AN INTERNATIONAL STUDY TO COMPARE LAND-USE/TRANSPORT MODELS AND EVALUATE URBAN POLICIES

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1. INTRODUCTION

1.1 The importance of the interaction between land use and transport

Evidence for the interaction between land use and transport is everywhere around us: cities would not look the way they do if that interaction had not been present over a long period of time. The advent of the railway and mass car ownership made it no longer necessary for cities to be located on rivers or at the sea and these faster modes allowed cities to spread beyond the distance that people could walk. Even though almost everyone now has access to these faster modes, new transport facilities can still cause changes in travel patterns and shifts in land use, as the M25 London orbital motorway has demonstrated only too well. Land-use changes also cause shifts in travel patterns and make new demands for transport infrastructure, as has been seen in the development of the Docklands area of London. Thus, interactions between transport and land use are just as important today, but knowing how to estimate their effects on the ultimate outcome of a policy remains a very real problem because of the complex pattern of effects all operating on different time scales. The only systematic way is to work out the basic mechanisms involved and incorporate these in a mathematical model. Even though a few such land-use/transport models have been developed in different parts of the world, it is comparatively rare for such models to be used for carrying out assessments in either the land-use or the transport field, the more common practice being to use more partial models of which the 4-step transport model and models of residential or industrial location are typical.

It is also the case that until recently none of these fully interactive land-use/transport models had ever been properly tested. Because of this the UK Transport and Road Research Laboratory set up a collaborative study and invited the relevant teams to participate. The response was encouraging and in 1981 the International Study Group on Land-Use/Transport Interaction (ISGLUTI for short) was set up comprising nine teams of modellers from seven countries, with one or two other research teams without models also participating. Table 1 gives information about the teams involved and the models at their disposal.

1.2 Aims and structure of the ISGLUTI study

The aims of the study were to compare existing models (their structures, mechanisms and performance) and evaluate the impacts of a wide range of land-

TABLE 1 PARTICIPANTS OF THE ISGLUTI STUDY

COUNTRY	ORGANISATION	MAIN MEMBERS	NAME & CODE OF MODEL & YEAR FIRST DEVELOPED	CITY MODELLED IN PHASE 1
Australia	Commonwealth Scientific and Industrial Research Organisation, Dept. of Building Research	J F Brotchie R Sharpe J R Roy	TOPAZ T (1970)	Melbourne
Fed Rep of Germany	University of Dortmund	M Wegener	DORTMUND D (1977)	Dortmund
Japan	(i) Universities of Tokyo and Nagoya	H Nakamura Y Hayashi K Miyamoto	CALUTAS C (1978)	Tokyo
	(ii) University of Kyoto	K Amano T Toda H Abe	OSAKA O (1981)	Osaka
Greece	University of Thessaloniki	G Giannopoulos M Pitsiava	-	-
Netherlands	University of Utrecht	H Floor	AMERSFOORT A (1976)	Amersfoort
Sweden	Royal Institute of Technology	L Lundqvist	SALOC S (1973)	Uppsala
UK	(i) University of Leeds	R L Mackett A Lodwick	LILT L (1974)	Leeds
	(ii) Marcial Echenique and Partners	M H Echenique A J Flowerdew D Simmonds	MEP M (1968)	Bilbao
	(iii) Transport & Road Research Laboratory	F V Webster P H Bly N J Paulley	-	-
USA	University of Pennsylvania	S H Putman	ITLUP I (1971)	Bay Area San Francisco

use and transport policies used by governments all over the world. Information on the effects of such policies is usually restricted to just the short-term impacts only, but it is the longer-term effects which are often of greater importance because these are concerned with where people live, work, shop and socialise and where new homes, offices, shops and factories are built.

To assess the performance of the models and evaluate the policy impacts, the various teams carried out an agreed set of tests using their own models applied to the cities on which they were initially calibrated. A brief description of the tests is given in Table 2. Of course, the predicted impacts are likely to depend on the type of city to which the policy is applied, so to provide a more rigorous test, a second phase of the ISGLUTI study was implemented in which models and data sets were exchanged. In this phase several models are applied to just one or two cities (to enable model comparison on a more standard basis) and some models are applied to several cities (to see how the type of city affects the outcome). Phase 1 is now complete and the results are published in a 520-page book (1); Phase 2 is nearing completion and some tentative results are presented in this set of papers.

This paper sketches the main results obtained in Phase 1 (though a paper of this size cannot possibly do justice to such a large study) and mentions the difficulties inherent in the Phase 1 exercise. It goes on to describe what has been accomplished in Phase 2, the approach and methodology, but not the results, which are given in subsequent papers.

2. MAIN FINDINGS OF PHASE 1

2.1 Comparison of model structure

2.1.1 Type of model

The main characteristics of the models represented in the study are compared in Table 3. Of the nine models tested seven are "predictive" models, ie they predict the outcome of a particular policy over a given time period, and two are "optimising" models. The latter devise a set of measures which are intended to lead to a particular desired outcome, e.g. minimising energy use while still permitting an acceptable level of mobility, but the implicit assumption that the population will live and work in the places suggested by the policy and travel in the manner proposed is not always realistic. It is possible that such models could incorporate suitable behavioural mechanisms so that solutions could be found which would satisfy both the aims of the policy and the locational and travel characteristics of residents and firms, but neither of these two optimising models can do this as yet, though one, TOPAZ, does incorporate some predictive mechanisms in its structure.

The theory underpinning most of the models is entropy maximisation but some models working at a more disaggregate level are based on random utility theory and micro-economic theory. Spatial interaction models, which are generalisations of the gravity model, are the most common techniques used, though other techniques involving utility maximising, market mechanisms, micro-

TABLE 2 POLICIES TESTED AND MODELS USED

POLICY TESTS++	MODELS# USED IN PHASE 1							CITY+/MODEL COMBINATIONS IN PHASE 2													
								Am.		To.		Dort.				Leeds				Bi.	
	A	C	D	L	M	D	T	A	L	C	L	D	L	M	M*	A	L	M*	T	M	M*
POPULATION CHANGES																					
12.1 Population grows at 2% pa: no land-use restrictions	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
12.2 Population grows at 2% pa: development restrictions on outskirts	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
12.3 Zero population growth: no land-use restrictions	✓		✓	✓	✓		✓														
12.4 Zero population growth: development restrictions on outskirts	✓		✓	✓	✓																
EMPLOYMENT CHANGES																					
13.1 Half non-service jobs move from inner to outer areas	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
13.2 Half non-service jobs move from inner area to outlying industrial estate	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
13.3 Half of all non-service jobs redistributed in proportion to population		✓	✓	✓	✓					✓	✓	✓	✓	✓	✓		✓	✓		✓	✓
SHOPPING POLICIES																					
14.1 Half inner-area retail floorspace redistributed to outer areas		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
14.2 Additional peripheral shopping centre (= 1/4 city-centre floor space)			✓	✓								✓	✓		✓		✓	✓	✓		✓
14.3 Unlimited free parking for city-centre shoppers				✓							✓		✓		✓		✓	✓			✓
14.4 Free public transport to city-centre shops				✓							✓		✓		✓		✓	✓			✓
TRAVEL COST CHANGES																					
15.1 All travel costs up 50%	✓		✓	✓	✓														✓		
15.2 All travel costs up 100%			✓	✓	✓						✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
15.3 Car operating costs quadrupled			✓	✓	✓						✓	✓	✓	✓	✓		✓	✓		✓	✓
15.4 Central area parking cost made equal to mean travel cost			✓	✓	✓																
15.5 Central area parking cost made equal to 3 times mean travel cost			✓	✓	✓						✓	✓	✓	✓	✓		✓	✓		✓	✓
15.6 Public transport free			✓	✓	✓						✓	✓	✓	✓	✓		✓	✓		✓	✓
15.7 Public transport fares up 50%			✓	✓	✓																
15.8 Public transport fares up 100%			✓	✓	✓						✓	✓			✓		✓	✓		✓	✓
TRAVEL SPEED CHANGES																					
16.1 Speeds of all mechanised modes up 20%	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
16.2 Speeds of all mechanised modes down 20%	✓	✓	✓	✓	✓	✓	✓														
16.3 Bus priority: bus speed up 20%, other speeds down 20%			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓
16.4 Speeds down 15% in inner area, 25% in outer areas			✓	✓	✓																
16.5 New outer orbital motorway: operating speed 80 km/hr			✓	✓	✓							✓	✓		✓		✓	✓		✓	✓
16.6 New inner ring road: operating speed 60 km/hr			✓	✓	✓							✓	✓		✓		✓	✓		✓	✓
16.7 New cross-town transit line: line haul speed 40 km/hr			✓	✓	✓																
16.8 New cross-town transit line: line haul speed 60 km/hr			✓	✓	✓							✓			✓		✓	✓		✓	✓
16.9 Car ownership same as base forecast: no extra transport investment			✓	✓	✓																
16.10 Car ownership grows at 2% pa more slowly than in 16.9			✓	✓	✓																
16.11 car ownership grows at 2% pa more rapidly than in 16.9			✓	✓	✓																
TIMING OF INVESTMENT																					
17.1 Public transport speeds and road capacity gradually double over 20 years			✓	✓	✓																
17.2 Public transport speeds doubled over first 10 years, road capacity doubled over next 10 years			✓	✓	✓																
17.3 Road capacity doubled over first 10 years; public transport speeds doubled over next 10 years			✓	✓	✓																
17.4 Public transport free in first 10 years; remains free thereafter			✓	✓	✓																
17.5 Public transport subsidy removed in first 10 years: not replaced			✓	✓	✓																
17.6 Public transport free in first 10 years; subsidy removed over next ten years			✓	✓	✓																
17.7 Public transport subsidies removed in first 10 years; travel becomes free over next 10 years			✓	✓	✓																
CHANGES IN ECONOMIC CLIMATE																					
18.1 Employment cut by 20%; travel costs increased by 20%			✓	✓	✓		✓												✓		
18.2 All people move into same income group	✓		✓		✓																
BASE FORECAST	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

+ City abbreviations: Am. = Amersfoort; Bi. = Bilbao; Dort. = Dortmund; To. = Tokyo

++ See the full report of the Phase 1 work [1] for more detailed description of the tests (the tests are numbered as in the Phase 1 book)

\# See Table 1 for model names and cities modelled

M* = MEPLAN (see Section 3.1)

TABLE 3 THE MAIN CHARACTERISTICS OF THE MODELS

MODEL:	AMERSFOORT	CALUTAS	DORTMUND	ITLUP	LILT	MEP	OSAKA	SALOC	TOPAZ
MODEL TYPE:	Predictive	Predictive	Predictive	Predictive	Predictive	Predictive	Predictive	Optimising	Optimising
MODELLING TECHNIQUES USED*:									
Spatial interaction	✓	✓	✓	✓	✓	✓			✓
Utility maximising		✓	✓		✓	✓	✓	✓	
Market equilibrium		✓	✓			✓	✓		
Cohort/Markov survival			✓		✓				
Input/output economic base						✓			
Micro simulation			✓				✓		
Linear regression		✓					✓		
Mathematical programming								✓	✓
LAND-USE LOCATION:									
Number of categories of:									
population	3	1	80	4	3	4	1	1	1
housing	1	2	30	-	1	**	-	2	1
employment	1	15	40	4	12	5	18	2	1
Workplaces	-	-	40	-	12	**	-	-	-
Model includes: land prices		✓	✓			✓	✓		
housing rents			✓			✓			
TRANSPORT REPRESENTATION:									
Model predicts: trip pattern	✓	✓	✓	✓	✓	✓			✓
traffic congestion		✓	✓	✓	✓	✓			
car ownership			✓		✓				
Number of: trip purposes	1	5	4	2	5	4			4
transport modes	1	2	4	2	3	3			2
DATA BASE:									
City represented:	Amersfoort	Tokyo	Dortmund	San Francisco Bay Area	Leeds	Bilbao	Osaka	Uppsala	Melbourne
Population (thousands)	153	27,904	1,075	4,064	497	970	14,556	160	2,697
Area (square kms)	202	14,565	833		164	75	8,000		3,000
Number of: internal zones	26	76	30	30	28	28	40	49	41
external zones †	12				12				
lower level zones ††		14,500					840		

Source (1)

NOTES:

** Supply of accommodation is represented by available floorspace for which the different categories of demand compete.

† External zones to handle in-and out-commuting.

†† Models contain two level zonal hierarchy: larger number of zones at lower level offer greater spatial detail.

simulation, linear programming and mathematical programming are also used, as indicated in Table 3.

2.1.2 Representation of land use

The location of basic employment is the driving force in most of the models and this provides the spatial framework for the location of all other types of employment and population. The basic mechanism is essentially the trade-off between the value of land for development and the cost of travel. This requires a knowledge of how accessibility between different industries, commercial activities, population and markets affect locational choice. In only four of the models (CALUTAS, DORTMUND, MEP and OSAKA) is money represented explicitly in all the major components of the models - land and house prices, rents and travel costs. Of these, only DORTMUND and MEP allow prices to change in direct response to any mismatch between demand and supply and in MEP measures of land values are carried through to calculations of a land-use net benefit. CALUTAS AND OSAKA calculate a bid rent for land which is based on the utility of the particular location, but does not reflect competition from other possible users. These models do not differentiate between the different social groups so they cannot model the competition which arises from this source. Other models take a rather different approach and use strict zoning regulations and priority rules for allocation, which in the case of housing are based on the locational preferences of the different social groups and the bargaining power of the higher income groups.

Housing stock and population are treated separately in some models which enable them to identify mismatches between supply and demand, ie to represent overcrowding and vacant homes. Only DORTMUND and LILT can represent mismatches in both housing and employment.

2.1.3 Representation of transport

On the transport side, DORTMUND and LILT incorporate a car-ownership mechanism to reflect the importance of the private car in travel and locational decisions, though the mechanisms chosen are perhaps oversimplified. Most of the models which have a proper transport network have capacity-constrained assignment to represent the effects of congestion. The walk mode is represented in only two models (DORTMUND and LILT), which is surprising since public transport tends to draw trips from walk and loses them to both walk and car. None of the models represents intra-zonal trips in any detail. In some models (OSAKA and SALOC) there is no detailed transport representation at all, so these models can say little about the transport implications of policies, though accessibility indicators are calculated for each zone. AMERSFOORT has no representation of modal split and represents travel in terms of distances only.

2.1.4 Treatment of time and space

All the models are quasi-dynamic and move from one time period to the next with all the interactions taking place within the simulation period (generally 5 years) or lagged by one or two periods. Travel and traffic tend to respond quickly to changes while land use takes considerably longer to respond. Space is modelled in all cases by dividing the area into zones but the models vary in the level of detail represented as indicated in Table 3. Where the study area is particularly extensive (CALUTAS and OSAKA) a 2-stage hierarchy has been adopted. The zonal system in all the ISGLUTI models is sufficiently detailed to model trip distributional effects.

2.1.5 Complexity and ease of use

The level of complexity of the models varies considerably, with DORTMUND having by far the largest number of categories of population and employment (see Table 3): it is the most detailed and least transferable. At the other end of the scale are AMERSFOORT, SALOC and TOPAZ which have modest data requirements, are easy to use and are most easily transferable. The first two of these locate population only and are essentially land-use models with only a bare minimum representation of transport - just sufficient to provide the necessary zonal indicators of accessibility for the locational mechanisms.

2.2 Performance of the models

Table 2 shows which tests were attempted by the various models. Because SALOC is an optimising model with no predictive functions, it was not able to attempt any of the tests. Some of the other models were also unsuited to some of the tests and lack of resources placed further limitations on the number of tests completed (particularly so with ITLUP which was not applied to any).

In all cases, the impacts of the policies were judged against a background trend (the base forecast), which represents a continuation of past trends and generally includes all committed land-use and transport changes. The values of the parameters at the end of the 20-year forecast period (and at other times also when necessary) were compared with corresponding values for the base forecast ie with what would have happened if the policy had not been applied.

2.2.1 Assessment of the individual models

AMERSFOORT concentrated on the land-use policies because its transport model is very rudimentary. The response of the population to changes in the location of employment and to changes in travel costs and speeds tends to be stronger than in the other models, partly because the model does not allow employment location to adjust to these changes so that the whole of the adjustment has to be borne by the population. The response of the different social groups is more diverse than in either DORTMUND or MEP, though similar to that of LILT (which uses the same type of mechanism for allocating population).

CALUTAS also concentrated on the land-use tests. Population reacts strongly to changes in employment location (especially retail) and travel speeds, but employment location is very insensitive to changes in travel speeds. The model predicts increased land prices when travel speeds rise (because improved accessibility increases the locational utility of an area and hence the price of land) but the price is insensitive to shifts in population or employment because competition for land between residents and firms is not reflected in the model's estimation of land prices.

DORTMUND, which completed all the tests, represents more aspects of the urban system and has more feedback links than any other model. This leads to a higher level of stability and a lower level of response of total population and employment than is found in the other models, though the individual social groups and retail employment are more sensitive. The car-ownership model (which is based on a money budget) produced some counter-intuitive results with regard to policies which involve a change in travel costs (this inconsistency has since been corrected).

LILT also completed the tests. Competition between employment and population results in some population being displaced by employment rather than being attracted to it (as happens in the other models), so that population appears to be somewhat unresponsive to changes in travel costs, speeds and employment location. By contrast employment reacts strongly to travel cost changes and there is a particularly strong link between increased use of public transport and centralisation of retail employment. Free public transport actually appears to reverse the decentralisation of service employment observed in the base forecast for Leeds. Population movements overall are generally small because of housing constraints, though the individual social groups move more (and sometimes in opposite directions since the top social group has first choice of accommodation leaving the bottom group to take whatever is left). This response is stronger than in DORTMUND and MEP which have proper market mechanisms, so perhaps it is overdone to some extent. The transport model includes walking and behaves plausibly in general though it does seem to be relatively more sensitive to transport costs than to travel speeds.

In MEP, which completed the tests, the link between population and retail employment is stronger than in any other model. By contrast population has a weak response to travel costs, though the different social groups move more and sometimes in different directions. Employment is less sensitive to travel costs than LILT or OSAKA but more than DORTMUND. Land prices show little response to travel costs (there is no utility function as there is in CALUTAS). Residential density adjusts to land prices to keep housing costs relatively stable. MEP does not represent walking and in compensating for this in the trip generation mechanism, it sometimes gives rise to unexpected changes in modal split (more recent versions of the model have corrected this).

Although OSAKA is essentially a land-use model, it completed some transport tests. There is a strong interaction in this model between population and the various employment sectors and they all move in the same direction when travel costs change because locational choice is based on utility indices which are influenced by travel costs. In contrast to the other models, population and employment move in the same direction when travel speeds change because OSAKA does not represent competition for land between population and employment.

TOPAZ carried out most of the land-use tests but only a few of the transport tests, because the objective function used rendered the optimum land-use configuration somewhat invariant to global changes in travel costs and speeds. In the tests carried out population responded moderately strongly to locational changes in retail employment, but only weakly to those of non-service employment. The modal split is much more responsive to speed changes than the other models and is perhaps more realistic in this respect than the others.

2.2.2 Overall assessment

The competition for land and the trade–off between the value of land for development and the cost of travel are important aspects of the locational process. They can only be represented in a realistic manner if there is a land market mechanism to equalise supply and demand (as in CALUTAS, DORTMUND, MEP and OSAKA). Without such a mechanism strict zoning regulations and priority rules for allocation have to be used but these are a poor proxy for a monetary mechanism and do not allow a cost/benefit calculation to be made which, if done properly, is probably the best single indicator of the merits of a particular policy. Nevertheless, the land-use sectors of the models seem to work plausibly. There is a general consensus that the location of employment is more sensitive to changes in travel costs than is the distribution of population, that retail is more responsive than non-retail service employment, which in turn is more responsive than non-service employment, while the individual social groups show more movement than the population overall. It is not possible to say whether the relatively strong responses of AMERSFOORT, CALUTAS, OSAKA, and for employment, LILT are more realistic than the weaker responses of DORTMUND, MEP, and for population, LILT.

While changes in travel costs and speed have a consistent effect on population location, ie increases in costs have the same effect as reductions in speed (because both are components of the generalised cost of travel) this is not necessarily so with employment location. With employment, changes in car travel costs generally have the opposite effect from changes in public transport fares because of the dependence of central-area activities on public transport and outer-area activities on car travel. The resultant movement of employment is therefore dependent on which of the two effects predominates.

It is surprising that substantial changes in population and employment location cause only minor changes in modal split, which raises the question whether the models underestimate the difficulty that public transport has in serving more dispersed areas. On the other hand, modal split seems to be relatively unresponsive to measures which increase bus speeds at the expense of car speeds, suggesting perhaps that public transport in these models is too uncompetitive against both car and walk (where represented). Several models do not include walk despite its importance in modal choice.

2.2.3 Potential application of the models

One of the aims of the ISGLUTI study was to give some indication of how useful the various models might be for studying particular types of policies. Table 4, which summarises the subjective views of the modelling teams on this aspect, suggests that most of the models are suitable for examining policies concerned with regulation and investment in both the transport and land-use fields but fewer models are suitable for investigating pricing policies as well. Only three of the models predict land or building prices and the response of several of the models to changes in transport costs was questionable. It should be noted, however, that many of the problems

TABLE 4 SUBJECTIVE ASSESSMENT OF THE APPLICABILITY OF THE MODELS

PREDICTION OF IMPACT ON:	TYPE OF POLICY					
	LAND USE			TRANSPORT		
	Regulation (eg zoning, density limits)	Pricing (eg property taxes or subsidies)	Investment (eg new infra-structure, public housing	Regulation (eg traffic management, parking, priorities)	Pricing (eg fuel tax, public transport subsidies)	Investment (eg new roads, improvements, new rail lines)
Population location	A•C•D•L•M•OT•	CD•M•	A•C•D•L•M•D•T	D•L•M•O	DL•M	AC•D•L•M•O•
Social structure	A•D•L•M•	D•M•	A•D•L•M•	D•L•M•	DL•M•	D•L•M•
Industrial location	C•D•L•M•OT	CD•M•	CD•L•M•OT	D•L•M•O	DL•M	CD•L•M•O
Retail location	C•D•L•M•O	CD•M•	CD•L•M•O	D•L•M•O	DL•M•	C•D•LM•O
Price of land/building	CD•M•	D•M•	CD•M•	D•M•	DM	CD•M•
Work trip patterns (time, distances, costs)	AC•D•L•M•T•	CD•M•	ACD•L•M•T•	D•L•M•T	DL•MT	ACD•L•M•T
Other trip patterns	CD•L•M•T•	D•M•	CD•L•M•T•	D•L•M•T•	DL•MT•	CD•L•M•T•
Modal split	D•L•M•T•	D•M•	D•L•M•T	D•L•M•T	DL•MT•	CD•L•M•T•
Car ownership	LD	–	LD	LD	L	LD
Distribution of benefits/costs	DM•	DM•	DM•	DM•	M	DM•

Source: (1)

illuminated in the ISGLUTI tests have now been solved in the current versions of the models. It should also be noted that the tests were aimed particularly at predictive models so that TOPAZ with its mixed optimising/predictive character could not be so readily compared with the other models. AMERSFOORT and OSAKA are essentially land-use models and cannot be expected to fare well in essentially transport policy tests. Much of the strength of CALUTAS and OSAKA lies in their ability to represent fine detail within their enormous urban areas but the lower level models were not appropriate for the ISGLUTI study. Thus while Table 4 indicates which models are probably best for which jobs, the applicability of some of the models could be extended quite easily, particularly on the transport side; this has already been done in some cases.

2.3 Policy impacts

The second aim of the ISGLUTI study was to gain some insight into the likely impacts resulting from applying the land-use and transport policies listed in Table 2. These impacts are summarised in Table 5. The terms "centralisation" and "decentralisation" (denoted by the letters C and D) refer to the movement of population or employment (relative to the base forecast) between the central area of the city and the suburbs (see(1)).

Development restrictions on the outskirts of a city naturally tend to slow down decentralisation and increase activity in the town centre, as indicated in the table: other land-zoning policies tested tend to have the opposite effects. Most of these land-use policies reduce the mean trip distance but not necessarily the travel time nor the cost, and even though the policy of putting homes closer to jobs appears to be successful in its aims, the gains are surprisingly modest. Policies which change the cost of travel have larger and more consistent effects on employment than on population, with public transport subsidies and taxation on car use reducing the rate of employment decentralisation with a corresponding strengthening of the town centre. Higher central-area parking costs and higher costs on car ownership, on the other hand, cause employment to move away from the more central areas. Public transport subsidies cause both car use and walking to decrease and journeys to lengthen, while extra tax on car use or ownership results in shorter journeys in distance, but not in time, with more walking and public transport use.

Road and rail investment measures which increase travel speeds have a generally centralising effect on employment and a decentralising effect on population with an increase in activities in the town centre. They result in a shift from walk to mechanised modes and increase the mean distance travelled, the cost and energy consumption of a trip but reduce the duration of a trip.

While some of the effects of policies diminish over time, new ones emerge as people adapt to their new situation, so that the benefits obtained from a particular measure are often in a different form from that originally envisaged - usually in the widening of choice of destination, rather than in the saving of time or money. In some cases the impacts may be modified to such an extent that the ultimate effect is in the opposite direction from that of the initial response. Planners should take note that if particular policies do not offer people what they want, they will seek more suitable alternatives elsewhere, even if present constraints prevent them from taking up these alternatives

TABLE 5 LIKELY IMPACTS OF LAND-USE AND TRANSPORT POLICIES

POLICIES / IMPACTS ON:	LAND ZONING				TRAVEL COSTS				TRAVEL SPEEDS (Capital investment)		TAXATION
	Development restrictions (Green belt)	Closer proximity of homes and jobs	Peripheral industrial estates	Out-of-town shopping centres	Public transport subsidies	Taxation on private car: on car use	Taxation on private car: on car ownership	Taxation on private car: on central area parking	Road improvement	New public transport lines	
	1	2	3	4	5	6	7	8	9	10	11
POPULATION	C	?	d	D?	d	d	?	?s	d	?	D?
High income	c?	c?	D	D?	d	?	?	?s	c	?	C?
Low income	C	d?	C?	?	c?	?	?	d	?s	d?	D?
EMPLOYMENT	C(1)	D	D	D	C	C?	O	D	?	c	d
Retail	C	?s	D?	D	C	C?	D	D	C	c	D
Non-service	c	D	D	?s	c	?s	d	d	?s	c	?s
DENSITY	++	+	?s	+?	-	-	+	-	?s	?s	?s
HOUSING PRICES											
Land	++	+	?s	?s	+	-	+	++	+	?s	--
Homes	?	+	?s	+	+	?	+	++	+	?s	--
ACTIVITY OF CENTRE											
All	++	--	--	--	+	++	-?	--	++?	++	--
Work	+	--	--	--	+	+	--	--	-+?	++	?
Shopping	++	+	?	--	+	++	-	--	-+?	++	--
MODAL SPLIT											
Public transport	+	?s	--?	-	++	++	++	-	?	++	?s
Car	-	?s	-	+	--	--	--	+	+	-	?s
Walk	+	?s	+	+	--	++	++	++	--	--	?s
AMOUNT OF TRAVEL											
Distance	-	-	?	--?	++?	--	--	?s	+-	++	?s
Cost	+?	-	++?	--?	--(2)	++(3)	--(4)	+?	+-	++	?s
Time	-	?s	?	?	++?	?	++	?	--	-?	?s
Energy	-?	-	?s	?s	?	-?	--	?	+-	?s	?s

Source: (1)

Key:
- C : tends to be relatively more centralised (c: effect is small)
- D : tends to be relatively more decentralised (d: effect is small)
- ? : influence could go either way (?s: ditto, but effect is likely to be small)
- ++ : relative increase (+: effect is small)
- -- : relative decrease (-: effect is small)

(all relative to background trend)

Notes:
(1) tends to be the inner suburbs, rather than the central area, which gains most employment
(2) decline in travel costs ignores the cost of subsidy
(3) overall travel costs likely to be reduced if extra taxation is discounted
(4) decline in travel costs ignores extra cost of car ownership

immediately. The non-interactive type of land-use model or the conventional transport model ignores all but the first-round effects of a policy so that the important adaptive responses of both people and firms are ignored.

3. PHASE 2

3.1 Models used and cities examined

By the end of Phase 1 a great deal had been learnt about the way the models performed and some improvements had been made to some of the models as a result of imperfections highlighted by the tests. Much had been learnt about the impacts of particular transport and land-use policies also, but one could never be sure whether the differences found were due to the particular characteristics of the models or were genuine differences resulting from applying the policies to cities of vastly different types (see Table 3). Phase 2 was designed to overcome some of these problems by applying several models to a particular city and one or two models to several cities. In practice it was more difficult than originally envisaged to transfer models and data sets between teams with the result that the final set of tests was far less comprehensive than had been hoped for.

One of the difficulties experienced by the modellers was in knowing whether to use an improved version of their models on the new data sets in Phase 2 or whether to keep to the original version used in Phase 1. Use of the latter provides a better comparison between their own Phase 1 application and the new cities tested by them in Phase 2, but does not provide the best comparison between models, nor the most useful guidance on the likely impacts of different policies: in the event the best versions of the models were used in Phase 2. In most cases the modifications were not so numerous or fundamental as to cause a problem, but with the MEP application so many advances had been made to the original Bilbao version used in Phase 1 that it was felt necessary to repeat the predictions for Bilbao with the new model, called MEPLAN (2), before applying it to the other cities with which comparisons were to be made.

TABLE 6 MODELS AND CITIES USED IN PHASE 2

Model \ City	Amersfoort	Tokyo	Dortmund	Leeds	Bilbao	Osaka	Melbourne
AMERSFOORT	✓			✓			
CALUTAS		✓*					
DORTMUND			✓*				
LILT	✓	✓*	✓*	✓*			
MEP			✓*		✓*		
MEPLAN			✓*	✓*	✓*		
OSAKA						✓	
TOPAZ				✓			✓

* Tests permit satisfactory comparison with other models or cities

Table 6 shows that there are two models (LILT and MEPLAN) with valid comparisons over three cities each, and MEP with two comparisons. Dortmund has been examined by four models (including the two MEP versions), Leeds by four models (though only two of these provide satisfactory comparisons) and Tokyo by two models.

3.2 Policy tests

In Phase 1, about 40 policy tests were attempted by at least some of the models (see Table 2) and while most of these were satisfactory some proved to be of limited value. Phase 2 could have provided the opportunity to set up a different set of tests, benefiting from the knowledge gained in Phase 1, but the comparison with the Phase 1 results would then have been lost. It was decided therefore to concentrate on about 20 of the more useful tests in Phase 2 (see Table 2 which also indicates which models were applied to which cities).

3.3 Base forecasts

Setting up the base forecast is particularly important because it is against this background that all the policies are judged. It is possible that the impacts of some policies are almost independent of the general background trend so that the use of different base forecasts would not invalidate the comparison between models, but mostly this is not so, for example the impacts from building a new Metro system are bound to be different if population and employment are both increasing compared with the situation in which they are both decreasing.

The difficulties in setting up the base forecast in Phase 2 were much greater than those experienced in Phase 1, where all the models were applied to cities on which they were originally calibrated. In Phase 1 the models were to some extent tailor-made for those cities, being designed to suit the data available and the particular characteristics of the cities. In Phase 2, on the other hand, the models were applied to cities whose characteristics were not necessarily well represented by the models. Moreover, the data required by the models for both policy testing and calibration was not always available at the appropriate level of detail for satisfactory performance of the models.

Obtaining the best possible base forecast was an over-riding consideration for all the teams, but trying to do this raised a number of questions. One of these concerned the use of data for the base run (and for calibration and validation also) which became available after the Phase 1 base forecasts had been set up but before the base forecasts for the same cities were set up in Phase 2 using different models. There was a gap of several years between these events during which time useful data sometimes became available. It was decided that the teams should take advantage of this because the better the calibration and the more accurate the base forecast, the more reliable would be the model predictions. Similarly, it was decided that where there was a deficiency of data which was required by the Phase 2 modelling, careful use should be made of any output from the "home" model (ie the model used in the Phase 1 application) to fill the gap. Using more recent data meant that a much greater proportion of the base forecast was validated by actual observations than was the case with the Phase 1 applications (in some cases almost the whole forecast period had already expired when Phase 2 testing began) and the input data for both the base forecast and the policy runs contained a smaller proportion of estimated data. This does not mean, however, that the policy tests are any less valid (testing is an entirely separate process from setting up the base forecast), though it does give the Phase 2 models a slight advantage over their Phase 1 counterparts. However, this helps to redress the balance of advantage only slightly. In any case, the input data for policy testing makes up only a small proportion of the information available at each time point of the forecast and is generally confined to global totals of, for example, population and employment (it is from such aggregate figures that the model provides all the detail necessary for simulating the land-use and transport changes across space and through time). Even though it is important that the base forecasts of the Phase 2 applications to a particular city should be as similar as possible to that of the "home" model used in Phase 1, this similarity should not be achieved at the expense of unwarranted changes to the basic mechanisms of the model because distortions introduced in this way are likely to adversely affect the model's predictive capability.

4. CONCLUDING REMARKS

During the course of the ISGLUTI study nine modelling teams from seven countries spread across the world have collaborated in a joint exercise which has put their models to the most rigorous programme of testing ever carried out on models of this type. It has drawn attention to both the strengths and weaknesses of the various models and has indicated which models are best for which types of tasks. The study has examined the longer-term impacts of a range of land-use and transport policies and gained fresh insights into the various interactive effects. It has pinpointed the dangers of taking a "blinkered" approach to land-use and transport planning in which the interaction between the two is ignored - unfortunately an all too common practice even today. This paper has briefly sketched the progress of ISGLUTI to date, its form and structure, who is participating, what has been found in Phase 1, why it was necessary to have a second phase and what has been carried out in that phase. Subsequent papers outline the main preliminary findings of Phase 2.

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REFERENCES

1. Webster, F.V., Bly, P.H. and Paulley, N.J. (Editors), (1988), Urban Land-Use and Transport Interaction: Policies and Models. Report of the International Study Group on Land-Use/Transport Interaction (ISGLUTI), Avebury, England.

2. Echenique, M.H., Flowerdew, A.D.J., Hunt, J.D., Mayo, T.R., Skidmore, I.J., and Simmonds, D.C., (1989), The MEPLAN Models of Bilbao, Leeds and Dortmund, 5th World Conference on Transport Research, Yokohama, Japan.