Land Use Transportation Models for Policy Analysis

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The objective is to assess the ability of land use transportation models to address some current policy issues. The nature of the relationship between land use and transportation is examined briefly in terms of empirical evidence and the results from modeling exercises. Two studies that use such models and that are being carried out in Britain are examined. Despite these and some convincing arguments by experts, there is little evidence of widespread use of such models. A number of current policy issues are discussed, and then a set of policy instruments that can be used to meet the policy objectives are identified. Evidence on the ability of land use transportation models to represent the impacts of the policy instruments is presented. It is shown how such models can contribute significantly in some areas of policy analysis, for example, reducing congestion and energy use, but can contribute very little to the objective of moving toward a market economy.

The objective of this paper is to assess the ability of land-use transportation models to address some current policy issues. The paper focuses mainly on models that represent the two-way relationship between land use and transportation. This relationship is examined in more detail in the next section. Then the methods used to model it are considered in the following section. In the subsequent section some of the current policy issues in urban transportation are identified and the abilities of the models to address them are discussed. The paper is concluded with an assessment of the way forward.

NATURE OF RELATIONSHIP BETWEEN LAND USE AND TRANSPORTATION

Figure 1 shows the basic relationship between land use and transportation. The diagram shows that land use, that is, the spatial distribution of activities, determines the pattern and scale of trips that use the transportation system. Variations in this affect the level of accessibility, making some places easier to reach, others less so, and so affecting where development occurs. The left side of the diagram is represented by conventional transport models, either aggregate or disaggregate. The right side is represented in a variety of models that have been developed in various countries around the world. Many but not all of these represent the whole two-way relationship. The link from land use to transportation may be regarded as well established and understood, but the converse is much less so, partly because of the long time that it takes for such effects to occur and the consequent lack of empirical data.

There is little doubt that land use does change in response to changes in transportation infrastructure and thereby causes second-round effects on travel demand in addition to the direct effects caused by route and mode switching. This is likely to cause new roads to be used to a greater extent than that forecast by conventional methods. A good example of this is the M25 motorway around London, which was overloaded as soon as it was completed.

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However, the nature of the response of land use is complex and causes much confusion. It is important to recognize that the land use response can cause extra traffic without any development occurring. If extra development is stimulated that is a third-round effect. The second-round effect is the result of people choosing a different set of homes and jobs because of the increased accessibility. For example, the opening of a new bridge across an estuary would allow people who work on one side to live on the other. That does not require new homes to be built, and people living on one side can now take jobs on the other side. These effects would lead to new trips above the number changing mode or route. Of course, if developers do build new dwellings, that would attract even more people to live there, causing even more trips. Some employers might choose locations to take advantage of the larger labor market caused by the bridge, producing even more trips.

Similar effects have been noted when railway lines have been electrified, thereby reducing travel times. This means that people can consider a wider range of areas in which to live. This implies that the potential commuters have some notional measure of the time that they are willing to spend traveling to work. If this is so, it implies that building a new major transport infrastructure that links to a major employment center will cause such relocation effects, and hence traffic flows may exceed those predicted by a conventional transportation model.

The three sets of effects may be summed up as

1. First-round effects: change of route and change of mode;
2. Second-round effects: change of residential location, change of employment location, change of shopping location, and change of trip distribution; and
3. Third-round effects: location of new dwellings, location of new jobs, and location of new shops.

If land use effects do occur they will be a form of redistribution rather than genuine generation. However, the redistribution effects may be from a long way away if they involve a change of home or job. Such effects have been modeled by the author for improvement to rail corridors around London using the Leeds Integrated Land-Use Transport (LILT) model (*1*). It was found that many of the extra trips on the improved corridor were due to people making a locational change as well as changing mode. It was found that about one-third of the extra rail trips on the corridor were by people who would have traveled by rail, but along other corridors, particularly the adjacent ones. The other two-thirds were switching mode and, in many cases, location. This effect has important implications for elasticity measurements based on observations on the line being modified, because the elasticity would not include the compensating effects elsewhere, and so would be an overestimate.

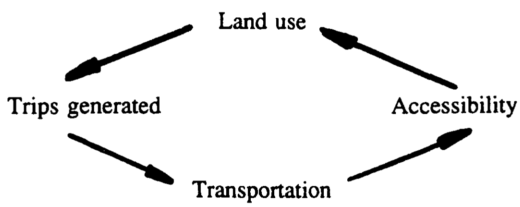

FIGURE 1 Relationship between land use and transportation.

The LILT model (*2*) has demonstrated two other land-use effects. The model was used to show the effects of changes in the price of gasoline and bus fares. The model was run in two ways: first, with spatial distribution of homes and jobs fixed, but allowing people to choose from the sets of homes and jobs, and second, allowing the patterns of homes and jobs to vary as well as the choice of them. Thus, in the former case the second-round effects were represented; in the latter case the third-round effects were added. It was found that when the cost of travel was changed in a way that favored car use, about two-thirds of the overall increase was due to the first- and second-round effects and the rest was due to the third-round effect.

The second phenomenon that the LILT model has demonstrated (*2*) is that when the pattern of homes and jobs is allowed to vary there is always more car use relative to keeping the location patterns fixed for changes in the cost of travel by car or public transportation in either direction. This is because car is the preferred mode. This suggests that as a new highway is built and development occurs there will be extra car use, because some people currently using public transport who are changing location will choose a new location that enables them to use their cars. This can be observed as part of the suburbanization process.

It is relevant to consider the empirical evidence of the land use effects of the building of transportation infrastructure. A major study was carried out on the impact of the Bay Area Rapid Transit (BART) in San Francisco. BART was found to have little impact on the net regional employment and population patterns (*3*), confirming previous evidence (*4*) and suggesting the need for the presence of other favorable factors (*5*). However, they were looking for third-round effects, which could take considerable time to appear. Kreibich (*6*) examined the effects of the building of the Munich, Germany, metro. He found that high-income families tended to move outwards and so exacerbated the separation of homes and jobs.

There have been several studies of the land-use impacts of new highways. The study of the Houston high-occupancy vehicle (HGV) highway (*7*) did not find much evidence of new development, but again, third-round effects were being sought. Moon (*8*) examined the development effects of interstate highway interchanges. He concluded that development does tend to occur there because certain organizations require access to the highway. Another study (*9*) found that land values tended to rise more near interchanges on interstate highways than elsewhere, and this was interpreted as evidence of urban development in response to highway construction.

Thus, the evidence on the land use effects of changes in the supply of transportation is not well defined. There is little doubt that such effects do occur. This lack of clarity means that there is not a single well-specified base on which models can be built. Instead there is a collection of different approaches. For example, Wegener (*10*) has examined 12 urban models and found that they include a wide range of theories. The modeling of these processes is considered in the next section.

MODELING

Transportation modeling started in the 1950s and became widely used as computers became more powerful. However, they were not always used in a sensible and sensitive manner, and there was the well-known backlash (*11*). Wegener (*10*) argues that this was partly due to the fact that such models were linked to the rational planning paradigm that was prevalent in the late 1960s. Boyce (*12*) argues that such models lost favor because of a mismatch between objectives, computer technology, and optimism. Other changes occurred that made them seem irrelevant. For example, during the early 1980s in Britain the government was unsympathetic to planning or anything else that could be labeled "social engineering" because it believed that "the market would provide." The market can provide some aspects of transportation, such as local bus services, but it does not produce large-scale public transportation systems or major highways because of the high cost and high risk. Given a free choice few investors would choose to put their money into transportation projects because they can obtain a better return elsewhere. However, it has become clear even to the British Government that a major investment in transportation is required and that it is useful to have some idea of the likely effects and to be able to compare alternatives in a systematic framework.

Two major transport proposals are being considered in Britain at present: road pricing in London and the rail link to the Channel Tunnel. Both proposals are being evaluated using very complex modeling frameworks.

Road congestion is now seen as a very real problem in London, which is causing London to become less attractive compared with other cities in Europe when it competes to provide a home to various international institutions (*13*). After years of prevarication the Department of Transport has set up a $5 million research program to investigate the merits of road pricing, which it can be argued is a procedure for setting up a market for road space. As part of the exercise a three-tier model is being set up. The middle tier is the London Transportation Studies (LTS) model, which is a conventional four-stage transportation model that is a direct descendent of the 1962 London Traffic Study model. It is still used to evaluate all major road proposals for London. Below this model in the hierarchy is a traffic simulation model that is used for local studies, and above it is a new strategic model that includes the effects on land use; it is being developed by the consultants Marcial Echenique and Partners, who developed the MEPLAN model (*14*).

The evaluation of the proposed Channel Tunnel Rail Link (The Union Railway) is also a very complex modeling structure. The issue is to determine an appropriate route for a new high-speed rail link from the Channel Tunnel into London. For passenger trains that use the Channel Tunnel (which is a railway tunnel with road vehicles carried on railcars), which opened 1994, the through passenger trains from Paris and Brussels, having used new high-speed lines on the eastern side of the Channel Tunnel, must use the existing track to travel the 100 km to London's Waterloo Station. It is predicted that this track will have reached its capacity by the year 2000, hence the proposal to build a new link. There have been debates between the Department of Transport and the Department of the Environment over the route, particularly through London, with the former supporting British Rail's proposal to follow the shortest, and hence cheapest, route, whereas the latter wanted a route more along the River Thames to help to stimulate development along the corridor. The Department of the Environment won the argument, but the station pattern still has to be decided. Since there will be spare capacity on the link, it is proposed that it be used for domestic traffic, that is, to carry commuters. The numbers carried will be influenced by the location of the intermediate stops, the train frequency, and routing. This is all being analyzed by using the complex modeling setup. Because the work is being carried out in a short time period, Union Railways Limited (a subsidiary of British Rail that will be sold to the private sector), which is building the railway, is having to use a variety of models since none of the existing ones could meet all of the requirements. The procedure followed to examine the impact of a particular route, station pattern, or train frequency is to find the revised travel times between pairs of zones through the rail network by using the tree-building elements of a model called the Union Railways General Evaluation Network Tool (URGENT). These are then entered into the generalized cost elements for the LILT model mentioned earlier. This is used to find the trip distribution and modal split pattern, allowing the choice of home and job to vary for subsets of the population. The rail trip pattern is then assigned to the appropriate detailed rail network by using URGENT, and an economic evaluation is carried out (*15*). The LILT model shows that the areas of increased rail accessibility would attract more residents who wish to commute by rail, mainly to central London. They occupy dwellings that would otherwise have been occupied by people commuting elsewhere, usually by car.

There are a number of models of the interaction between land use and transport, as shown in Figure 1. Usually the models contain all of the elements of the conventional four-stage travel demand model, that is, trip generation, trip distribution, modal split, and assignment. In some cases assignment is not included, with the model focusing on strategic issues rather than detailed network effects. Usually, trip distribution comes directly from the locational element of the model. The models include the choice of residence and employment as functions of the accessibility to the opportunities available, that is, homes and jobs, respectively. Some models include the explicit locations of new homes and jobs. The accessibility term contains travel time and cost plus other relevant factors, usually in the form of generalized cost. The models work over time, often incorporating time lags between the variables as the response of land use to changes in the transportation system occurs over a number of years.

The Transport Research Laboratory, which is part of the U.K. Department of Transport, organized a systematic study of land use transportation models by setting up the International Study Group on Land-Use Transport Interaction (ISGLUTI). Part of the original rationale behind the study when it was set up in 1980 was to examine whether the decline in urban public transportation patronage was inevitable or whether land-use policies could be used to reverse the trend. A more general interest was to see whether the long-term effects of transportation policy are simply magnifications of the short-term effects or whether at least some aspects operate in the opposite direction. The work included models from Britain, the United States, Germany, Japan, Australia, Sweden, and The Netherlands. In the first phase of the work (*16*) the models were analyzed in detail, and a series of policy tests was used to examine the impacts of policy. In this phase of the work the policies were examined by using the original data bases on which the models had been applied. This meant that the variations in the responses could have been due to the behaviors of the models or the nature of the cities. To overcome this difficulty, in the second phase of the work a subset of the models was applied to other study areas (LILT to Dortmund and Tokyo and Marcial Echenique and Partners' MEPLAN model to Dortmund and Leeds). This meant that three models were applied to Dortmund in Germany [the original DORTMUND model developed by Wegener (*17,18*), LILT and MEPLAN], two were applied to Leeds (LILT and MEPLAN) (*19*), and two were applied to Tokyo (LILT and the CALUTAS model) (*20*). This work enabled comparative analysis of the ability of the models to predict the impact of policy. The policies examined included the effects of changes in transport costs, changes in travel speeds, such as those caused by the introduction of bus-only lanes, and changes in employment and retailing location policies and measures to improve the vitality of the central areas of cities, measures to reduce urban sprawl, and measures to reduce resource consumption. There did appear to be some discrepancies between the responses of the models, but these can be explained by examination of the structure of the models and their representation of the study area (*21*). For example, it was shown that differences between the models of the effects of changing the cost of car travel on employment location could be explained by the nature of the logit functions used in the models and the relative dominance of other modes.

The ISGLUTI study (*22*) covered nine of the urban models that exist, but as Wegener (*10*) has indicated, there are at least 20 groups of urban modeling centers around the world, with clusters in the eastern United States, western Europe, and Japan, with others in places as far apart as Chile and Australia. Each of the centers has developed one or more models, so many models are available. Both Boyce (*12*) and Wegener (*10*) argue that many of the weaknesses of the complex urban models of 25 years have been overcome. The advances that have been made include better theory, greater computing power, and better algorithms.

Thus, a large number of models are available, many of the weaknesses have been overcome, there has been a systematic study of a number of the models, and there are two examples in Britain of the use of such models in current studies. However, despite all of these factors there does not seem to be widespread application of such models.

Potentially these models have a great deal to offer in analytical terms. The growing awareness of the impact of transportation means that they should be used if they can offer analytical assistance. In the next section the relevance of the urban models to some of these issues will be considered.

POLICY ANALYSIS

In this section some of the current transport policy issues are considered, and the appropriateness of integrated land use transportation models will be examined.

The following are some of the more significant transport policy issues:

1. Congestion. Cities are becoming more congested as car ownership and use grows. Congestion causes travel times to increase and makes journey planning more difficult as variability increases. It can cause the environment to deteriorate as vehicles travel below their optimal speeds. Hence, a policy objective is to reduce congestion.
2. Energy. There are finite energy resources, and transportation uses a significant proportion of them. As the population moves outward from the city, trips become longer, and cars are used more,

energy usage increases. There is a need to reduce energy consumption. This can be done partly by using more efficient car engines, but there is a need for more drastic action.

3. Safety. Although road safety is improving in many countries, particularly when compared with the rate of growth in car use, there is still scope for improvement. Public transport accidents are relatively rare, but they can be the cause of many fatalities.

4. Environment. Cars produce many pollutants, not only emissions but also noise. Technical innovation can reduce these, but it is very unlikely to eliminate them.

5. Quality of life. Transport is the means to reach opportunities distributed in space, and so improving access can improve the quality of life. There may be a conflict here with other policy objectives.

6. Social inequalities. As some people become richer and acquire more material goods, the gap between them and those without grows wider. Many poor people have no car, so appropriate public transportation is necessary to provide opportunities for such people. It is important to monitor the social impact of policy to see whether the gap between the rich and the poor is narrowed.

7. Public expenditure. In many countries, including Britain, there is a move to control public expenditure to try to control the economy. Transportation is a major item of public expenditure, so a policy of reducing public expenditure is likely to affect investment in transportation.

8. Market economy. Many countries in eastern and central Europe are now moving from a planned to a market economy. The changes include the transportation sector, which means selling state-owned enterprises, often breaking them up into smaller organizations and trying to introduce a market culture into the workforce.

There are other areas of concern, but the eight topics identified here cover a wide range. Although one could consider the application of the models directly in these areas, it is more rigorous to consider a set of policy instruments that can be used to address one or more of the policy objectives identified in the previous list, since the models can be used to examine the effectiveness of the policy instruments in terms of achieving the objectives. In fact some policy instruments may have a negative effect on the achievement of some objectives, implying a conflict between the objectives. The models are useful for exploring such conflicts.

The following policy instruments are available to one or more levels of government.

1. Restriction of peripheral development. In many countries, including Britain, local government has control over where development occurs, often by some form of zoning. This means that it is possible to prevent (or at least slow down) development on the periphery of urban areas.

2. Gasoline tax. Government decides the level of taxation on gasoline. If it is increased, the cost of car use will go up, reducing the level of car usage, and possibly of car ownership. Conversely, a gasoline tax reduction will cause an increase.

3. Public transportation subsidy. Government can decide to pay money to public transportation operators in an attempt to achieve various policy objectives, such as reducing car usage or for social equity reasons. Reducing car usage may be part of a package of measures to conserve energy, reduce pollution, and increase safety.

4. Investment in highways. Public (or private) funding can be used to invest in highways. Usually the appraisal system requires the evaluation of various options, and models can be very useful for determining the impacts of the possible alternatives. As discussed earlier such developments are likely to have implications for land use, which in turn affects the demand for highways.

6. Investment in public transportation infrastructure. Arguments similar to those presented earlier apply to the investment in public transportation infrastructure.

7. Transportation system management. Transportation system management is the modification of the operational characteristics of the system to increase efficiency from the existing facilities. It can include traffic management schemes involving linking traffic signals, ramp-metering to influence access to major highways, and introducing bus-only lanes.

8. Transportation demand management. This is the use of measures such as encouraging carpooling, flexible working hours, and employer subsidies to buy public transportation tickets to change the behaviors of motorists.

9. Road pricing. Charging for the use of road space may be introduced to achieve several objectives, including reducing congestion and reducing public expenditure. It will reduce car usage and raise revenue.

10. Privatization. Much transport infrastructure is publicly owned and so uses public money. It can be argued, as the British Government does, that privatizing transport facilities will improve efficiency and ensure that supply is better matched to demand.

11. Deregulation of local transport services. Deregulation encourages competition and, it can be argued, as the British Government does about bus deregulation, which took place in 1986, causes costs to be reduced and also ensures that supply better matches demand.

These policy instruments link to the policy objectives, as shown in Table 1. The relationships are not simple, and the strengths of the linkages are subjective. Nonetheless, it is useful to illustrate the existence of such relationships so that the policy objectives can be linked to the land-use transportation models via the policy instruments. The policy objectives have been specified in terms of the direction in which policy wishes to move. The links are expressed as positive or negative relative to the indicated direction for the policy instrument. The strength of the relationship is indicated by the number of signs. Thus, an increase in a gasoline tax is expected to have a very strong effect on a reduction in congestion but a fairly weak effect on reducing public expenditure. In many cases there are several effects at work, and the symbol in Table 1 indicates the net effect. It is fully recognized that this is a subjective procedure, but it serves several purposes. First, it shows that many policy instruments will help one objective but will hinder progress toward another, and so there are conflicts; second, it shows that there is more than one way to achieve many of the objectives, and so there is a need for analytical tools to help judge the one that is the most appropriate; third, it permits linkages with the land use transportation models, as shown in Table 2. This shows the strengths of the various effects that might be expected. These are shown as the first-, second-, and third-round effects discussed earlier. The first-round effects would be shown by a conventional transport model, but the others only appear in integrated land use transport models.

It is pertinent to examine the evidence for these effects from various models, because if it is valid then it can be related back to the policy objectives listed in Table 1. The evidence for the impacts of policy comes mainly from the ISGLUTI work discussed earlier, particularly from the second phase of the work in which several models were applied to the same city, since this helps to distinguish

TABLE 1 Linkages Between Policy Instruments and Policy Objectives

Policy instrument	Policy objective: Reduce Congestion	Reduce energy usage	Increase safety	Improve the environment	Improve the quality of life	Reduce social inequalities	Reduce public expenditure	Move towards a market economy
Restriction of peripheral development	++	++	+	+	?	+	+	?
Increase in gasoline tax	+++	+++	++	++	?	++	+	?
Increase in public transportation subsidy	++	++	++	++	+	++	-	–
Increase in investment in highways	?	--	?	+	?	-	-	?
Increase in investment in public transportation infrastructures	++	++	+	+	+	+	-	?
Increase in transportation system management	++	+	+	+	+	?	-	?
Increase in transportation demand management	++	+	+	+	+	+	+	?
Introduction of road pricing	++	++	+	+	+	+	+	+
Privatisation	-	-	-	?	?	-	+	++
Deregulation	-	-	-	?	?	-	+	++

Note: +++ very strong positive relationship; ++ strong positive relationship; + weak positive relationship; ? relationship not clear; - weak negative relationship; -- strong negative relationship; --- very strong negative relationship

the differences caused by the models from those caused by the cities. In all cases the cities are decentralizing, and so the land use effect is in terms of the speeding up or slowing down of this process. Similarly, car ownership is increasing in all cities, so the effects are also in terms of speeding up or slowing down the growth. In theory it would be possible to reverse the processes, but this would require huge changes in the inputs. The discussion will focus mainly on the first- and second-round effects, because at an urban scale the third-round effects tend to be very difficult to detect. It should be stressed that the analysis here is essentially illustrative, to show that land-use transportation models can demonstrate such effects, rather than a definitive statement of the impacts.

1. Restriction of peripheral development. This was examined in the ISGLUTI work by examining the effects of urban growth with and without restriction on development at the urban periphery. In the application of the LILT and MEPLAN models to Leeds, a city in the north of England (*19*), both models showed that peripheral restrictions would slow down the decentralization of population and employment, reduce the growth in car ownership and car use, and reduce the distance traveled. The models did not agree on which alternative mode would gain from the loss of car trips: LILT said that public transportation would grow more, whereas MEPLAN said a greater number of people would walk. As shown elsewhere (*21*) this difference arises from the base modal split and the nature of the logit model, whereby the alternative mode with the greater initial share gains more of those shifting mode. In theory the ratio of the share on public transportation to that walking remains constant, but the land use change means that this is not strictly the case, since slightly different spatial distributions of population and employment are being used. Similar effects were demonstrated by the LILT and CALUTAS models for Tokyo (*20*). Thus, these models do show the effects of restricting peripheral development in a much more comprehensive way than a conventional travel demand model does.

2. Increase in gasoline tax. This was examined in the ISGLUTI work by looking at the implications of quadrupling of the price of gasoline over a 20-year period. In the application of the models to Leeds, both LILT and MEPLAN produced elasticity values of about −0.3 (*19*). Rather lower values were produced by these two models for the city of Dortmund, at about −0.2, but the DORTMUND model produced values slightly larger in magnitude than −0.3 (*18*). In the case of Leeds, there was a difference between LILT and MEPLAN on the effects on the location of employment, with LILT suggesting a slowing down of the decentralization process and MEPLAN suggesting a speeding up. This difference is associated with the fact that the majority of those ceasing to use a car switch to public transportation in LILT and to walk in MEPLAN for the reasons explained earlier. Because of its radial nature, public transportation serves the city center well and so slows down the job loss, whereas walking requires short trips, and most people live in the suburbs so jobs tend to move outward faster. Both scenarios are feasible. This is an interesting dichotomy and illustrates the strong interrelationships between land use and transportation. The effects for LILT applied to Tokyo were similar (*20*).

3. Increase in public transportation subsidy. This was examined in the ISGLUTI work by considering the impact of making public transportation fares free. Although that would be an extreme example of subsidy, the direction of the effects would be the same for a smaller fare reduction. In the Leeds example (*19*) both LILT and MEPLAN showed that there would be less decentralization of economic activity and more decentralization of population because the housing would be more spread out because of less land being available in the central area. This would exacerbate the direct effect of

TABLE 2 Linkages Between Policy Instruments and Outputs of Land Use Transportation Models

Policy instrument	Land use effects		
	First round effects: travel	Second round effects: locational choice	Third round effects: land-use infrastructure change
Restriction of peripheral development	+	++	+++
Increase in gasoline tax	+++	++	+
Increase in public transportation subsidy	+++	++	+
Increase in investment in highways	+++	++	+
Increase in investment in public transportation infrastructures	+++	++	+
Increase in transportation system management	++	+	+
Increase in transportation demand management	+++	+	+
Introduction of road pricing	+++	++	+
Privatisation	+	?	?
Deregulation	+	?	?

Note: +++ very strong linkage
++ strong linkage
+ weak linkage
? possible link

the increased public transportation patronage, which would be further encouraged by the slowing down of the growth in car ownership. This shows the reinforcing effect of the land use response in addition to the direct transportation impact. This means that a model that did not include the land use effect would underestimate the response.

4. Increase in investment in highways. This was examined in the ISGLUTI work by considering the impact of inner and outer urban ring roads. For Leeds there was a small overall shift to car use and an increase in the mean distance traveled according to both the LILT and MEPLAN models. However, the land use effects were very small, probably because the analysis was at an urban scale. One would expect a clearer response at a regional level. As discussed earlier much of the excess growth in traffic on the M25 motorway around London is probably due to the land use response. Currently, the Standing Advisory Committee on Trunk Road Assessment, which advises the British Department of Transport on all major highway schemes, is examining the trip-generation effects of such roads, including the land use effects, including considering the potential use of integrated land use transportation models.

5. Increase in investment in public transportation infrastructure. In the ISGLUTI work this was examined by considering the impact of a metro line across the city center. For Leeds (*19*) the LILT and MEPLAN models showed increased public transportation use, greater distance traveled, and more money and less time spent traveling, all of which are reasonable. However, the overall effects were small because of the localized effects of a single line of metro in a fairly small city. The land use effects did not show up. However, as discussed earlier a simplified version of LILT is being used at a regional scale to examine the impacts of the potential new rail link to the Channel Tunnel, having previously been used to identify the strength of the factors that underlie the demand for rail commuting (*1*). The model produces results that are significantly different from those that a conventional transportation model would produce because of the land use effects.

6. Increase in transportation system management. The only example of transport system management considered in the context

of the ISGLUTI work was a bus priority policy whereby bus speeds were increased by 20 percent and car speeds were decreased by 20 percent. For Leeds (*19*) both the LILT and MEPLAN models show the expected shift from car to public transportation use with an increase in the time spent traveling. However, the land use responses are different with LILT, showing less decentralization of economic activity and the population location not being affected, whereas MEPLAN shows slightly more decentralization of both. The extra decentralization of economic activity is associated with the shift from car use to walking. These differences partly explain the different modal shifts in the two models.

7. Increase in transportation demand management. The only form of transportation demand management considered in the ISGLUTI work was a significant increase in the city center car-parking charge. This is a good example of a case in which the land-use effect could be very significant. For Leeds (*19*) both the LILT and MEPLAN models show that economic activity would move out of the city center. There is a shift from car to public transportation use and walking for the journey to work. There would be an increase in car trips to suburban locations, so it could be argued that such a policy would spread congestion rather than reduce it. Similar effects were found for Tokyo with the LILT model (this policy was not examined with the CALUTAS model) (*20*).

8. Introduction of road pricing. This is a form of transportation demand management that would have effects similar to those of the increased parking charge, but it would also increase the cost of making trips across the city center. There would be a reduction in congestion, but this might well lead some people with high values of time to switch to using a car. There would also be some route switching to avoid the charging area. Overall a switch from car use would be expected, but this would be mitigated by the increase in car trips to the suburban location of economic activities outside the charging area.

9. Privatization. It is very difficult to identify the potential land use effects of privatization. In effect it would make the supply side more responsive as operators modified their services to match demand. It would also make it more useable as operators enter and leave the market. This means that people might become less willing to make significant locational changes because of a lack of confidence in the future of the local transportation system. If this is so the land use response might be smaller. On the other hand it might be faster as the supply side changes. It also means that there is a need for a new set of models of transportation supply. When these exist they can be incorporated into the land use transportation framework, so that the suppliers of transportation can identify the best long-term options, allowing for land use changes.

10. Deregulation. The removal of regulation in transportation would also enable the supply side to be more responsive in terms of service and fares, so the comments for privatization apply here. There is a need for more empirical as well as theoretical work on the long-term impacts of both concepts.

Table 2 reflects the relationships discussed here. Returning to Table 1, if the linkages indicated are accepted as reasonable then the type of model being discussed here is useful for helping to achieve certain policy objectives. These are summarized in Table 3. This shows that there is a wide range of policy areas in which this type of model is of value. Such models would be particularly useful for examining policies associated with congestion and energy use and, to a lesser extent, with safety, the environment, and social inequalities.

TABLE 3 Degree of Usefulness of Land Use Transportation Models for Policy Analysis

Policy objective	Degree of usefulness
Reduction of congestion	Very useful
Reduction of energy usage	Very useful
Increase safety	Useful
Improve the environment	Useful
Reduce social inequalities	Useful
Improve the quality of life	Moderately useful
Reduce public expenditure	Moderately useful
Move towards a market economy	Of little use

CONCLUSIONS

It has been shown that land use transportation models have responsive mechanisms that modify the effects that a conventional transportation model would show. The results here are illustrative rather than definitive, but show the complexity of the responses that the models can represent. The fact that different models can produce apparently different results shows the need for clear understanding of the models. It also suggests that different urban systems can respond in different ways to the same policy instrument.

A number of suggestions for further work can be made.

1. A systematic appraisal of the empirical evidence of the land use effects of transportation should be carried out, since the evidence is spread widely in the literature. Gaps for further empirical work can then be identified. Such further work might well include monitoring of the impact of new transport infrastructure, including surveys of the various responses. This work should be used to validate the existing models.
2. The land use transportation relationship should be extended to include the environment. The effects not only of transportation on the environment but also the effects of the environment on locational and travel choices should be included.
3. Economic evaluation of new transportation schemes should include the land use effects. The appraisal framework should be extended to include such effects. It is important that the welfare effects on the various bodies concerned are shown. These include the users, the operators, and the government, so the impacts shown by the models should be disaggregatable to permit this.
4. Methods of incorporating political processes and fuzzy data should be considered since politics has a strong influence on land use and the current models tend to focus on topics that can be easily measured. There may be useful ideas from the field of artificial intelligence that can be adopted.

It is not clear why these models are not more widely used. The arguments put forward by Boyce (*12*) and Wegener (*10*) are persuasive. This paper has shown the policy relevance of the models. There is a need for more research, application, and debate.

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