LAND USE / TRANSPORT INTERACTIONS : POLICY RELEVANCE OF THE ISGLUTI STUDY.

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INTRODUCTION

This paper examines the relevance of including the interactions between land use and transport when evaluating urban policies. The repercussions of policies take place over many years and their longer term impacts are likely to be very different from the short term responses. Because of the complexity of these interactions the only practical way to evaluate policy impacts is to use a mathematical model based on a thorough understanding of the mechanisms at work. Traditional transport models are not able to estimate these longer term land-use impacts but a number of interactive land use/transport models which can do so have been developed over the last twenty years. Until recently these models had rarely been used as policy tools by planning practitioners and had not been rigorously tested. Because of the perceived importance of including these interactions in the assessment process, the International Study Group on Land Use/Transport Interactions (ISGLUTI) was set up by the UK Transport Research Laboratory. Eleven teams from eight countries with nine models between them collaborated in the study. The results have been reported in Webster et.al. (1988), Paulley and Webster (1991), Webster and Dasgupta (1991) and in a series of papers in Transport Reviews. A wide range of urban policies affecting the location of population and employment and the costs and speed of different modes of travel were tested by the models. In this paper, an evaluation is given of the relevant impacts for various cities.

1 URBAN TRENDS AND POLICIES

In most Western cities, the growing levels of affluence have been accompanied by an expanding need for urban space. In virtually every city (the ISGLUTI cities are no exception), there has been a relative shift of both people and jobs from inner to outer city locations. Growth in car ownership and car use has reinforced the process of decentralisation. At the same time public transport use has tended to fall as more and more people find it convenient to use their own cars to reach the increasingly dispersed destinations. In many cities the demand for road space exceeds supply. Consequently, the growing levels of traffic have resulted in increased congestion and there has been an attendant increase in the contribution to the greenhouse effect from vehicle emissions. These problems are likely to be exacerbated unless appropriate measures are taken. In addition to these problems are those of deteriorating mobility of people without ready access to a private car, inner city decay, road traffic accidents, increasing noise pollution and other environmental problems. To deal with these commonly experienced problems planners and policy makers have a number of levers at their disposal. These include investment in new infrastructure, traffic management measures, fiscal policies as well as a wide range of land use policies. In applying these levers, however, policy makers need to take into account any adverse repercussions arising from the measures taken. For example, the policy responses to deal with growing traffic by building more infrastructure may well be in conflict with the need to reduce greenhouse gases and to improve the environment. Similarly, increasing speed limits in order to improve mobility might result in higher accident risk and increased pollution. Account should also be taken of the longer term impacts of policies since these can also have an adverse effect. Policies to restrain vehicular traffic in the city centre for instance can ultimately cause city centre activity to relocate elsewhere.

2 THE ISGLUTI STUDY

In order to gain greater insight into the impacts of commonly applied policies, a wide range of transport and land use policy tests was devised for the ISGLUTI study. The study was carried out in two phases: some 40 policies were tested in Phase 1 by applying the models to a variety of cities. A selection of the more appropriate tests was used in Phase 2 in which some models were applied to a few cities and some cities were examined by more than one model. Dortmund was examined by the DORTMUND, LILT and MEPLAN models (Wegener et. al. 1991), Leeds by LILT and MEPLAN (Mackett, 1991a), Tokyo by CALUTAS and LILT (Mackett, 1991b) and Bilbao by MEPLAN (Echenique et. al., 1990). The transport policies tested were concerned with changes in costs and speeds of travel whilst the land use policies were concerned with changes in the location of population and employment. The results formed the basis of a comparative assessment across models and across cities. The lessons learnt in the ISGLUTI study are drawn from both phases but most of the results quoted in the subsequent sections are taken from Phase 2. In all the ISGLUTI tests, the impacts were predicted by the different models over a 20 year period and compared with what would have happened over the same period had the policy not been implemented (that is, the base forecast). For ease of comparison, the results are presented as arithmetic means across the models for each city and, where appropriate, across the cities for each policy. The main impacts of the policies are examined in terms of changes in modal splits, trip lengths, speeds, vehicle emissions and land use. The calculation of emissions (expressed as CO_2 equivalents) is based on changes in total distance travelled and speeds. Total distance travelled is measured in pcu-kms, where pcu refers to the flow expressed in passenger car unit equivalents. Speed is critical in the urban context because emissions rise steeply with increasing levels of congestion (Waters, 1990).

The Phase 2 tests were carried out in only four cities the main characteristics of which are described in Webster and Dasgupta (1991). While most of the cities tested showed similarities in trends over time, there were important differences in their land use characteristics (in population, area, density and industrial and social structure) and in their cultural and historical backgrounds. The largest study area has a population 200 times that of the smallest and the range of residential densities is nearly 20:1. There were large variations in transport supply: Tokyo is served by an extensive rail network which connects important sub-centres, whereas there is a relative absence of rail in Leeds though Leeds is well served by bus. Travel costs were exceptionally low in Bilbao and Dortmund and high in Tokyo. The average trip length was an order of magnitude greater in Tokyo (38km) than in Leeds (less than 4km). Car ownership was low in Tokyo. These differences were reflected in the modal splits for the base year. The car/bus split was 39:35 in Dortmund, while in Tokyo 28% travelled by car and 68% by public transport. Given these major differences in urban structure and transport, it would not be surprising if the impacts of policies were different in the different cities.

3 IMPACTS OF TRANSPORT POLICIES

The transport policies tested included measures affecting public transport fares, car running costs, parking charges, speeds of both public and private transport as well as improvements to the road and rail network. The results are given in Table 1. The three **public transport fares**

Table 1. Effects of Transport Policies (percentage change)

Policy	Fares X 2	Zero fares		Car costs X 4	Parking charge (3 X mean journey cost)	All travel costs X 2	All speeds up 20%	Speeds PT up 20% Car down 20%	New investment *+		
		All day	Off-peak only						Outer ring road	Inner ring road	Cross -town metro
Mode share:											
Car	3.5	-5.3	-1.9	-19.8	-2.4	-3.1	1.1	-5.7	0.3	0.2	-2.7
PT	-17.6	32.3	19.9	23.9	1.3	-13.4	4.4	8.7	-0.2	0.0	5.1
Walk	13.3	-18.6	-11.9	16.1	3.3	20.2	-6.1	0.1	-0.8	-0.3	-0.1
Mean trip:											
Distance	-4.1	11.8	6.5	-12.2	-0.4	-10.8	3.1	-0.9	0.9	0.0	0.7
Time	-4.2	10.8	6.8	-0.2	-1.0	-5.7	-8.0	4.7	-1.2	-0.7	-0.6
Cost	6.0	-28	-	69	12	58	3.2	-1.9	-	-	-
Pcu-km	1.7	-1.8	-0.2	-16.6	-2.3	-3.9 -6.2*	1.3	-5.0	-0.3	0.2	-0.6
Road speed	-1.1	1.2	0.1	11.1	1.6	2.6 4.1*	19.1	Car: -16.7 Bus: 12.9	0.2	-0.1	0.4
CO2 equivalent	1.5	-1.4	0.4	-20.8	-3.0	-5.7 -8.6*	-8.0	3.2	-0.3	0.2	0.5
Population*	c	d	d	c	?	c	?	d	?	?	?
Employment*	D	C	C	?	D	d	c	?	?	c	?
Trips to CA	-1.6*	3.1*	7.3*	0.9	-2.1	-0.6	0.3	0.5	-0.0	0.0	0.3

Key: **PT** Public Transport ***** Excluding Tokyo **+** Modal shares for work trips only
CA Central Area **D** Decentralisation **C** Centralisation (**d**,**c** weak effect)

policies tested were: doubling fares, eliminating them altogether, and, allowing off-peak travellers to travel free of charge. When fares are doubled there is, as expected, a modal transfer from public transport to walk, with car gaining only slightly. The effect varies with the type of city and with the transport system in use: in Leeds and Dortmund, for example, public transport use falls by about a third but in Bilbao where fares are currently extremely low and in Tokyo where there is very little alternative to travelling by rail (there is widespread congestion on the roads and journey distances are in general too long to walk), the effect is marginal. Travel distance is reduced by about 4% partly because of the switch from public transport to walk and partly because existing public transport passengers make shorter journeys. Because the gain in car use is small, the increase in pcu-kms and the fall in speeds are correspondingly low, giving rise to a small increase in emissions. The doubling of fares makes the central area less attractive resulting in further decentralisation of economic activity. People, on the other hand, tend to move closer to the central area (to be nearer to the jobs) and there is consequently some centralisation of population. The effect of eliminating fares altogether is roughly opposite to that of doubling fares (public transport gains, mainly at the expense of walk), though the effects are larger. The effect on car use is relatively small (-5%) and the saving in emissions is no more than 2%. With the off-peak fares policy, the modal shifts are smaller than when the concession is applied all day, though more trips are generated to the central area, particularly for shopping. The effect on speeds, vehicle-kms and emissions is negligible. For both policies there is an appreciable effect on centralisation of economic activity (relative to the base case) while population continues to decentralise.

Two policies concerning **car travel costs** were tested: quadrupling car running costs (running costs are perceived by the motorist to be equal to the petrol costs) and increasing central area parking costs to a value of three times the monetary cost of the average car journey in the city in question. Of all the policies tested, the quadrupling of car running costs was the only policy which had a discernible effect on car ownership causing it to fall by about 2% on average. The models suggest that car travel falls by about 20% on average (30% in Leeds, 20% or so in Dortmund and Bilbao and by less than 10% in Tokyo). In all the cities both public transport and walk gain in roughly equal proportions. Higher car running costs cause mean trip distances to decrease by 12% but because there is a transfer to slower modes of travel, there is virtually no change in mean trip times. Despite the four-fold increase in actual car running costs the mean trip cost (by all modes) rises by about 70% whereas the increase would have been about 200% had travellers shown no adaptability in their travel behaviour. The decrease in trip lengths, coupled with modal transfer from cars to other modes causes a reduction in pcu-kms by 16% and this, added to congestion relief (speeds increase by 11%), results in a saving of over 20% in vehicle emissions. There is a major difference between the models in the way they predict how the location of economic activity reacts to car travel costs. In Leeds and Dortmund, LILT suggests that higher car running costs help to strengthen the central area, because public transport (which increases its modal share when car costs rise) is best suited to serving people living in suburbs and travelling to the town centre. DORTMUND suggests there is a smaller level of centralisation in Dortmund. MEPLAN on the other hand suggests that jobs decentralise to be closer to homes and population centralises (most of the model applications agree on this) to be closer to jobs which also seems plausible.

Turning now to the effect of high parking charges in the central area, the ISGLUTI study highlighted some unexpected results. The effect on car travel is fairly modest (-2.4% on average) particularly in the smaller cities where the central areas are small enough for at least some car users to park outside the central area and walk in. The overall effect on public transport is also small with some models actually predicting a decline in public transport share mainly because of the movement of economic activity, particularly retail activity, away from the central area. There is almost a direct correspondence between the reduction in car use and the decrease in pcu-kms because public transport use hardly changes under this policy compared with the effects of fares policies discussed earlier. The reduction in emissions is 3%, about twice as large as when fares are eliminated but only a fraction of that when car costs are quadrupled.

A test on **composite cost changes** looked at the effects of doubling the cost of all mechanised modes of travel. The main effect on modal split is that walk gains mainly at the expense of public transport and to a lesser extent from cars. This **average** effect conceals wide variations between cities. In Leeds and Dortmund the losses to public transport are much greater because fares represent a much higher proportion of generalised costs in these two cities. In Bilbao, on the other hand, the fares are so low that doubling them has very little effect, so public transport, as well as walk, gains from the losses suffered by the car as a result of the higher running costs. In Tokyo, the number of trips transferred to walk is very low because the distances travelled are too large for walking to be a viable alternative. Some of the trips lost to rail are converted to car trips because the cost element of car travel is a smaller proportion of the generalised cost of travel than it is for rail. Despite a doubling of fares and fuel costs, mean trip costs rise by only 58% once the adaptive processes have taken place. In general, doubling monetary costs causes population to centralise and employment to decentralise in order to bring jobs and other activities closer to homes. Mean trip distances reduce by 11% and pcu-kms by 4% with a corresponding saving of 6% in emissions. In Tokyo, emissions actually rise (without Tokyo, emission savings would be 9%).

Two policy tests were carried out which had the effect of **changing travel speeds** of cars and public transport. In one, all speeds were increased by 20%, while in the other, public transport speed was raised by 20% and car speed lowered by 20% (the latter attempts to simulate the effect of bus priority measures). When all speeds are increased the tendency is for both public transport and car travel to increase at the expense of walk. As expected, trip distances increase to take advantage of the higher speeds and trip times fall but by less than the 20% speed improvement (which only affects the line-haul speed and not the access times). The benefit offered in lower travel times is traded, in part, for a wider choice of destinations. Under conditions of urban congestion, the increase in speeds has a substantial beneficial effect on emissions despite a small increase in pcu-kms. When public transport speed rises and car speed falls, the effect on modal shares is in the expected direction. The reduction in car travel is reflected in a similar reduction in pcu-kms. However, since car speeds are reduced substantially, thereby increasing congestion, emissions actually rise.

The three tests which examined the effect of **transport infrastructure** were: improving or constructing outer or inner ring roads and providing a new cross-town metro. The road schemes had little effect on modal shares (generally 1% or less), which is perhaps not surprising since all these cities allow reasonable orbital movement at present both near the centre and on the outskirts, though there is some congestion at peak times. However, at the zonal level the impacts are quite substantial in some cases, but when averaged over the whole city, or large areas of it, the impacts become very diluted. In general, provision of a new or improved inner ring road encourages centralisation. The land-use effects associated with the outer ring road could not be easily determined since they depended on where the new road was located in relation to the boundary of the study area. The effect of building a new cross-town metro is much more pronounced in the peak than in the off-peak period. For work journeys, public transport increases its modal share by 5% on average but at the expense of car travel rather than walk (a metro competes more effectively with the car for centrally-oriented journeys). All of the policies on new transport infrastructure, have a negligible effect on travel distances, times, pcu-kms and speeds and consequently on vehicle emissions.

4. EFFECTS OF LAND USE POLICIES

In order to examine the effects of a rapid **expansion of population and employment**, two tests have been implemented. The first assumes a growth of two per cent per annum, while the second takes the same growth but places development restrictions on the fringes of the urban area. The results are given in Table 2. Without restrictions, population decentralisation speeds up. Since the models locate at least some categories of employment as a function of accessibility to population, employment decentralises also with the central area losing some of its share of trips. The effects on modal split are relatively small with, if anything, a small shift to public transport on average (though the effects were different in the different cities). There was a small reduction in car use resulting in a 2% saving in emissions. When restrictions are placed on development, relative to the unconstrained case, population and employment centralise in all the cities and this contraction of the urban system results in a modal transfer to walk resulting in a further reduction of 2% in emissions.

The three tests concerned with the **relocation of manufacturing jobs** were: movement of half of such jobs from inner to outer areas or to a peripheral industrial estate, and redistribution of manufacturing jobs in proportion to population. When employment is relocated to the outer suburbs or to an industrial estate population decentralisation tends to increase, bringing people closer to jobs. In the third test, the models gave varied results for population decentralisation. For all three tests, there is a reduction in the numbers of work trips to the central area, as expected, but since only manufacturing jobs are relocated, there is little effect on shopping trips. The

Table 2 Effects of Land Use Policies (percentage change)

Policy	Population and employment growing at 2% per annum. Outer area development:		50% of inner area manufacturing jobs to:		Manufacturing jobs spread uniformly amongst population	50% of CA retail jobs to outer areas **	New shopping centre in the outer area (= 25% of CA retail)
	Unrestricted	Restricted*	Outer suburbs	Industrial estate			
Mode share:							
Car	-2.0	-1.3	0.4	0.3	-0.1	0.3	-0.1
PT	3.7	-1.0	-1.1	-0.4	-0.4	-0.7	-0.6
Walk	-3.3	8.1	-0.1	-0.5	0.0	-0.4	0.6
Mean trip:							
Distance	-4.6	-3.3	0.4	1.7	-0.3	0.3	-1.1
Time	4.1	-4.1	-0.2	1.0	-0.3	0.2	-0.7
Pcu-km	-1.8	-1.3	0.3	0.3	-0.1	0.2	-0.1
Road speed	1.2	0.9	-0.2	-0.2	0.1	-0.2	0.1
CO2 equivalent	-2.1	-1.8	0.4	0.3	-0.1	0.3	-0.2
Population	D	C	d	d	?	d	d
Employment	D	C	D	D	D?	D	d
Trips to CA:							
Work	-1.5	-0.0	-3.9	-4.7	-3.6	-3.0	-0.6
Shop	-4.2	-0.3	0.3	0.3	0.8	-5.2	-2.2
Total	-1.5	0.0	-1.5	-2.1	-1.2	-2.9	-0.8

Key: * Compared to unrestricted case ** Bilbao not included
PT Public transport CA Central Area **D,d** & **C,c** as in Table 1

changes in modal splits and hence in emissions were small. Surprisingly, such major land use policies aimed at reducing the need for travel had little effect on overall travel distances and in fact the models predict that for the second test, travel distance would actually rise.

Two tests concerned with the **relocation of retail employment** were: halving city-centre shopping floorspace and redistributing the jobs lost to other areas of the city and building a new shopping centre (with floorspace equivalent to a quarter of the city-centre floorspace) on the outskirts of the urban area. As is to be expected, under both policies employment tends to decentralise with corresponding reductions in the numbers of trips to the central areas for both work and shopping. There is a general tendency for population to decentralise also. The changes in modal split, trip lengths, pcu-kms and emissions are small for both policies.

5. CONCLUSIONS

The importance of taking full account of the interactions between transport and land use has been amply demonstrated in this paper. With almost any urban policy, the ultimate impacts will be different from the initial response. In some cases, the longer term impacts will reinforce initial effects, while in others they may reduce or even reverse them, thus emphasising the need for planners to take a long term view. The paper has shown that the type of city plays a central role in determining the outcome of polices. The nature of the impacts will depend, in particular, on the size and density of development, the internal structure of the city and on the transport system.

The ISGLUTI study was able to confirm many of the well-known effects of policy implementation. From the policies examined it seems that, on their own, public transport fares have little effect on car use and hence on congestion and vehicle emissions. By contrast, large increases in the cost of using the private car can substantially increase the use made of public transport (in appropriate circumstances) as well as reduce travel distances. In general the car abstracts from public transport, walking and cycling, whereas public transport tends to draw mainly from walk and cycle. Of all the transport policies tested, raising car travel costs had the greatest potential for changing the modal split in favour of public transport and reducing congestion and vehicle emissions. However, there is a limit to the effectiveness of policies which apply the 'stick' in this way: complementing such policies with measures to improve the quality of public transport (the 'carrot') can improve the effectiveness of both types of policies.

Examination of the impacts of a range of transport and land use policies showed how difficult it is to alter the overall distribution of population though the location of employment seems to be more responsive. There is an underlying trend in most cities in the way land use changes and the tests showed that these trends tend to reassert themselves. However, some of the tests (such as higher travel cost, whether by public transport or by car, and a higher density of population and employment particularly when restrictions are placed on outer area development) showed that there is scope for altering the locational choices of people so that they live and work in closer proximity. However, reducing travel distances will not, on its own, result in emission savings: the resulting speed of travel (because of the dependence of emissions on speed) and the effect on modal split are both critical in determining the level of emissions. In the case of higher public transport fares for instance, shorter distances were not translated into equivalent savings in vehicle emissions. In some cases, particularly when speeds are increased under congested conditions, there is a saving in vehicle emissions despite an increase in distance travelled.

Even if planners encourage developers to build workplaces and other facilities closer to homes, the tests showed that journey distances changed only marginally. However, by coupling appropriate transport policies with these land use measures it is possible to significantly improve the effect on emissions. Of course, there is unlikely to be a universal panacea; because different types of cities respond in different ways, it will be necessary to develop different packages of transport and land use policies.

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