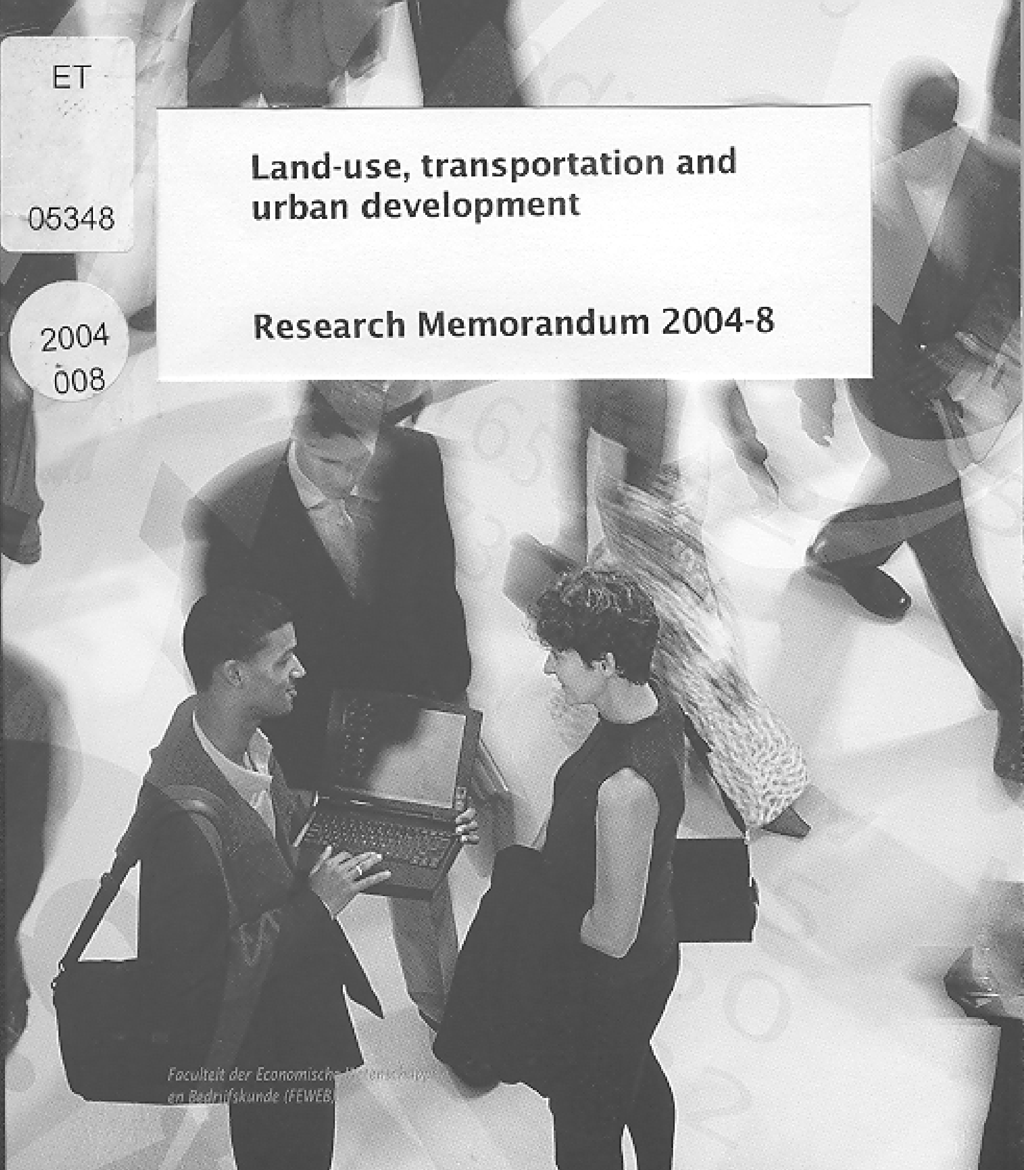
Land-use, transportation and urban development

Research Memorandum 2004-8



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LAND-USE, TRANSPORTATION AND URBAN DEVELOPMENT

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INTRODUCTION

Urban land-use and transportation are closely interwoven. Urban density and sprawl are influenced by the volume and density of traffic as well as by the capacity and spatial structure of transport infrastructure. Many changes in urban form and scale are incremental but more significant shifts in form and structure can result from transportation infrastructure investments, innovative transportation management, or new technologies.

This chapter deals with a vast topic and is thus inevitably selective in its coverage.[1] To begin with it deals almost exclusively with economics, as the theme of the book demands, but in doing so misses out very important literatures in fields such as sociology,

[1] One reason for the selectivity is to avoid excessive overlap with other volumes that have appeared recently dealing with similar themes. Early work linking transportation and urban form includes Solow and Vickrey (1971), Mills and de Ferranti (1971), Langley et al (1973), Kraus (1974), Miyan (1978) and Kanemoto (1980). A survey of this literature can be found in Medda (2000).

geography and political science that have helped better our understanding of linkages between land-use, transportation and urban development. The coverage is also limited largely to recent advances, again following the theme of the book. 'Recent' in our context is from the mid-1980s or so.[2] But what is does try to do is to focus on some of the major developments in our economy of the ways urban form and location are influenced by transportation and, conversely how transportation is influenced by urban form.

The chapter gives relatively little emphasis to the way that simple transportation variables can be 'plugged' into land-use and urban form modeling.[3] The focus of much urban economics is not specifically on transportation, which is frequently treated as an exogenous factor and defined simply as an input variable (travel time or distance). This is quite legitimate in many cases where the concern of the analysis is on other attributes of urban economies and systems. This type of analysis is covered in detail in other chapters in the volume. Here the attention is much more on the recent economic work that has been conducted seeking to get a better understanding of how transportation functions in an urban setting, and how the transportation variable can be refined should a more sophisticated variable be needed in land-use driven analysis. It is also important in instances where transportation matters are at the heart of the issue being addressed.

Some initial thoughts on previous trends are included by way of introduction and to establish threads, but as any serious student of the subject will soon realize, this is a very cursory account, and also a very selective one. The discussion is also largely limited to theoretical advances. There have been significant advances in the way data are collected, in econometric analysis and in the political economy of land-use and transportation policy, but space precludes any detailed assessment of this. There are passing comments on advances in these areas where there have been strong ties to theoretical developments but they are kept to a minimum. The chapter also looks at both the internal form of urban

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2 Many of the classic earlier papers that cover a similar theme to this chapter are to be found in Berechman et al (1996) and Rietveld et al (2003).

3 The traditional way of treating transportation is to view it as a derived demand to meet the needs of other activities. The approach in urban and regional economics is often to take a difference stance and see transportation as an input variable in the longer term determination of the spatial distribution of production and consumption. This raises issues such as the role of traffic congestion in in influencing urban sprawl and the growth of edge cities. It is really this latter type role that is the main focus of this paper.

areas and, especially in the context of urban development, more general issues of urbanization and interactions between urban areas.

LINKING LAND USE AND TRANSPORT

We start with a few words on the general state of the status of the economic work that is being done linking land-use, transportation and urban development. In many ways the perception of work in this area has changed little in recent years. Traditionally, and despite the early work of analysts such as Von Thünen, 'space' has not been a central subject for study by economists. The American Economics Association JEL Classification System places 'Urban, Rural and Regional Economics' only before 'Other Special Topics' at the end of its very comprehensive listing. The UK's Royal Economic Society in a 1991 issue of the *Economic Journal* celebrating it centenary, contained articles by eminent economists on 'The Next 100 Years'. There was no piece in the collection even remotely concerned with regional or transportation economics, let alone one linking them. Despite this there have been changes and one can perhaps trace them back to the work of Paul Krugman and, in a slightly different context, to that of Michael Porter.

Krugman has been credited with much of the recent work in what has become known as 'The New Economic Geography'.[4] Beginning in the early 1990s, Krugman (1991; 1998) began producing a series of papers that sought to bring more realism to analysis of international, and, subsequently, regional trade. There are numerous dimensions to his arguments, and in particular an emphasis on the importance of agglomeration economies, but they did bring about a greater focus on the role that such things as transportation costs play in trade and economic development at all levels of spatial aggregation. More specifically, he showed that when there are scale economies, and non-linear transportation costs are introduced into an interregional location model, the ultimate spatial distribution of activities critically depends on initial conditions including the

[4] The *Spatial Economy* (Fujita et al 1999) offers perhaps the most complete work on new economic geography to date. More basic accounts are Ottaviano and Puga (1998) and Fujita and Thisse (2002). Krugman (1993)ties his trade theory ideas to those of location. For a critical assessment of new economic geography see Neary (2001).

starting distribution of activities and the nature of the non-linearity embodied in the activity transportation interaction.

Michael Porter's role has been somewhat different; it has much less to do with formal, mathematical modeling, and more to do with changing thinking about the competitive advantage of different locations. It has more to do with notions of industrial organization and economic development than with spatial economics in its more traditional sense. From the time of his seminal work on competitive strategy (Porter, 1980) he has developed a series of ideas about management and competition that have influenced the way business strategy is viewed, and with this, the way location and production costs are implicitly treated in more formal modeling.

There have been many more generic developments in economics that have also influenced work on local spatial issues. In terms of style and approach, the economic analysis of land-use, transportation and urban development has followed that of all other fields of economics. If there was any agreement amongst the contributors to the centenary issue of the *Economic Journal* it was that, first, economics has become more fragmented, and second, that it has become more mathematics. Regarding the first, there are now certainly more specialized economics journals, and the electronic media has added to these. While the more general publications such as the *American Economic Review*, *Economic Journal*, *Journal of Political Economy* etc. have traditionally carried only an occasional article on the interface of transport, land-use and urban economics there has gradually been a growth in more focused academic publications over the years. Although their names have sometimes changed, the *Journal of Regional Science* and the *Journal of Transport Economics and Policy* were launched in the 1960s, *Regional Science and Urban Economics* and the *Journal of Urban Economics* first appeared in the 1970s, and these were joined the 21st century with the appearance of the *Journal of Economic Geography.*

Whether this trend towards greater specialization is good or not is a topic well beyond this narrow paper. So only a few observations. On the one hand there are arguments that it is to be expected in a maturing discipline, which one may argue economics is, and with the onset of greater professionalism (Friedman, 1991). It is, in this sense simply a manifestation of Adam Smith's arguments for divisions of labor and is just a reflection of trends seen earlier in the physical sciences. On the other hand it does probably mean that cross-fertilization of ideas across 'sub-areas' of economics is less easy than in the past and wheel reinventing may become an industry in its own right.

In terms of the use of mathematics, the interface between transportation and urban economics has been as absorbent as all other fields of economics. This has been combined with enhanced computer power and new estimation and programming techniques to produce an ever-increasing number of econometrics studies in the field (Anselin, 1992)[5]. The availability of GIS data has provided a massive amount of ammunition for such work. With all this, however, has come the demise of the Marshallian method of economic analysis – the notion that you use mathematics to work through the logic of an argument but then move to express this in good prose. The tendency that many point to when refereeing academic papers, or examining PhDs theses that much work seems to be based on 'a technique seeking a problem', is perhaps one outcome of this. Also, the divide between what was traditionally called political economy and economics would seem to be growing in spatial economics as in many other areas.

THE DISTANT PAST – UP TO THE MID-1980S

In his classic work establishing the basis of neo-economics, Alfred Marshall, perhaps rather arrogantly, gave little credit to his predecessors, but von Thünen was one economist whose work he did acknowledge. Von Thünen's (1826) analysis highlighted ties between land values and transportation costs, and led directly to the seminal work of Alonso (1964) on urban form. But one should also go back to contemporaneous work with that of von Thünen, namely to the French engineering school of economists, Dupuit, Napier, Minard, etc., to find some of the earliest work tying transportation to spatial patterns (Ekelund and Hébert, 1999).

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5 There has also been an increasing interest in deploying kleometrics to look at transportation and urban including work by Gin and Sonstelie (1992).

Later came the seminal work of Weber (1909) on location theory, where the ties between location and transportation were clearly articulated. This in turn led to the more detailed work of Isard (1951) and provides a clear lineage to modern regional economics. Predöhl's (1928) was more in line with much of modern general equilibrium economics, and provides a backdrop to Moses' (1958) contribution. Nevertheless, much of the work done in both the field of urban economics and transportation economics was largely what would today be called 'institutional economics'. It often contained a significant amount of normative discussion and frequently was focused on quasi-legal issues. There was also little that could be considered as a comprehensive theoretical approach and, for example, text-books were much more individual topic based.

The 1950s saw significant advances in applied economics as computers began to appear, new data sources emerged, and the role of government expanded with a concomitant need for strategic analysis. Some of these techniques, although often not used immediately, had important implications for studying the interface between transportation and urban form. Path-breaking work appeared on both linear (Koopmans, 1951) and nonlinear (Kuhn and Tucker, 1951) programming that by the late 1950s was being regularly applied to optimization topics in location and transportation. Interest in micro-management of economic systems, often within a Keynesian framework, led to the development of regional and urban input-output analysis as a direct result of Leontief's (1953) pioneering work at the macroeconomic level. The techniques also provided an important component of equilibrium models that were beginning to be constructed.

From the transportation side, the gravity model was introduced in land-use-transportation planning exercises, initially more or less as a pragmatic tool with little intellectual undepinning, and adapted for use in spatial location analysis. The period also showed a renewed interest in the economic analysis of traffic congestion (Vickrey, 1959: Walters, 1963) and links between pricing of transportation infrastructure and investment in new capacity (Vickrey, 1969). This was reinforced by considerable intellectual efforts to incorporate non-market factors, such as the costs of travel time, into urban transportation modeling (Moses and Williamson, 1963; Beesley, 1965). Without this better description of how transportation systems function, and the implications of their market imperfections, any model of urban form would have been deficient.

The 1950s and the 1960s saw ad hoc technical advances, but fragmentation of methods and a problem-based ethos meant that a unified way of approaching location, transportation and urban form was lacking. The picture changed in the 1970s. The so-called New Urban Economics (Mills and MacKinnon, 1973; Richardson, 1977) emerged building much on neo-classical economics and focusing on broader questions of urban size and form. It involved some of the major economic figures of the latter part of the twentieth century, including Nobel Prize winners James Mirlees (1972) William Vickrey (Solow and Vickrey, 1971) and Robert Solow (1972), and reintroduced more positive analysis to urban and transportation economics.

These analytical developments in urban economics also occurred at a time when the modern field of regional science began to attract attention. While the new urban economics largely helped define the study of intra-urban form, regional science offered additional insights into inter-relationships between cities. Regional science combined, amongst other academic disciplines, the skills of economists with those of human geographers, environmental scientists and applied mathematicians who sought to understand more completely location patterns and spatial dynamics. It has led not only to an area of study in its own right but also has stimulated, by bringing new tools and concepts to bear, significant new work linking land-use, transportation and urban form. In particular, it has provided powerful new ways of viewing urban areas as parts of larger spatial economic systems.

Although there has been a significant shift towards abstract theoretical modeling many of the recent advances at the interface of transportation and urban development have come about because of larger changes. Effectively, at least part of the research in recent years has reflected a changing urban policy and commercial environment.

On the transportation side, major changes have occurred in the way transportation services are delivered.[6] Advances in management science in the 1970s, particularly in costing and scheduling, have led to significantly different ways in which transportation logistics is now viewed. It has led not only to new demand patterns for urban transportation infrastructure but also to changes in related activities, such as warehousing, that have primary and secondary effects on urban forms. Equally, major developments in regulatory economics[7] and changes in regulatory regimes have impacted on modeling of institutional structures and their influence on transportation supply. There have been technology changes as the 'Information Society' has gradually emerged. It has affected the lives of people in general but also the demands they place on the transportation systems of cities, on the way suppliers of transportation services can respond and on urban geography (Gasper and Glaeser, 1996). There have also been significant changes since the 1980s in urban form. Urbanization has grown, suburbanization has grown but there has also been the emergence of new urban spatial structures, of which edge cities are perhaps the most discussed (Garreau, 1991).

The edge city was first described as a new form of urbanization. It refers to a spatial constellation where large companies form a new nucleus outside a city's central business district and induces new suburban development in the area. Various approaches have been advocated to explain this development One explanation can be found in the equilibrium forces between agglomeration and dispersion forces that determine the spatial-economy of the city (Fujita and Mori, 1997). A second embraces the micro locational choices of business in an urban area (Krugman, 1996). Other approaches are reviewed in Medda et al. (1999).

Henderson and Mitra (1995) and Glaeser and Kahn (2003) have developed economic models with explicit attention to agglomeration economies for firms in central locations. These central locations are hindered in their development by the high generalized transport costs of workers living in remote suburbia. Sub-centers emerge as the result of

[6] See papers in Brewer *et al* (2001).

[7] In the case of transportation it is not simply that the new ideas of regulation were applied but in addition they were tailored in many cases to the particular characteristics of a network industry (Economides, 1996).

the trade-off between lower transport costs of workers and lower agglomeration economies resulting from the spread of activities.

In recent years an interest has developed in the relationship between urban dynamics and modal choice (Newman and Kenworthy, 1999). In particular, the use of public transport and of other more environmentally-benign modes of transport have attracted attention (Dorins, 1992; Pucher and Lefèvre, 1996). The implications of urban public transport (or transit-oriented developments) have been studied not only from a transportation perspective, but also from an urban land-use viewpoint, for example, the emergence of subcentres along a transit connection (Calthorpe, 1993).

There are a number of different threads to what is emerging at the interface of economic work between land-use, transportation and urban development. These are not easily delineated but some effort is made here for reasons of exposition. These trends also reflect in many cases continuations of previous trends, advancing, refining and testing fairly well established basic concepts. There is, for example, an expansive contemporary literature that effectively refines Alonso's work. Others are breaks in trends, or possibly new trends. No attempt is made here to try to separate these various possibilities.

CONGESTION AND PRICING OF TRANSPORTATION INFRASTRUCTURE

Traffic congestion is a major problem and is one of the main determinants of location decisions in cities. Car ownership and use have grown considerably since the 1970s, and the pattern of road use has altered in a way that often conflicts with the design aims of road networks. In particular, in the US in 1969 some 25% of aggregate urban car trips were for commuting reasons and there was the prospect of channeling this along a limited number of arteries. Now only 15% are exclusively for journey to work purposes, and trip chaining involving complex trips that embody such purposes as shopping, recreation, and child movements as well as a movement to and from employment, is much more widespread making the traditional focus on radial urban transportation networks much less relevant.

The upsurge of interest amongst academics, as well as practitioners since the 1960s moving to better understanding the economics of congestion, and in making better use of urban transportation infrastructure, has led to refinements in assessing how the Road Price should be calculated. As Vickrey pointed out, there is in ideal circumstances, a need to vary the price according to traffic demand and costs. The time of day, the traffic mix, the physical features of the network and local road conditions (such as the weather and accidents) may influence these. While there has been a number of important contributions over the past 15 years, not all of these areas have been looked at in detail and, indeed, some very important issues such as pricing congestion caused by incidents have received limited attention. But certainly the economic understanding of urban traffic congestion has made considerable steps forward.

Congestion theory has also moved forward in a different sense over the past forty years.[8] The initial model of traffic congestion is time independent – it is essentially a snapshot at a point in time. This approach can be refined by looking at how travel demand varies over time, and at how traffic flows evolve over time and space – the model becomes time dependent. It looks, for example, at the evolution of traffic congestion over a rush hour. The detailed modeling takes a variety of forms that, however, often assume vehicles are precluded from overtaking etc. and results emerge that are highly sensitive to factors such as demand elasticities and, related to this, the valuations placed on travel time. What they are essentially doing is treating congestion as arising from a bottleneck in the system. A second generic form of the dynamic congestion model is now also sometimes employed that is concerned with flow congestion. This approach does not completely eliminate travel delays at the social optimum. Both approaches involve the distribution of travel delays and scheduling of costs at the peak, and the duration of the peak in the untolled equilibrium and the social optimum, all being determined endogenously.

Road pricing is designed to produce a Pareto optimal use of a facility, but this is dependent upon the standard assumptions that surround first-best partial equilibrium analysis and especially that all other prices are equal to marginal costs. Moving into the

[8] The recent literature on traffic congestion and its economic pricing is large and is only skimmed here. For a survey of recent developments see Lindsey and Verhoef (2000).

realm of 'second-best', where the assumptions of the Pareto world are relaxed, is less tidy, and inevitably the efficient price becomes situation specific. The tendency is to relax one or two assumptions at most to seek an efficient outcome. In reality, a larger number of assumptions may not hold.

One issue that has long been of interest is the pricing of substitutes to road transport. Subsidies may be given to public transport to optimize the modal split of traffic. A subsidy for public transport, accurately reflecting the cross-elasticity of demand between the modes, could theoretically be used to attract sufficient motorists from the roads to reduce pressure on them. The difficulty, beside the standard concerns over X-inefficiency that accompany subsidies, is that while they can theoretically optimize mode split, they can lead to an excessive overall use of transport with implications for the local economy.

It is now realized that similar situations arise when only part of a road network is subjected to Road Pricing (Verhoef, 1996). This essentially leaves road users with a choice between a facility where access is unpriced but the service quality poor and one where there is an access price but congestion is optimized. The Road Price introduced on such routes must reflect the opportunity cost of not using the unpriced roads as well as the first-best toll on the priced road. Ignoring the cross-effects will lead to sub-optimally high use of the unpriced facility. Marchland (1968) was one of the first to look at this situation in terms of setting a charge that weighs the welfare benefits of reducing traffic on the unpriced facilities against the losses from deviating from first-best pricing on the Road Priced route. But more recently Verhoef et al (1996) have shown that in some cases a Pigou optimal subsidy may involve a negative Road Price.

Second-best considerations may also be important in the context of complements and substitutes for a Road Priced facility. Parking is the most explored complementary good (Verhoef, 1996; Glazer and Niskanen, 1992; Voith, 1998). In a first-best world parking fees would reflect the opportunity cost of taking up land to 'rest' a vehicle as well as the congestion costs associated with cruising around seeking a parking spot. In practice, parking is often provided free or perverse charging regimes are employed. Such regimes are frequently structured to limit certain categories of users, such as long stay users, irrespective of willingness to pay. But parking costs can affect land-use. They are a fixed cost of a trip, they are spread more over a longer trip than a shorter one and thus may affect congestion in suburban areas.

Much of the early work on Road Pricing treated all road users as identical. Variations in income and, linked to this, the valuations that they place on travel time saving as well as the size of vehicles driven, which affects road take, are now appreciated as being important consideration for both efficiency and equity reasons. At the very least, they raise questions about whether the Road Price should reflect these features. If the concern is purely with efficiency, and standard first-best conditions hold, then there is no need to consider income variations with time-varying Road Pricing. This is because all that matters in optimizing charges are the congestion costs imposed, and Arnott and Kraus (1992) provide rigorous proof of this.

Where there are alternative routes in the network (including different lanes on a road) and users have different utility functions, optimality is attained by offering various Road Price/congestion level combinations. This maximizes welfare by allowing those with a high travel time value to buy their way onto the faster routes, leaving those with lower time values on the cheaper, more congested ones. The situation can also be compared with that involving a variety of users with different trip-time preferences using a single route. Arnott et al's (1992) work on situations where there are temporally inflexible Road Prices that may involve either a single price for each of a pair of roads, or different prices, indicates the greater efficiency of the latter.

Another situation that has attracted attention includes that of drivers having different preferences for speed, that are unrelated to income. Here the models have often tended to exclude the possibility of overtaking making them particularly relevant to bridge and tunnel cases. The results suggest that the Road Price should be higher for slow vehicles to reflect their impact of slowing higher speed vehicles. Yet, because slow vehicles affect fewer fast vehicles on average and also because the speed of fast vehicles declines asymptotically to that of the slower vehicle, the price differential should *decrease* with the proportion of slow vehicles in the traffic stream. This may come as a surprise as it contradicts the standard result in transport economics that congestion charges increase with traffic demand (Rouwendal et al., 2002). This approach would require differential approaches to Road Pricing depending on drivers speed preferences – in practical terms this may be done by having different pricing regimes for cars and trucks.

Urban motor traffic places considerable strains on the environment, and the costs involved are external to the market. These effects are both wide-ranging, including the emission of a variety of local, regional and global atmospheric pollutants, noise, ground water contamination, and visual intrusion, and, in some cases, very large. The lack of adequate pricing of these inputs indicates that there should be adjustments to the Road Price to meet second best conditions. This is a large subject area. The issue is complex and the literature substantial, and is not dealt with here.[9]

There is another side to the second-best debate that should just be touched upon. There has been a mounting interest in how other elements of transportation should react in the absence of appropriate Road Pricing of motorists – what should be the second-best strategy for them to adopt? In this context Arnott and Yan (2000) have looked at pricing across multimodal systems, while Chia et al (1996) examined the appropriate fuel taxation policy to pursue if appropriate congestion charges are absent.

Added to these challenges of defining optimal charges are those of developing mechanisms for charging. These may be significant and may become entwined with other issues such as how much information the road user has on the 'product' that is being purchased (de Palma and Lindsey, 1998).

Incorporation of transactions costs inevitably leads to trade-offs, the outcomes of which are case specific. The simple cordon toll systems and area licensing present a clear picture to drivers of the price for entering a road. But charges under such regimes are not easily adjusted to reflect local traffic conditions, and will not accurately indicate the level of congestion that is likely to be encountered. Most electronic, real time charging regimes

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9 See papers in Hensher and Button (2003).

are sensitive to immediate congestion levels but do not tell the trip-maker in advance of the Road Price to be paid.

The idea of using electronic technology to collect a real time, variable Road Price was initially advanced by William Vickrey as early as the late 1950s. Despite the largely successful testing of electronic Road Pricing equipment in Hong Kong, transactions costs, issues of privacy and concern over technical reliability have favored area based systems. This means that a Road Price does not vary directly with traffic conditions but rather location or time of day is used a proxy for congestion levels. The Singapore and other schemes outlined in Small and Gomez-Ibanez (1998), together with the recent London system ,use a combination of these surrogates largely for pragmatic reasons.

The efficiency of these discrete charges is less than of a fine tuned continuous Road Price, the loss of efficiency being a function of just how closely the proxies reflect changing congestion levels. This in turn often depends on the extent to which cordons coincide with the location of bottlenecks, the number of 'steps' involved and the prices charged at each step. Empirical estimates of the extent to which these systems lose efficiency are found in Chu (1999) and Arnott et al (1993; 1998) and they seem to be significant.

INVESTMENT IN TRANSPORTATION INFRASTRUCTURE

The notion that transportation infrastructure, or indeed virtually any form of public infrastructure provision, had an impact on economic development at any level of aggregation tended to lose favor in the 1970s and 1980s as supply side-economics and the associated emphasis on the benign effects of tax cuts dominated much economic thinking.[10] The appearance of a provocative empirical study by Aschauer (1989) rekindled old fires and led to a major reassessment of the inter-relationship between infrastructure investment and economic efficiency. It also coincided with emergent new theories of endogenous economic growth (the 'New Growth Theory') associated with

Lucas (1988; 1990), Romer (1986) and others. Basically, the new growth theory, redefining older theories of circular-and-cumulative causality, argues that, over time spatial economic growth will continually diverge because of dynamic economies of knowledge growth. Since this poses problems of equity, economists sought ways of efficiently bringing about spatial convergence.

Aschauer's analysis indicated that transportation infrastructure improvements can lead to decreases in transport costs, stimulate inter-area trade and potentially contain divergent growth.. The intensity of competition increases because sectors in urban areas that were formerly sheltered are now confronted by relatively cheap imports. The result is that, while consumers in these cities may be able to buy goods and services at lower prices, employment in these sectors and in such regions declines. In exporting regions an increase in employment may be anticipated. The theory of trade, therefore, predicts that in each urban area employment in some sectors will expand, while in others it will contract as a result of the infrastructure improvement. The overall impact on any city will depend on, amongst other things, its sector structure. The flexibility of the labor force is also important, and a rigidity can mean that employment loss in one sector cannot be completely compensated for in others (Rietveld, 1995).

It should be noted that the majority of firms that relocate move a very short distance. Relocation of firms in response to infrastructure improvements mainly occurs on a local scale and is not a major cause of differences in regional growth rates. A study of the location behavior of firms with more than 10 employees in the eastern part of the Netherlands, for example, found that 75% of those that relocated did so to places in the same municipality (Bruinsma *et al.*, 1997). A closer inspection reveals that in the relocation process, 42% of the firms remained at approximately the same distance from the nearest ramp of a highway, 41% moved to a closer location and 16% moved further away. Such findings underline that the rapid growth in the number of firms that is sometimes observed at particular places near newly improved highways is to a considerable extent the consequence of relocation within regions. These relocation

[10] While the focus here is more on the general urban development implication of transportation infrastructure there have been numerous studies have refined our understanding of the implications of

processes are, of course, quite relevant at a local level, but from a broader regional or national perspective they are less important.

The implications of transport investments for the spatial behaviour of firms and residents manifest themselves in new growth patterns of firms and populations. There is usually a mutual causality phenomenon involved – development creates the funds to finance infrastructure and infrastructure creates development potential. There is now a multiplicity of studies addressing such mutual relationships (Nijkamp, 1998).

There have also been advances in our understanding at a more micro level of the links between the pricing of urban transportation infrastructure and optimal investment strategies. A market price serves not only to allocate current facilities optimally but also provides signals to where capacity should be expanded, and the revenues from the price provides resources for that expansion. In a perfect market situation, effectively Knight's (1924) position, there is no requirement for separate consideration of capacity expansion – the net revenue flows give the necessary guidance. Given the reality of public ownership of most road track, and the context of the recent emergence of interest in Road Pricing, studies quickly emerged looking at the link between this and road investment strategies (Mohring and Harwitz, 1962).

In the first-best situation with Road Pricing, where there are constant returns associated with roads, the investment decision is also straightforward in its generality. Road Pricing reflects the opportunity cost of making use of a road. If this the benefits of road use exceed exceeds the opportunity costs of expanding the network then more road space, or investment in improved management systems (e.g., signaling or signage), is justified. Basically, if the road agency is earning a return above costs then investment should be considered by comparing the net present financial value of more road capacity with that of investing elsewhere.

The optimal amount of capacity with Road Pricing is arrived at with a constant cost of expansion when the Road Price reverts to covering the maintenance cost of the system.

individual investments (e.g., Bollinger and Ihlanfeldt, 1997)

This is a standard finding for any economic activity when marginal cost pricing is ubiquitous. The situation becomes more complex if the long-run marginal cost is not constant or when capacity cannot be expanded incrementally (Hau, 1998). Nevertheless, in concept it still conforms to situations in other sectors involving capital capacity decisions under similar conditions.

Essentially if there are diseconomies of scale then, at the optimal capacity and with an optimal Road Price, economic rent will be earned. This reflects a scarcity rent on a fixed factor of production; in this case it will be land. Equally, if there are economies of scale, and in some instances when there are large indivisibilities in investments, then Road Pricing will not generate sufficient revenue to cover the full long-run costs of optimal road provision. Subsidies will be required and techniques such as cost-benefit analysis come into play in determining their level.

Much, therefore, depends on the view taken about the nature of the long-run cost curve. Whether the assumptions do hold is an empirical matter. Work by Small (1992), amongst others, indicates that in many cases the relevant cost conditions approximate to those conditions providing a direct link between an optimum Road Price revenue and optimum investment levels.

TRANSPORTATION, INFORMATION AND LAND-USE[11]

There has been considerable interest in the links between communications, transportation and urban land-use patterns, and in particular to investigating teleworking (telecommuting), as an alternative to commuting to a non-home work site.[12] This is attractive politically because it avoids generally unpopular traffic constrained by

[11] This is a growing area of analysis and the rapidly exapnsing literature is barely touched upon here – a useful collection of papers is contained in Stough et al. 2003.

[12] Teleworking is defined here as any proportion of work done at home, which would normally be done at the workplace. This would include parts of days or weeks working at home, regional centers, satellite work centers, local work centers or neighborhood work centers. While the focus here is on the links between work travel, communications and land-use, work has also been undertaken on such things as teleshopping (Manski and Salomon, 1987) and on the impact of ebusiness (Borenstein, and Saloner, 2001). See also Shapiro and Varian (1998) for a general discussion of the economics of a communications society Button and Taylor (2001) for a wider review.

measures such as Road Pricing.[13] There is also the spatial implication that if telework expands then conventional land-use patterns will change, and be come less structured (Gasper and Glaeser, 1996)

There are, however two broad possibilities about the links between transportation and telecommunication: they may be substitutions or complements (Salomon, 1985; Schuler, 1992).[14] Until recently, substitution, involving a physical trip to be replaced by electronic communications technology, has been the more popular of the hypotheses. Overall, attempts to identify a wide spectrum of substitution effects have generally been inconclusive (Salomon, 2000). A complicating factor is the oft-invoked assumption of this type of work that total interactions, whether by travel or communication, tend to be constant, may not be valid. If, for example, people have a constant travel time budget then the availability of telecommunications does not reduce the amount of travel undertaken.

Supporting the hypothesis that substitution is unlikely, at least in the short term, Nijkamp and Salomon (1989) point to the fact that over time the total amount of all forms of communication has increased. Incomes have risen, car ownership has risen and the socioeconomic life of Western economies has evolved to encourage greater levels of interpersonal contact. Further, high growth in the service sector and information industries has resulted in a greater inherent emphasis on face-to-face communication and the development of interpersonal relationships during work hours (Storper and Venables, 2002).

Increasingly, business and pleasure are merging, and networking is a valued skill in contemporary working life. However, at any point in time there are physical and logistical constraints on the capacity of individuals to meet face-to-face. This leads to location patterns with an emphasis on proximity and easy access to high-speed connections via airports and railways. Concerns about the environmental implications of

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[13] One may also add that the improvements in telecommunication that are taking place can also add to the efficiency and effectiveness of policies such as road pricing (Verhoef et al. 1996)

[14] At the theoretical level, Safirona (2002) offers a general equilibrium framework tying transportation, land-use and communications in a single model.

further infrastructure expansion and the high costs of such investments, combined with changes in life-styles, suggest that this interaction curve is now beginning to flatten. Through telecommunications technology, a greater number of interactions are possible. The implication is that telecommunications has the scope to not only fill the potential interactions needed, but also to push up the potential for additional interactions.

The economic argument for the decline in spatial variation, and indeed the potential end of conventional cities, ties in closely with the degree to which electronic communications are substitutes for face-to-face contact (Gaspar and Glaeser, 1996). As we have seen the evidence on this is far from clear since face-to-face contacts are important for trust, which appears to be the basis of many types of social and commercial interactions (see for example Fukuyama, 1995). This implies that transaction costs are highly relevant for urbanization patterns, and that these costs cannot easily be substituted by ICT means. There has been a tendency historically for urbanization to be unevenly spread, but often to broadly follow a consistent hierarchical pattern (Krugman, 1996). Whether this pattern is sustainable in the context of the widespread use of the Internet is still uncertain and in need of further empirical work.

This lack of any confirmation with the neoclassical convergence theory for Internet supply is also tending to be replicated in terms of physical distribution. The developments in information systems and ecommerce more generally have led to a tendency to concentrate interchange and consolidation at a limited number of nodes. This fact, that largely refutes neoclassical economics, may not be that surprising, however, in light of the standard (Vernon, 1966) theory of product cycles. When new products emerge they tend to be located in regions with high quality labor and access to specialized information. Time erodes these needs as the product becomes more standardized. The Internet is too new to be able to ascertain whether it will follow this pattern or not. The situation at present is that economic theories abound linking the Internet and ecommerce to land-use developments, but the empirical support for any of them is still extremely tenuous.

TRANSPORTATION DEMAND MODELING

Transportation modeling and forecasting, in part because of a certain intellectual arrogance on the part of economists, had until the mid-1970s been dominated by engineering models based around aggregate behavior and a rather mechanistic view of how travel choices are made.[15] The basic analysis involved a four-stage sequence that initially forecast aggregate trip making in an urban area, then distributed this between origins and destinations, then to modes and finally assigned it to individual routes. The overall framework hardly corresponded to an economic model, although some of the sub-models used, most notably those used to distribute traffic between various origins and destinations, did have a basis in utility theory. But the aggregate trip generation model, in particular lacked a sound economic basis and explicitly assumed a zero cost of travel elasticity.[16]

This approach changed with the advent of discrete choice modeling for which Dan McFadden would later win the Nobel Prize for economic science (McFadden, 2001). This disaggregate to modeling approach, that initially emerged in the 1970s, has been considerably refined and developed since.[17] For example it now can embody more flexible forms (Bhatt, 2000).

There have been a significant number of developments to traditional modes of transportation demand that have refined our understanding of links between transportation and urban form. In the context of this review, DeSalvo (1996) and Sasaki (1990) developed a model linking income, residential location and transportation, and Mori and Nishikimi (2002) focus on transport density and industrial agglomeration.

[15] Exceptions to this include Beckmann et al. (1956), Meyer et al. (1965), and Mills (1972)

[16] While this was seen as as an unrealistic situation as far back as the 1850s, it was largely dismissed until the sudden discovery by traffic engineers that there was 'latent' demand for road space when congestion exists, and that 'induced demand' emerges when capacity is added. Reducing the generalized cost of trip making stimulates more travel in the aggregate (Abelson and Hensher, 2001)

[17] There has also been important development in the nature of modeling. The widespread use of revealed preference models has been supplemented by the development of stated preference methodologies that examine how actors will act when confronted by hypothetical situations. This work is not covered in detail here but does allow, in particular economists, to explore, for example, the introduction of entirely new forms of transportation or unusual transport policy options in an urban area.

Sasaki (1990) examines the implications of using charging for two competing transportation modes in a city, and looks at the affects on outward physical expansion of the urban area.

An important policy discussion relates to the potential contribution of spatial planning to curb urban sprawl and the associated negative externalities of transport, such as congestion, noise and other emissions. Brueckner (2000) mentions three main reasons – market failures- to worry about urban sprawl. The first concerns the failure to take into account the social value of open space when it is converted to urban use. The second is the failure of individual commuters to recognise the social costs of congestion created by their use of the road network. The third failure is related to the real estate developers who do not take into account all of the public infrastructure costs generated by their projects. The first issue of negative externalities related to the use of open space may indeed be a reason for government intervention in the form of spatial planning in order to prevent excessive fragmentation of open land. However, to address the other two problems, pricing measures in transport would be natural tools to use, implying that spatial planning is typically a second best instrument, to be used when pricing measures are not feasible.

One of the problems is that from an empirical viewpoint the impact of spatial planning on transport seems to be smaller than is sometimes thought. For example, average daily travel distances in highly urbanized areas tend to be lower than in other areas, but the differences are limited (Rietveld, 2002). Also the effects of particular spatial planning doctrines such as compact cities, new towns, or diffuse patterns have smaller effects than anticipated. One of the reasons is that most of the settlements in mature economies are already given, so that spatial planning has, by definition, a limited effect. Another point is that, although spatial planning may have substantial impacts on choice sets of people in their travelling behaviour, the specific choice of a travel alternative will be driven by other factors, including prices. This underlines the second best character of spatial planning compared with pricing policies.

CONCLUSIONS

This survey has focused on some of the main areas where our understanding of the economic links between location, transportation and urban form have moved forward since the mid- 1980s. It has been a time when economics itself has changed, and this has affected the feel of the work done and the methods used. There has been a considerable focus on the more efficient use of urban transportation networks, and especially the use of congestion charging to reduce traffic congestion levels. Other fields of focussed research concern investment in urban public infrastructure and its effect on land use and productivity. Also the theme of substitution versus complementarity between physical transportation and interactions through telecommunications media use has been an important field of research. There is still much uncertainty about how this interaction affects urban growth and form. This theme also touches on the central question of agglomeration advantages and may therefore be expected to be a major focus for future theoretical and empirical research in urban economics. To undertake this, however, and also other areas of work of a similar vein, will require more and better hard data than have often been available in the past.

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