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SOME ISSUES IN MODELLING THE IMPACT OF CHANGES IN TRANSPORT COSTS ON RESIDENTIAL AND EMPLOYMENT LOCATIONS

by

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ABSTRACT

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This paper is written as part of a project on the effects of increases in rail fares on location and commuting decisions in London and South East England. The main theme of the paper is the relationship between accessibility and locational choice. The various factors determining the choice of residence, and to a lesser extent, job, are discussed, in particular, the importance of accessibility in the process. A wide variety of urban locational models are then discussed, in particular from the point of view of how accessibility is taken into account. The models described are urban economic, spatial interaction, regression, disaggregate and demographic. A model of the relationships between land use and transport that has already been applied elsewhere is then examined in terms of its suitability for analysis of the processes being studied in this project. A variety of possible extensions to the model are then put forward including the treatment of interaction with the rest of the country, the relationship between transport costs and the overall level of activity in the study area, the use of the different transport costs for different purposes, and an accounting framework including population, households and employment. The implication of these ideas for the survey are then discussed. The conclusion of this work is that the problem should be divided into a set of topics, with a variety of different analytical techniques being used, rather than a single comprehensive model of all the relevant decision processes involved in the impact of rail fares on location and commuting in London and South East England.

1. INTRODUCTION

This paper has been produced as part of an SSRC funded project to investigate the implication of increases in rail fares on location and commuting decisions in London and South East England (Kirby, Mackett and Nash, 1979). More specifically, we wish to increase understanding of the behavioural factors and processes that affect individuals in terms of residential and employment location choices, and firms in terms of decisions on location and travel or housing subsidies for employees.

This project has been developed from the fusion of ideas from the authors mentioned above in discussion with other interested parties. One contributory stream of work has been the development of a computer model of the inter-relationships between transport and land use. The objective of this paper is to consider some of the important relationships within the study in terms of the objectives of the project, the existing model and work by other researchers in the field. In particular the relationship between accessibility and the choice of residential and employment location will be considered. This is only one aspect that will be examined within the project. Other topics include the perception of travel costs, particularly for mixed mode trips, the behaviour of the housing and labour markets, migration and the behaviour of the firm. It will, almost certainly, be impossible to consider all these topics in depth within the resources of the project. Consequently we intend to utilize a variety of techniques, to shed light on these topics in the context of increasing rail fares in South-East England. It is intended to carry out a survey of commuters and to use the existing model as part of the project. In the next section the relationships between accessibility and locational choice will be considered. In the following section the way in which various models represents this relationship will be discussed. In section four and five the representation of the relevant issues in the existing integrated model and the implications of developing the model within this project will be described. The role of the survey and other data sources in the project are discussed after that.

2. THE RELATIONSHIP BETWEEN ACCESSIBILITY AND LOCATIONAL CHOICE

In this paper we are only considering the locational choices of individuals not of firms. Whilst it is important to consider both residential and employment location decisions much more research relevant to this project has been done on the former, and this is reflected in the paper. To date, most work has considered that either the residential or the employment location is fixed and the other is to be determined (Beesley and Dalvi, 1974). Few studies have considered the inter-relationships between the two location decisions.

Chapin (1968) made the important point that the relocation procedure is a two-stage process, firstly the decision to move ('push factors') and then the choice of location ('pull factors'). This has been tested by Butler et al (1969) who found that different factors were important, for example the age of the head of household is an important determinant of mobility, but not of the location chosen.

A great many factors are important in the residential location choice procedure. Much work has been by sociologists who consider the process in terms of the housing needs of the family (Rossi, 1955) and the stage in the life-cycle (Goldstein, 1973, McCarthy, 1976, Mincer, 1978). Catanese (1971) argues that income is an important determinant of residential location, but McCarthy (1976) found it not to be so. Stegman (1969) offers empirical evidence that neighbourhood characteristics are

more important than accessibility to work in determining residential location. Butler et al (1969) found that accessibility to neighbourhood facilities was not important in the residential location process. However, accessibility to workplace is a fundamental componant of many location models, as described in the next section. Several authors have found direct evidence of the relationship. For example Brown (1975) examined data from household interviews conducted by the Bay Area Transportation Study Commission and found households with job changes are more likely to move residence, households with job moves outside their work zones have higher moving rates than others and that a household is more likely to move if a new workplace requires an increase in work trip length. De Langen and Verster (1978) used data from a household survey in Zaanstad in West Holland to examine the relationship between the locations of residence and workplace. They concluded that a substantial improvement in the network (in this case the opening of a tunnel) had a substantial impact on the location of households, and that, in general, beyond a certain magnitude commuting distance becomes a constraint residential location. Butler et al (1969), although finding the stage in the life-cycle to be the most important indicator for prospective residential mobility, also found accessibility to work important because those living more than 40 minutes away from their job were more likely to move than those closer to their employment location. A rather different approach is that of Zahavi (1978a, b) who has found a constancy of travel time to work for a wide variety of cities, and suggests that an increase in speed will lead to a more dispersed cities, thus implying the importance of accessibility to work in the residential location process.

Several authors have argued against the use of accessibility to work as a determining factor. Richardson (1971) argues that there is empirical evidence that changes of residence are usually associated with a longer journey to work and that surveys of consumer preferences indicate a strong desire of most households to move out. Richardson then goes on to develop a model in which journey to work distance is only used as a constraint, not a determinant factor of residential location. Kirby (1979) has suggested that an individual's job search procedure maybe random in a search space around the given job location. In this case the location of the job determines the location of the search space, which may be a function of the mode of transport available to the worker. In addition Kirby quotes from the General Household Survey that only 2% of respondants gave living nearer to work as a reason for changing home. Catanese (1971) uses evidence from four North American cities to disprove the hypothesis that households attempt to minimise home and workplace seperation. O'Farrell and Markham (1975), using data for Dublin tested to see whether commuters had ever made a previous estimate of their car transit costs. They argued that those who had not done so did not include the journey to work in their household location decision.

Clearly there is some debate as to the importance of factors determining residential location, in particular the role of accessibility to workplace. Some of the critics are being extreme in their attitudes. Few would argue with Catanese's rejection of the hypothesis that people try to minimise the distance between home and workplace. Richardson (1971) also dismisses the hypothesis, without citing any other author as putting it forward. Catanese's evidence is two rather old papers (Liepmann 1944, American Society of Planning Officials, 1951) who were in fact, not suggesting that people do try to minimise the distance, but that cities should be designed to reduce the distance, which is a rather different issue. More recently Manning (1978) has examined data for Sydney, Australia and argued that expenditure on the journey to work could be reduced by reorganisation of the city. Both Richardson's and Kirby's work requires the definition of some form of area around the workplace within which people search.

The debate is not really whether journey to work costs have a role to play, but how important a role. It is possible that some of the disagreements arise from the different scales being considered. For example, in a city like Leeds a change in transport costs is unlikely to cause many people to move, but in a commuter in South East England may be spending a large proportion of his income on the journey to work and an increase in cost may have a drastic impact. The impact may be the bringing forward in time of a decision that would have been made later for other reasons. In addition , people's perception of the effects of travel costs on residential (or workplace) location, may be very different in a climate of large increases in such costs from a general desire to travel a shorter distance to work.

It is pertinent at this stage to consider the possible impacts of a large change in the cost of travel to work. Suppose British Rail puts up its fares in real terms in South East England. The simplest decision for a rail commuter is to pay the extra, but this may mean reducing savings or general economy on other items. The commuter can switch mode, but they may not be practical for a long trip to central London. The whole household may move home, to reduce transport or housing costs. As mentioned above, this decision could be associated with other factors. Similarly, the worker can change his job to reduce travel costs, and perhaps increase his income. Once again the increase in travel costs is unlikely to be the sole factor. It might be decided to increase the household income by the wife finding a local job. Alternatively, if she also commuted to central London for a relatively low paid job she might stop working altogether or find a local job. If there are children who live at home but are in employment in London they might decide that they can no longer afford to commute and decide to move into rented accomodation in London, thus setting up a new household. Once again, the fares increase is unlikely to be the only factor in the decision process. From this discussion it is quite clear that this is a complex problem. It also suggests that there may well be changes within the household resulting from the change. Jones (1978) has considered the impact of changes in travel costs at a rather different scale on household behaviour, and developed the Household Activity - Travel Simulator (HATS) (Jones 1977) to aid analysis of the impact of such changes.

In the next section some models of the residential location process will be discussed, in particular how the accessibility to workplace is considered.

3. MODELLING THE PROCESS OF LOCATION

A wide variety of models have been developed to represent the process of location. Most such models represent the outcome of such decisions in terms of the distribution of population, others try to represent the decision process more explicitly. Alternatively, other models are too disaggregate to provide any general statement about the form of the city. The type of model used should reflect the nature of the problem being considered. In practice it would seem to be more a function of the disciplinary background of the model-builders.

Probably the strongest tradition of models of the location process comes from urban economics. Here work by Alonso (1964), Kain (1962), Muth (1969) and Wingo (1961) is based on the trade-off between accessibility and housing space. Basically this means that households substitute travel costs for housing costs. The models tend to use grossly simplyfying assumptions to make the mathematics manageable. For example, it is usually hypothesised that the study area is circular and that all jobs are located at the centre of the city; consequently distance to work is the only locational measure. Land rents are assumed to decline from the city centre monotonically.

Households are assumed to maximize a utility function of expenditure on the residential space, the journey to work and other goods, subject to an income constraint. From thus, a bid-rent function can be derived, by using calculus, representing the demand for land at different distances from the centre of the city. Household location is derived from this. A related model was that by Herbert and Stevens (1960) which was developed as part of the Penn-Jersey Transportation Study. Unfortunately the vast and complex data requirements prevented it from being operationalised. As Senior (1974) has pointed out, most of the operational versions of this type of model have been based on regression analysis, which tends to be rather poor and suggests a large gap between theory and application. Evans (1973) has demonstrated many of the theories with data mainly for London. Ball and Clark (1975) tested Alonso's (1964) theory on data for South-East England and suggested that it can only offer a partial explanation of the residential pattern of commuters, and that other factors such as decisions by Building Societies are also important. Other criticisms of this type of model including the assumption that congestion and housing transaction costs are zero, everybody has the same value of time and perfect knowledge of the market, taste has no effect on consumer choice and there is perfect competition.

Geographers, quite naturally, have taken the effects of space on the process rather more seriously. Hansen (1959) devised a simple accessibility model to represent the relationship between transport costs and land use. It should be stated here that this type of spatial interaction or gravity model is not saying that individuals try to minimise the distance between home and workplace, rather, that at a macro level a representation of the pattern resulting from locational decisions can be obtained by the use of the model. One of the most widely applied models of this type is the based upon work by Lowry (1964) in the residential componant of which, accessibility to workplace is the main determinant of location, with a constraint mechanism to ensure that zones are not filled beyond capacity. Wilson (1971) has suggested ways in which the intrinsic attraction of housing could be introduced and the constraint mechanism be made internally consistent (Wilson, 1969).

Wilson (1967) developed a theoretical basis to spatial interaction models, and devised a 'family of spatial interaction models' (Wilson 1971b). Wilson (1970a) disaggregated the model and relaxed the static equilibrium assumptions and introduced a quasi-dynamic framework in which, over a given time period, some people have a fixed residence, others have a fixed workplace, others have both, and the final group have neither (Wilson, 1970b). Those with both locations fixed are located using a doubly-constrained spatial interaction model, those with one location fixed are located with a singly constrained model and the others with an unconstrained model. In fact, this assumes that travel costs are constant over time. If they change a modified formulation has to be used (Mackett, 1976c). Wilson (1970b) extended the model to include different income groups, different wage levels by location, different types of house by location, and more than one worker per household. This model has been applied to Reading (Cripps and Cater, 1972) and to Leeds (Senior and Wilson, 1974a) with some success. However there were, in both cases, some unexpected results which could not be interpreted satisfactorily, since it was found the greater the difference between the price of a house and the available expenditure, the more attractive that house was. The authors attribute this problem to data difficulties but Sayer (1976) says that this is a result of the a priori selection of a curve of the distribution of housing expenditures, rather than making this an output of the model. A further very interesting extension of this work has been the demonstration of the connection between the disaggregated residential location model of Wilson and the Herbert and Stevens model (Senior and Wilson, 1974b, Wilson and Senior 1974). Wilson (1974) has

extended the concepts of his residential location model into a general urban model, which integrates the concepts of demography and migration into the framework, but with no feedback from the residential and workplace location mechanism to the spatial demography and spatial economy stops of the model. The model also has extremely demanding data requirements.

Similar work on the disaggregation of spatial interaction residential location models has been carried out at the University of Cambridge (Anthony and Baxter, 1974, Baxter and Williams, 1972, 1973).

The main weakness of this type of model is its macro nature. It focusses on the outcome of the decision process rather than the process itself. On the other hand, this type of model can be made operational and can be extended fairly easily and is very useful for giving a picture of the overall form of the city. There is a need for improvements in the modelling of the supply side and for thought to be given to the impact of finance on the housing market.

A different type of urban model, that, according to Pack (1974) is the most widely used in the United States, is EMPIRIC (Irwin and Brand, 1965, Hill 1965), which uses regression analysis, in which the share of the change in the population and employment in each zone is proportional to the change in the share of the other variables being located in that zone and the change in a set of other factors, including accessibility to workplaces. However, there is no theoretical basis to the model, it does not represent the decision processes at work, and has been found to be a poor forecasting tool (Stokes, 1974).

A very different style of models are the disaggregate choice models. The commonest form of the model is the multinomial logit model which was proposed as a theory of psychological choice by Luce (1959), has been extended by McFadden (1973, 1976), and used widely in modal choice studies (for example, Richards and Ben-Akiva, 1975). McFadden (1978) has proposed a model of residential choice. The problem with this type of approach is that, while it is very good for examining demand behaviour it cannot easily include interaction with supply side constraints which tend to be impinge at the aggregate level, except in a very ad hoc manner (Los, 1978).

A rather different micro-analytical approach is the ASMUG model developed by Mason (1977) in which the decision processes of individual households are represented. In a given time period the households which wish to migrate are allowed to choose from the available houses. The upper income households have first choice. Various simplyfying assumptions are made, for example the study area is a set of concentric rings with accessibility functions described solely in terms of radial distance. The study was only for 600 households. The approach is very interesting but the operation of supply side constraints is not clear. The very detailed nature of the modelling could lead computing problems, since using a larger population would take a very long time. Again, once the simplyfying assumptions have been relaxed this could be a very promising approach.

The final type of model to be considered here is different from the others described because it is insensitive to accessibility to workplaces. It is the demographic model, which is in essence an accounting technique. The usual method used is the cohort-survival technique in which the base year population is divided into age and sex categories (the cohorts) and birth, death and migration (or survival) rates applied for the forecasting period to derive the cohort populations at the end of the forecast period. The method has been improved and made internally consistent by Rees and Wilson (1977) who have extended the model to the multi-regional case, made it continuous and given it a stronger accounting basis, by ensuring

the inclusion of all the possible cases. The main weakness of this type of model is that it is not policy sensitive. For example, the population of the area is not related to the availability of houses, nor is it sensitive to changes in transport cost. The demographic model could be integrated with some other model, for example, of migration to replace the usual assumption about temporally stable rates.

In this section a variety of approaches to the location process have been discussed. Most of the models have been concerned with residential rather than employment locational choice, because that field has been more widely studied, but some of the models could be used for the employment decision. The various models all have their strengths and weaknesses, and reflect the problems that have been examined and the backgrounds of the model-builders. There is scope for integration of some of the techniques, for example to obtain the representation of the choice process from the micro models with the interaction with the supply side and overall representation of the changes from the macro models. It would be useful for some comparisons to be made between the models in terms of internal structure and forecasting ability, as done by Swerdloff and Stowers(1966).

4. THE INTEGRATED LAND USE - TRANSPORT MODEL

As mentioned in the introduction, part of the work upon which this project builds is a model that represents the interaction between transport costs and the location of population, employment, jobs, housing, shopping and land. It has been described fully elsewhere (Mackett, 1979b, c) and so here only general comments on its structure and performance will be made. The behaviour of the various components of the model relevant to the locational choice process will then be described.

The model was originally developed within an SRC sponsored project on urban transport planning. The model started from the integration of the framework devised by Lowry (1964) with the trip distribution and modal split stages of the conventional four-stage transportation model. It can be used in several ways, for example as a transport model with land use responsive to the transport policies being considered (Mackett, 1976a, 1977a) or for testing the effect of alternative land use and transport strategies (Mackett 1977b). The model has been designed with three social groups, twelve industrial sectors, two modes of transport and car ownership categorisation. A distinction is made in the model between physical infrastructure and the activities that go on within, that is, between housing and population, and between jobs and workers. This means that there can be vacant jobs and houses, overcrowding of houses, and people entering and leaving the job market. The model has been designed so that some variables can be located exogenously to represent planning policies, for example, a new housing estate, a hypermarket or new industry. The information is built into the model by means of a constraint mechanism, and the resulting forecast will be consistent with the planning policy being considered. The model has been made operational for the areas of Leeds and Harrogate in a project sponsored by the Transport and Road Research Laboratory in which the model has been used to examine a variety of topics such as the effects of rising fuel costs, the influence of transport policy on the inner city and the long term impact of transport costs on urban morphology (Mackett, 1977c). The model has been tested over a five year period and been found to give a good fit (Mackett, 1979a).

The various aspects of the model that are relevant to the new project will be discussed in turn. Housing can be located exogenously within the model, since in reality it does tend to be under the control of the planners. However, the further a forecast goes into the future the less precise the information that is available, and it may well be that only the total number

of new houses to be built in the study area is known, in which case the zonal allocation is made on the basis of the area of land available for new housing, the area of existing housing and the relative accessibility to jobs and other residential areas. The use of the two area terms means that a zone is most likely to attract new housing when it is about half full. A similar mechanism was used in the Projective Land Use Model (PLUM) (Goldner et al, 1972). Demolitions are considered in a similar manner. Once again this will usually be an exogeneous input in a short-run forecast, but in the longer run when only the total number is known the number demolished in each zone is a function of the number of houses and a factor calculated in the base year representing the different rates of demolition in each zone. Since the demolition of houses forces people to move out, a mechanism is used to determine how many houses occupied by each social group will be demolished. It is assumed that the lower the social status of the occupants the more likely they are to have their houses demolished, subject to a maximum proportion to prevent the complete removal of a social group from an area. In addition the effect of urban blight, whereby many houses are vacated because they are in a demolition area, is taken into account by assuming all empty houses in a zone in excess of the mean occupancy rate for zones with no demolitions, are empty because of the blight, and so are the first to be demolished. The housing stock in each zone is found by means of a simple accounting system. The housing occupancy rate is specific for both zones and social groups.

The twelve industrial sectors are grouped into three categories according to the degree of response to changes in transport costs (Mackett, 1976b). The primary industries are agriculture, mining, and gas, water and electricity which are site dependent and so least responsive. Agricultural jobs are a function of the area of land in agricultural use, which is calculated within the model, the number of jobs in each zone at the previous time point, and the total number of jobs in agriculture. The zonal distribution of jobs in the four secondary sectors of manufacturing, construction, transport and public administration is also a function of the total number of jobs and the previous distribution, but also of the ratios of accessibility to the supply of labour and other economic activity at the current time point to those at the previous time point. The use of these ratios mean that a substantial increase in accessibility in part of the study area will mean that area will tend to attract more of this type of jobs than would otherwise be the case. The five tertiary sectors are convenience and durable retail, and business, educational and personal services. These are located using a production constrained spatial interaction model, with two modes of transport, and allowing for car availability. For the retail sectors, sales in each zone are calculated and converted to employment. Employment is calculated directly for the other sectors. The location of these sectors is thus sensitive to changes in transport costs. The housing and economic sectors represent the physical infrastructure of the city. The location of new housing and the secondary and tertiary sectors are all sensitive to changes in transport costs.

The model is quasi-dynamic, that is, it works over time. Consequently it is necessary to ensure that the non-moving population and workers are kept in the same locations. Over a period of time people who were living in an area at the begining can be in three states at the end - still living there, living elsewhere or dead. Those in the first category are described as survivors. In the model a survival rate is calculated for each zone and social group. In addition, people can be born, so a birth rate is applied to the population at the begining of the time period. None of these rates are sensitive to changes in transport costs. In other words, an increase in the cost of travel will not affect the number of people leaving an area. As discussed previously, the process of job location has

been studied rather less than residential location. There is also much less information about length of stay in job. Consequently, the employment survival rates are national figures, based on work by Harris and Clausen (1967). These rates are also not sensitive to transport costs.

Migration is only represented implicitly within the model. Only arrival in, or departure from a zone is considered. Migration data at the level of detail required by the application of this model at an urban scale are difficult to obtain, unless a special survey is carried out.

The residential choice mechanism is based on the so-called trade-off approach, but includes a wider variety of factors than is usual. For new locators the intrinsic attraction function contains five factors multiplied together. The first is the number of houses available to each social group, since at a macro level this is the most important determinant of the attraction of a particular zone. The top social group is located first, with the choice of all available housing. The second social group chooses from houses that have not been taken by the top social group, the bottom social group has to choose from the remainder. In other words, the higher one's social status, the greater the choice of housing - a fairly realistic approach. The second factor is the car ownership level for members of each social group already living in the zone. This is included to ensure that those with no car available will tend to be attracted to areas with a low level of car ownership, since such areas will be more accessible by public transport. The mode actually used for the work trip will depend upon the relative cost of travel by each mode. The third term is the proportion of houses occupied by the next higher social group. Thus has two purposes. It represents peoples aspirations to locate in the most attractive housing available by making them choose housing that is attractive to those of higher social status. Its second purpose is rather more pragmatic since it helps to ensure that the more attractive housing is filled first. The fourth term is the proportion of the zone's population at the previous time point that was in each social group. This ensures that people are located near to those of similar social status. The fifth term is an enviromental factor that is composed of terms representing the amount of open space and the number of housing demolitions in each zone. The other factor besides the intrinsic attraction is the accessibility to employment term. This uses the cost of travel by public and private transport and the distance deterrence factors for car owners and non-car owners, and takes the conventional exponential form. It is interesting to note that five terms multiplied together are required to counteract the pull towards jobs induced by the accessibility term. This suggests that other models using only, say, the number of houses, may tend to emphasise the effects of accessibility to employment, leading to some of the criticisms of this type of model.

The job choice mechanism is similar to, but rather simpler than, that for residential location. The intrinsic attraction factor for those choosing a new job is the number of available jobs, found by subtracting the number filled by survivors from the total for each social group in each zone. The accessibility term is similar to that for the residential location process.

It can be seen that transport costs are quite an important determinant of residential and employment location, but the use of the intrinsic attraction functions ensure that it is not the dominant factor. As discussed previously, a change in transport costs will alter the residential and employment choices made (and the pattern of housing and jobs to a lesser extent), but will not alter the number of people seeking new locations. This feature is common to all similar models, and needs further investigation, perhaps linking this type of model with work on travel cost elasticities.

The main weakness of this type of model is its macro level approach. We cannot link together all the characteristics that individuals have and use these in the various processes. In reality many decisions are household based, but there are not represented explicitly in the model. The job survival process is rather weak, but this reflects the paucity of research in this field. The model has been tested over a five year period and found to give reasonable results (Mackett, 1979a). Unfortunately, what cannot be tested is all the individual structural relationships within the model, only the resultant distributions. Once again, this is common to all such models and would require a vast comprehensive survey to supply information on the impact of various factors on decision processes and raises issues about individuals' perception of opportunities and costs, post hoc rationalisation of decisions made, incomplete recollection of events and reasons, and so on. In other words it is very difficult to check the behaviour of complex models. This may seem to be an argument for simple models, but these can suffer from the same difficulties, and we are dealing with very complex systems and cannot always make the assumptions implicit in simple models that all other factors remain constant. The need to obtain more explicit information on the behaviour of individuals is part of the reason why it is intended to carry out a survey as part of this new project. This will be considered further, after the description of the various improvements to the existing model in the next section.

5 POTENTIAL IMPROVEMENTS TO THE EXISTING INTEGRATED LAND USE - TRANSPORT MODEL

In the previous section the existing integrated land use - transport model was shown to contain many of the elements required to demonstrate the impact of changes in transport costs on locational decision processes, but there is scope for improvement.

The main problem, which is common to all such models, is that it is concerned with the allocation of activities between zones, not the overall level of activity in the system. For example, one would like the level of employment to be a function of transport costs, so that if it became more expensive to travel some people would cease to work. At present, in this model the overall levels of population, jobs and new housing are input exogenously. It would be possible to follow Lowry's (1964) approach of making one factor exogenous and linking the others to it by keeping simple, exogenously defined, ratios constant, but this is no solution, and rather tends to obscure the assumptions being made. Three alternative approaches would go some way towards solving the problem. One is to apply a model at a lower level of resolution, for example, a national model, using regions as zones. This is similar to the approach used by Echenique (1974) and de la Barra (1975) in the model for Santiago in Chile where an input-output model at a national scale is used to provide the totals for the employment in the particular area being studied. However, there is no feedback from the urban and transport models to the national model. An alternative approach is a hierarchical model of the type devised by Barras et al (1971) in which different amounts of interaction are modelled in different parts of the study area. This can lead to difficult computational problems, and ideally would require a model of the whole country. A third, and similar, approach is to use a set of external zone, as is already used in this model (Mackett, 1974), but extending these over a large area. The problem here is to ensure consistency between the internal and external zones under all required circumstances, while being consistent with the desire to require much less information for the external zones.

A related issue, which was mentioned at the end of the previous section, is the two-stage decision process made in relocation, that is the decision to move, and then the choice of location. Within the existing model the second decision is a function of transport costs, but the first is not. This is similar to the problem

of inelastic trip generation where the number of trips made is independent of the cost of travel. One approach to that problem is that of Southworth (1979) who uses regression to relate trip generation to accessibility. Similar work has been carried out by Martin and Dalvi (1976). Whilst this does represent one approach to the problem, the use of regression means that the underlying mechanism is not being modelled, just the statistical relationships that arise in the data source. This cannot really be regarded as very satisfactory.

There is another issue related to transport costs. At present the same costs perform several functions. They are used for residential and employment location, for trip distribution and for modal split. It can be argued that the detailed knowledge required to make the choice of mode may not be available to the person seeking a new residential location. Wilson et al (1969) used different costs for the trip distribution and modal split stages of a conventional transport model, but without detailed evidence to support this theory. Clearly information on the perception of transport costs is required.

Another improvement to the model would be the introduction of an accounting framework to keep track of everybody from one time point to the next, rather than just representing departure and arrivals of migrants, for example. Within this framework we would wish to distinguish between heads and non-heads of households, and to represent household formation. In fact, the accounts might be better based on the household or there could be two sets with links between the two, with household formation being equivalent to birth in the population accounts. Another type of accounts that could be introduced are of the employment process. Here entry into the job market would be equivalent to birth and retirement or leaving the job market, for other reasons would be equivalent to death. These would be much more interesting than population accounts because people can enter and leave more than once and so marginal workers such as housewives could be represented. If these frameworks were applied at the zonal level and included sensitivity to transport costs we would be approaching the type of model required. A related concept is that of migration. We would need such a model to include household characteristics, housing characteristics and accessibility to work. A model of employment mobility would also be required to represent the movement from one job to another, taking into account the skills of the individual, the skills required and accessibility to residence. These sub-models could then be fitted into accounting framework, enabling suitable survival rates to be calculated and the movement fron zone to zone to be followed explicitly.

There is a need for a better model of the housing market. The type of approach used by de Leeuw and Struyk (1975) and Ingram et al (1972) would seem to be most fruitful. The work by Ingram et al on the NBER Urban Simulation Model contains many of the required elements, but as Kain (1975) has pointed out, still has migration rates independent of the cost of travel.

The type of model that emerges from this section is similar to the model suggested by Butler et al (1969) for the residential location process based on their detailed survey. They suggest the use of two models. The first to produce estimates of mobility by household type in small areas, the second of residential choice which would use the mobile households and vacated housing along with estimates of immigrants and newly formed households in a search process in terms of competition among the locating households for the available housing on the basis of each household's characteristics and preferences.

If all these improvements were made to the existing integrated land use-transport model we would probably have the most sophisticated model of this type, certainly of an operational nature. The best approach will probably

be to consider the various problem areas in isolation then to put them into the model if possible. There is also scope for examining the behaviour of individuals using some form of disaggregate approach, based on the results of the survey, as described in the next section. Putting it another way, it will be impossible to study all the relevant problems associated with location and community in London and South-East England within the resources of the project, and so a selection of particular topics to be studied will be made, and then appropriate techniques used. One approach will be to examine the overall impact of changes in transport costs on the patterns of activities in the study area, and the improved model described here will be one way of doing them. Other approaches will be the disaggregate one mentioned above. A third approach could be a model of transport cost elasticities to examine the impact of change on a particular rail line. It would be desirable, but extremely difficult to integrate these approaches. However, the use of various models to approach different aspects of the same problem will mean that the results of one model can be used in another, and may lead to valuable insights into the behaviour of the various models by relating the results from one with another.

6 THE SURVEY

The use of a survey has been mentioned several times above. With the limited funds available it is important to obtain information that is both useful for telling us about behaviour of individuals and for model testing and calibration.

It is intended that the survey will be carried out by self-completion questionaires using a sample of workers at a selection of firms in Central London, including some firms that offer assistance with fares and some workers who have left that place of work recently and some who have recently started. More information on the survey strategy is given in Kirby, Mackett and Nash (1979).

The following information will be required from the survey: personal and household characteristics, present housing characteristics and location, journey to work costs, times and modes used, previous housing and job locations and the reasons for changes in location. It may be over-ambitious to attempt to obtain all this information in a self completion questionaire, and a pilot study will be invaluable in the determination of the type of information that can be obtained. The problems of the type mentioned towards the end of Section 4 of individuals' perception of costs and opportunities, rationalisation of decisions made in the past, incomplete recollection of events and reasons and so on, may all arise, and the approach adopted must allow for this. The approaches used in other surveys of past locational decisions by Butler et al (1969) de Langen and Verster (1978), and Floor and de Jong (1979) will all the studied.

There are other complicating factors. For example in considering the trade-off between transport costs and housing costs both of these will have to be measured. Transport costs present problems because there may be four or more stages in the trip (for example, walk, rail, underground and walk) and so the relative weightings of those must be considered. In addition, the effect of modal interchange is important. It is very pertinant to consider whether average values can be adopted for this analysis, or whether such factors are totally subjective. Housing costs present the problem of what should be measured. The amount being paid on a mortgage is not necessarily a function of current market conditions, but of the conditions at the time of purchase. There are other complications such as tax relief and the various types of mortgage, some of which include life assurance.

It should be made clear that it is not intended to rely entirely on the survey for data for the study. Information will be taken from the Census of Population, including unpublished data on migration and the journey to work, the London Travel Survey and the Greater London Transportation Study. In addition there may well be local studies carried out by local authorities and the transport operators which can be drawn upon. This data will tend to convey information on what people have actually decided to do in the past. The survey will, hopefully, shed light on why decisions have been taken, and provide some links between the different sectors covered in the survey and represented in the model.

7. CONCLUSIONS

This paper has been written in an attempt to outline some of the current thinking on a project to examine the impact of changes in rail fares on location and commuting decisions in London and South-East England. This is an extremely complex topic and it will be impossible to study all the relevant topics with the limited resources available. There is a need for some research into the processes of residential and job choice, and this paper has concentrated on these, looking at the way other researchers have approached the topic, in particular, considering the role of accessibility in the process. Various other related topics will also have to be considered, for example, the housing and labour markets, the role of local authorities, the perception of travel costs and migration. The different problems associated with each topic mean that different approaches will be required. Some will be largely descriptive, others operational models. It is unlikely that a large scale comprehensive model of location and commuting decisions will emerge because that would involve scale shifts from decisions within the household up to the effects of large firms and local authorities. A more realistic approach would be to produce a set of models of various topics related to the general problem, possibly linked together informally. A useful starting point will be the integrated land use-transport model, since this has already been built and tested. It will have to be modified to allow for the change in size of the study area and the different problems being considered.

Resources have been provided for a survey. This will be carried out with the duel objectives of providing information that can be studied on the processes at work and for model testing and calibration.

The problems of the effects of railway fare changes on location and commuting in London and South-East England are complex. They are also of interest to a wide range of public authorities. It is intended that this project will contribute to the understanding and solution of the problems, and the development of useful analytical techniques in this field.

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