Japan – and even the USA [15,16]. Fig. 2 compares aggregate car kilometres in several countries, and shows a levelling off in national car use well before the onset of the global recession in 2008; although there is not the scale of decline in car use nationally which has been observed in some of their larger cities.

There is much dispute over the causes of this aggregate levelling off, or reduction, in car use, which seems to be underlain by a complex set of contrasting influences and responses. Le-Vine and Jones [17], for example, look behind the aggregate levelling off in British car driving mileage since the mid-1990s to find a series of counter-balancing trends: less driving by men (largely due to reductions in company car mileage) offset by more driving by women; less driving by younger people, but more by older people; and less driving in cities offset by more in rural areas.

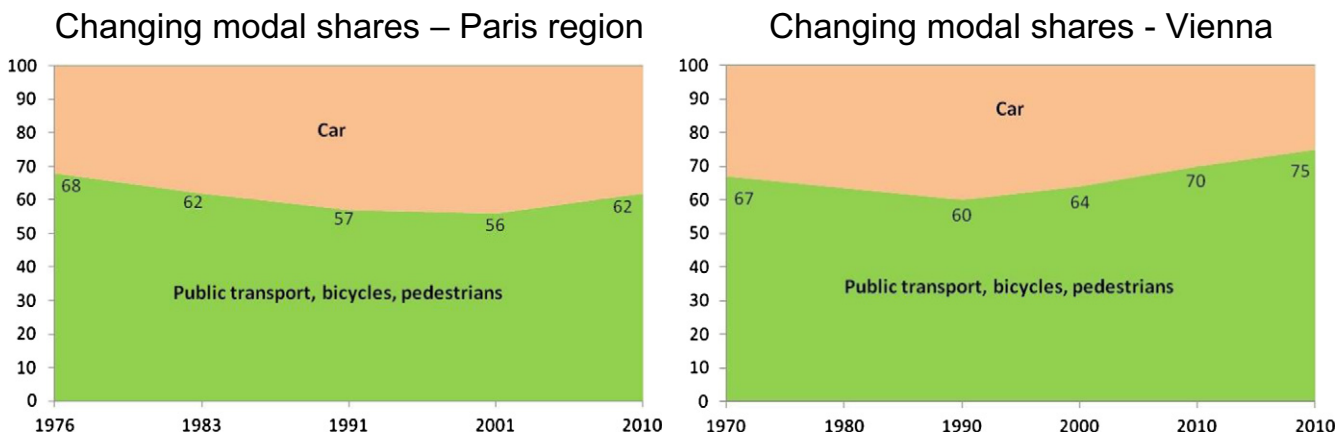

Fig. 1. Decline in car modal shares in two European cities. Source: based on data provided by city authorities.

Some of the causes may be country specific; for example, the major reductions in company car mileage in Great Britain seem to have been caused by large increases in personal taxation on the benefit of having a company car for private use, and for being provided with free fuel [17]. But what Fig. 2 illustrates is that this is not an isolated phenomenon, only found in one of two countries, so many of the causes must be more generic. It demonstrates that what is anticipated in Stage One to be the inevitability of continuing growth in car use as GDP increases is not actually the case in many situations.

4. Interplay between academic/applied research and policy practice

Looking back over the past 40–50 years, we can observe variations in the interplay between academic/applied research and debate and the state of policy practice [18], with research leading policy thinking at some points in time and finding it necessary to 'catch up' with the reality on the ground at other times. In particular, in some areas there have been important legacy effects at various stages of the paradigm enlargement – some only temporary, others more permanent – which have constrained much of what is still applied in practice, and has influenced some of the academic debates and practices.

The analysis and modelling tools that were first developed to address the requirement of the 'Stage One' strategic, vehicle based perspective bequeathed the profession a methodological legacy that has subsequently partially distorted and compromised the application of the person trip-based perspective, at least for a period of time. In particular:

- There has only been a belated consideration of walking and cycling trips due to a lack of empirical data, as such trips were not measured within the vehicle-based perspective. This was partly because most of them were short trips and largely intra-zonal rather than inter-zonal in nature (and so not relevant to planning for longer distance car trips on new road networks), and because they were not seen as potential substitutes for car travel.
- It has led to a poor understanding and modelling of modal choice behaviour, because the vehicle trip-level unit of analysis that had been developed for analysing and modelling car travel was adapted to measure person trips. But conceptually this makes no sense, since mode choice decisions between taking car and non-car modes are not made at a trip level, but rather at the level of the home-based tour.

Subsequently, the enlargement of the paradigm from person trips to activities has, in turn, been held back by the following person trip-based legacy considerations.

- The continued use of travel diary data for most activity-based studies has prevented an analysis of the trade-off between in-home and out-of-home activities, and by assuming only one trip purpose/activity per non-home destination, it has underestimated levels of out-of-home activity participation [19].
- The focus on individual behaviour (as a legacy from the original vehicle-based perspective), with very little experience of looking at interactions between the decisions of different household members.

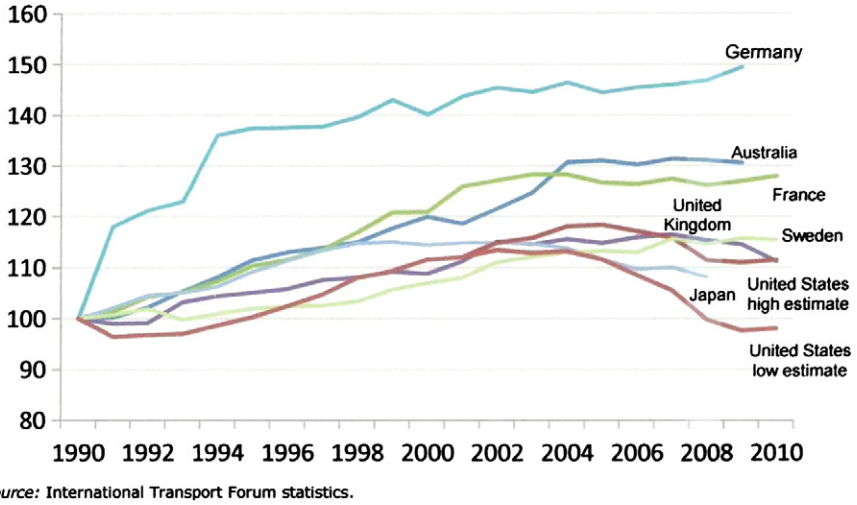

Fig. 2. Passenger kilometres by private car and light trucks 1990–2009. (Index 1990 = 100) Source: [15], Fig. 1.

4.1. Legacy modelling issues

In some cases policy thinking has been seriously constrained by legacy effects in models. One of the clearest UK examples was the use for several decades of a fixed origin–destination matrix in traffic assignment modelling. This procedure was adopted during the 1960s as part of the vehicle-based paradigm analysis; but at that time it was recognised as being a simplification because computing limitations made it impractical to iterate with trip destination choices – and in a policy environment where the objective was to cater for, not constrain, the growth in traffic demand this was less of a problem. However, over time, the understanding that this was just a pragmatic simplification was lost, and the belief emerged amongst practitioners and policy makers that vehicle trip demand was inelastic and so had to be catered for (or switched to other modes). This both encouraged the view that increased road capacity would eliminate traffic congestion (and not generate increased demand), and that it would be impractical to reduce road capacity in congested networks (e.g. to provide bus priority lanes). In the UK, it took the SACTRA report [20], and subsequent empirical studies, to demonstrate the fallacy of this assumption [21], but it severely constrained and for several decades policy initiatives to reallocate road space from general traffic to sustainable travel modes or street activities.

More generally, while the nature of 'transport as a derived demand' is widely stated as being a truism, most travel modelling frameworks do not embody this thinking at all. Fig. 3 provides a highly simplified representation of the main drivers of transport demand and the major alternatives to personal travel, on the basis of explicitly treating (most) travel as a derived demand.

This starts with the recognition that different types of consumers will have varying demands and patterns of preferences, based on well-established characteristics such as income, age, and gender. These can then be associated with different patterns of consumption of goods and services, strongly influenced by the range of products on offer, their relative prices and social and cultural factors – which are partly influenced by branding and image.

Realised consumption depends on the consumer obtaining access to the relevant good or service, which would traditionally require them to travel from home, or receive a delivery (good or service) to the home – but with increasing scope for access via the internet. Consumer travel behaviour is influenced by car availability, the provision of services by different modes, and their times and costs. The suitability of accessing goods and services via deliveries to the home, and use of the internet are heavily dependent on the types of equipment available within the home.

The parts of Fig. 3 in grey are normally excluded from transport analysis and modelling – and so are also largely missing from transport policy analysis. Instead of treating travel as arising indirectly from the demand for goods and services, transport analysts posit a direct link (dotted line) from consumer types to travel behaviour, bypassing any consideration of the characteristics of the non-transport goods and services on offer – as well as the alternative forms of access other than personal travel, and the types of investment that make these alternatives possible.

This raises the basic question: to what extent can we rely on concepts and methods which – for simplicity – treat transport as a direct demand, when we understand in principle that transport is primarily a derived demand: a delivery agent within a much more complex economy and society? This is explored further in the next section.

4.2. Legacy appraisal issues

In the case of the UK at least, until recently appraisal techniques have lagged even further behind the development of the newer policy perspectives than is the case with modelling [18]. This means, for example, that the appraisal of sustainable transport and activity-oriented

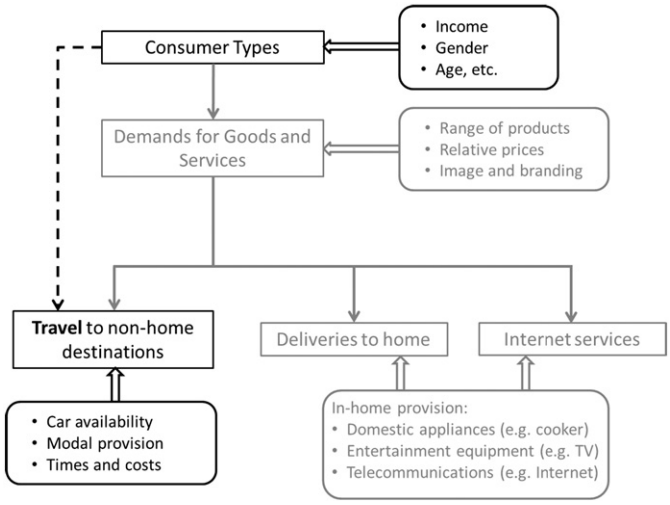

Fig. 3. Role of travel as part of the wider consumption process. Source: Fig. 1 in [22].

strategies has to satisfy requirements that were originally developed to justify investment in car-related infrastructures. In particular:

- Vehicle-related effects dominate the monetised parts of the transport scheme appraisal process, from operating cost and travel time savings to the negative impacts of air and noise pollution and road traffic accidents.
- From an activity perspective, it might be more efficient and less stressful to undertake a set of daily activities with reduced amounts of travel (through trip chaining, site consolidation, or in-home activity substitution), but at present reductions in trip rates tend to be viewed negatively: time savings per trip count as a plus, but trips 'foregone' tend to be viewed as a disbenefit rather than a benefit.
- Appraisal focuses on valuing reductions in unproductive travel time savings (e.g. driving time) rather than on valuing productive time spent (e.g. working time on a train) – so this encourages transport investment intended to save travel time in roads (where time is spent less productively) rather than in rail (where there is more potential to use time productively).

5. The wider socio-technical context

While these successive paradigm enlargements have brought new disciplinary perspectives to bear on transport policy – particularly in areas such as road safety, where it is common for engineers, psychologists, police, health and educational professionals to pool their knowledge to tackle multi-faceted problems – it is still largely true to say that transport is relatively 'self-contained' and deals only with issues of transport demand and transport supply.

In recent years, however, this bounded approach to transport has been challenged by a group of sociologists and technologists who have been looking at change from a broader perspective of 'socio-technical systems', working at the interface between technologies and social and business practices. Brand [23], for example, explores the notion of the synchronisation of technologies and business practices as a basis for changing behaviour patterns; while Geels [24] has noted that, at the onset of the introduction of the oil-based vehicle mobility system at the start of the twentieth century, the development, adoption and diffusion of this new socio-technical system involved the coming together of a much wider range of interests and organisations than would have been considered as relevant 'transport interests' in previous centuries.

Jones [25] shows how the socio-technical approach can throw valuable light on changes in travel behaviour – for example, in understanding food shopping practices. He accounts for the shift in the predominant mode/frequency of travel for shopping over time as

being not simply due to changes in mode availability, but linked to wider technological changes across several branches of the economy.

Table 1 summarises the wider set of socio-technical changes which underlie the observed changes in shopping travel patterns.

This identifies three successive socio-technical clusters.

Socio-technical cluster one – the first half of the twentieth century and earlier: various types of fresh food were sold in a series of small, local, family-owned specialist shops where the premises were constructed from local materials of brick/stone, tile and wood. The shops would obtain most of their supplies of fresh foods from farms or food processing businesses in the surrounding region, with tinned foods coming from further afield. Households would typically shop on a daily basis, as they did not have the facility to keep them fresh for long time periods, carrying their purchases home on foot and paying for them in cash.

Socio-technical cluster two – the late twentieth century: by now, most grocery shopping is carried out at one supermarket site offering a very broad product range; the very large building is constructed using a steel frame and cladding and is typically located on the edge of town or outside the built up area close to a high speed road network. Products are now sourced from around the world, using global communication systems and delivered using advanced logistics. Most people make weekly grocery shopping trips by car, which has sufficient storage space to carry this size and weight of goods. Payment is made either using cash or credit card.

Less obvious, but underpinning this socio-technical cluster is the invention of the fridge-freezer, without which it would not be possible to have global supply chains, nor for households to store fresh foods for a period of a week – or much longer in the case of frozen foods. And, at a higher level, most of this would not have been possible without the widespread availability of a cheap and reliable electricity supply.

Socio-technical cluster three – an emerging pattern: here the weekly shopping trip to the supermarket by car is being replaced by home deliveries, on demand, from the supermarket's distribution centre directly to the household, using small vans. This shift in grocery shopping travel behaviour is due primarily to two non-transport technological developments: the widespread availability of fast broadband internet connections in people's homes, and the facility for electronic payment by credit card. Le-Vine and Jones [17] find a sharp reduction in car driving in Great Britain between 1995/97 and 2005/07 amongst men in their twenties (a drop of around 1,900 miles per year averaged across the whole population group), which is disproportionately due to reductions in shopping and out-of-home social activities – which might be associated with increased internet use for shopping and social interaction.

Thus, without major advances in building construction materials, in global logistics and associated communications, and particularly in cooling/freezing technologies, then most shopping trips would still be most likely to be made on a daily basis to local shops – regardless of the availability of a car.

The implication of this analysis is that, in order to achieve major increases in levels of sustainable travel patterns in the future, policy makers should be looking to encourage new forms of cross-sector, socio-technical clusters and associated business/social practices that facilitate more sustainable patterns of behaviour in general. We turn to this issue in the next section.

6. The future for urban mobility

Having spent most of the paper looking back over the past 40–50 years, this section looks in the opposite direction – to the future. What might be the future transport policy paradigm and how might cities be addressing mobility issues around the middle of this century?

There are signs in some of the larger European cities with advanced sustainable urban mobility policies that continuing increases in population and employment are leading to growing congestion and overcrowding – not just on the general road network but also on the public transport, walking and cycling networks. Particularly in cities where population is expected to grow rapidly and substantially in the coming decades (e.g. in London), such problems are anticipated to get much worse, and it is likely at some point that simply introducing further applications of existing 'Stage Three' sustainable mobility policies will be insufficient to tackle the problem.

There are also likely to be a differing set of policy concerns: a continued emphasis on reducing traffic accidents, improving air quality and reducing CO_2 emissions, alongside an increasing emphasis on city liveability and quality of life, as well as ensuring resilience to more extreme weather conditions (high winds, flooding, etc.).

These challenges are likely to be addressed through a combination of applying advanced technologies and encouraging changes in business and social practices. One important development is likely to include various advances in transport technology and management. In particular:

- New technologies to increase all forms of transport network efficiency and to reduce congestion/overcrowding, applied to the operation, management and information provision of transport services; for example, network management based on predictive traffic congestion, real-time parking and loading space assignment, and dynamic public transport scheduling.
- Changing forms of car (and other private motorised vehicle) provision, away from traditional patterns of personal ownership to various forms of shared use – reducing overall vehicle fleet sizes and particularly taking pressure off providing on-street parking spaces in denser parts of urban areas.
- The likely future impact on city traffic and congestion, and road safety of the availability of self-driving, autonomous vehicles; these are particularly likely to appeal to older drivers, who would traditionally have had to start thinking about giving up driving due to ageing and poor health.

Table 1
Comparison of the three socio-technical clusters and their associated travel patterns (source: Table 2 in [25]).

	Building construction of shop	Shop type/location	Grocery logistics	Home food storage	Grocery ordering	Grocery delivery pattern
STC one	Brick and wood	Small, many, within built up area	Mainly locally sourced	Limited – cool room or marble slab	In person, paying cash	Daily collection on foot
STC two	Steel frame and cladding	Large, few, often out of town	Globally sourced	Fridge freezer	In person, using cash or card	Weekly collection by car
STC three	Not used	Not used	Globally sourced	Fridge freezer	By internet, using card	Deliveries direct to home by van

In addition, as discussed in Section 5, advances in non-transport technologies and associated changes in business and social practices could also have a major impact on future patterns of travel – both passenger movements and freight/servicing transport. For example, through:

- The widespread take-up of 3D/additive printing, leading to the localisation of manufacturing; or the wider application of self reporting and self-diagnosis of faults in household appliances, resulting in 'on demand' service visits by vans.
- The further development of a range of internet and mobile phone services (e.g. extended e-shopping, more advanced home working models, simpler public transport journey planning).

It is interesting to speculate on whether there are further paradigm enlargements which will come to influence transport policy and practice. One new field which is causing a great deal of academic interest is 'Mobilities' research, led by Urry [26] and other sociologists. This is very broad in concept and deals with all forms of mobility, from the traditional interest in the movement of goods and services to the movement of data, ideas, etc., and complements more established research on patterns of migration. This is helpful in broadening policy understanding of the changing nature of mobility.

One recent observation that is beginning to raise basic questions is the evidence of a levelling off in car use per person in the USA, Australia, the UK and several other European countries, as noted in Section 3. This apparent break between the growth in GDP and growth in travel is contrary to what has traditionally been expected and observed. It is an open question as to whether this phenomenon can be explained through one or more of the existing paradigm expansions, or whether addressing it will require further disciplinary outreach – perhaps through engaging with anthropologists or historians.

A better understanding of this phenomenon has major implications for forecasting traffic growth and the likely levels of future traffic congestion and CO_2 emissions, both at city and national levels. For example, in the British research on 'peak car' by Le-Vine and Jones [17], a series of simple 'what if' questions were posed, to look at different possible future scenarios.

- ➢ Scenario 1: company cars. Company car mileage dropped by nearly 40% between 1995/97 and 2005/07. If company car mileage were to disappear completely, without any corresponding increase in personal car mileage, then this would cut total national car mileage per person by a further 10%.
- ➢ Scenario 2: gender comparability. If women's car driving rose over time to the same levels as men's in 2005/07, right across the age spectrum, then this would add 35% to the average national car mileage per person.
- ➢ Scenario 3: generational change. If men currently in their 20s (and younger) were to preserve their lower car driving patterns as they age, then over time this would eventually imply a decrease in per-person driving mileage of approximately 20%, once it had worked its way through the population as younger cohorts aged.

As can be seen these very different, but all plausible behavioural assumptions would result in very different future car traffic levels in the UK – with consequential impacts on traffic congestion, air quality, road safety and CO_2 emissions.

7. Conclusions

This paper has sought to show that urban mobility policies have evolved over time, from early attempts to support and encourage growth in car ownership and use, through policies of containment and finally a degree of car traffic suppression and replacement with policies designed to encourage sustainable travel and promote urban liveability and quality of life. This evolution has been closely intertwined with changes in an underlying paradigm, which has both affected ways in which mobility is defined and addressed, and the methodologies used in its analysis. This process has been assisted by the involvement of new academic perspectives and disciplines.

Looking to the future, continuing economic growth and increasing urbanisation will put further pressures on transport systems and demand new policy responses, which are likely to be found both in new technologies and in the further enlargement of the academic disciplinary base to help provide new policy perspectives.

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