GENERATION OF INTEGRATED MULTISPATIAL INPUT–OUTPUT MODELS OF CITIES (GIMIMoC) I: INITIAL STAGE

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ABSTRACT

This paper deals with the first stage – initial description – of generating an Integrated Multispatial Input-output Model of Cities (GIMIMoC) by incorporating multiple systems (urban economic, socio-demógŕaphic and housing subsystems), and multispatial scales (urban zone, city, region and a nation) into the framework. First, attention is paid to construct multispatial input-output model (MULIO module). It shows how new insights can be generated when multispatial levels are considered. Second, the multispatial socio-demographic module (SOCDEM) is described, which can be either operated independently or incorporated into the GIMIMoC framework. Third, the multispatial housing stock module (HOSTOC) is treated, in which a spatial interaction type model is applied to estimated the housing demanding flows. Last, the integration, model solution, together with potential application, are outlined. The second stage - the dynamics of the GIMIMoC framework - is dealt with in another paper (Jin and Wilson, 1991).

Key words:

Multispatial, multisystem, MULIO, SOCDEM, HOSTOC, integration

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Generation of Integrated Multispatial Input-output Models of Cities(GIMIMoC)

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I. Introduction

Since the initial outline presented in Isard's (1960) <<Channels of synthesis>>, integrated modelling in regional science has developed over three decades. From recent literature, however, [Isard and Anselin(1982), Batey and Madden (1981,1986), Hewings (1986), Boyce (1988) and Anselin and Rey (1989)], three issues can be identified.

First, integrated models are achieved from one of two system articulations: either *embedding* or *connection*. The *embedding* approach considers all systems in one methodological framework and operates the model by using one calculation system. A typical example is Batey and Madden's (1981) extended input-output framework. The *connection* approach attempts to link separate models (or systems) together in terms of their inputs and outputs. A typical example is Isard and Anselin's (1982) integrated modelling framework.

Secondly, each uses existing modelling approaches. This may result in new problems whilst at the same time some of the old problems remain unsolved.

Thirdly, possibly because of problems of data availability, or inability to formulate proper notation, almost all of the models ignore the multispatial features of the reality. That is the combination of urban zone (that is, the elements of intra-urban structure), city, region and nation, which constitutes a major element in a comprehensive study.

In this paper, we attempt to Generate an Integrated Multispatial Input-output Modelling framework for Cities which is termed as GIMIMoC. The model generated is both integrated and connected. Three main human activities are identified as our study of interest: working, living and travelling, and there are three subsystems - economic, housing, and socio-demographic. The economic subsystem focuses on goods and service market which describes the interrelationships between different industries. The socio-demographic system deals with the labour market, and its relationships to other demographic factors, and interrelationships between this subsystem and other urban subsystems. The housing system is mainly concerned with the housing market -- house stock demand and supply. In addition, we believe the representation of different spatial scales is one of the key elements in comprehensive analysis. Four spatial levels (urban zone, city, region and nation) are considered in our modelling framework. Thus, the focus is on constructing a new module for each of the identified sub-systems at the different scales from which we can generate the GIMIMoC framework. This framework has two main features: (1) it differs not only from the Isard-Anselin integrated modelling in that their model used existing models, but it also differs from the Batey-Madden framework in that the GIMIMoC considers non-economic systems such as demographic and housing systems and integrates them, through the *connection* approach, into a framework in which the main core is input-output modelling; (2) each module of the framework, according to different objectives, can be either operated individually or connected with each other and operated systematically.

The completion of GIMIMoC requires two stages: initial description and dynamic simulation. The present paper is mainly concerned with the first stage and generate an initial modelling framework, based on which the second stage - the dynamic simulation - can be achieved. The structure of this paper is as follow: firstly, the notation system is discussed; secondly, the input-output model for an urban economic system at multispatial scales is constructed. It demonstrates various input-output models at a variety of assumed multispatial scales, and that the conventional 'interregional' input-output model is merely a special case of the multispatial input-output model; thirdly, a module that exposes both the internal and interrelationships within the social-demographic subsystem is described; fourthly, the housing stock conditions (shortage, surplus, balance), in particular, the housing demand flow which is based on spatial interaction model, are treated; finally, in the summary, it is suggested, as what the present paper deals with is a comprehensive description of an urban system, the initial description or the outcomes from the operation of the framework should lay the foundations for further researches: (a) dynamic GIMIMoC; (b) being incorporated into the Batey-Madden demo-economic input-output framework to derive multiple impacts upon the urban system; (c) a CGE solution may be introduced to solve the whole framework.

II. Assumptions and Notation

The construction of the GIMIMoC framework starts from two major assumptions: the multispatial and multisectoral nature of the real world. A variety of spatial systems, needs to be identified. We assume that a nation is constituted by a mixture of regions and cities; and a region is composed of a number of cities and subregions; and a city consists of urban zones. The GIMIMoC could be operated at each spatial level, i.e. urban zone, or city, or region, or comprehensively, a combination of all the spatial scales. Suppose, there are up to R regions in a nation and K^r cities in rth region, and $I^r{}_c$ residential and $J^r{}_c$ industrial zones in cth city in rth region. In practice, the residential and industrial zones are usually mixed, and the distinction between residential and industrial zones are only for theoretical convenience, and then zone i can be zone j. This kind of multispatial system is shown in Figure 1.

The multisector feature is also identified. We assume: (1) there are S industries which can perhaps be classified into primary, energy, manufacture, construction, distribution and service, labelled as n (n=1,2,...,S), etc, that are located in a industrial zone in a particular city in a particular region; (2) there are M groups of people who live in a residential zone. The people can be classified into various groups, for example, by social skill levels (professional, manual, non-manual, etc) or by income (low, middle and high), or by age, or by sex etc, which are labelled as m (m=1,2,...,M); and (3) there are a number of household units (houses) which can be subgrouped as owner occupied, city council, housing association and rental houses; or as detached, semidetached, bungalow ... etc, that are labelled by y (y=1,2,...,Y).

Three types of interactions need to be distinguished; (i) the service and goods flows between (and within) any pair of industrial zones at various spatial scales; (ii) the travel-to-work flows between any pair of residential and industrial zones (including the flows within the residential zone); (iii) the housing demand 'flow' of, for example, those who own type y house in one residential zone but demanding type y' house in another residential zone. These kinds of interactions, together with the multispatial and sectoral systems which we are likely to end up with are shown in Figure 1 and the notation symbols in Table 1.

III. The Multispatial Input-Output Module (MULIO)

The multispatial input-output module (MULIO) represents the interindustrial relationships within the economic system. It generates the output products, final demands, value added products, personal and public consumption, income, export and imports, and intermediate products at various spatial scales, which can be used as inputs into other modules. It determines the employment levels, labour requirements, household incomes and investments in housing construction, through which the socio-demographic and housing systems are, to some extent, affected.

The MULIO module is basically taken in from the conventional interregional input-output model developed by Isard in 1951 and whose use is illustrated by, for example, Hewings in 1985. The common feature of the conventional interregional model is that they are achieved by partitioning the national control totals into regional magnitudes by sector. Its presumption is that regions have to be continuous. In other words, the conventional interregional input-output model for some reasons ignores the discrete features of regions, for instance, if the research objective is to specify the interindustrial relationship between Scotland and the region of Yorkshire and Humberside, the conventional interregional model maybe find it difficult to address such relationships. Jin (1991) suggests that a multispatial input-output model (MULIO) in this case be developed. In this section, we thus demonstrate how the conventional input-output model can be developed if various spatial scales (including discrete features) are constructed, and then show that the conventional input-output model is merely a special case of the MULIO module.

We start from assuming that there are only one urban zone in a city and one city in a region [see Table 2(a).1 and (b).1]. Then an intrazonal input-output model for such an assumption is shown in equation (1), where X^{n}_{jcr} is the gross output product, $Q^{nn'}_{jcr}$ intermediate transaction flow, and F^{n}_{jcr} is the final demand, and superscripts n and n' indicate *n*th and *n'*th sectors; the subscripts j, c and r are the *j*th urban zone, *c*th city and *r*th region. It soon be found that this model [Table 2(a).1] and table [Table 2(b).1] are actually identical to the conventional Leontief-type intraregional input-output model. All the subscripts are only dummy spatial scales, because the size of the urban zone is equal to the size of the city, and also, since only region is assumed, the number of regions is equal to 1.

Then, let us assume that there two urban zones, one city and one region [see Table 2(a).2], an interzonal input-output model for this assumption is shown in equation (2), in which subscript j' indicates *j'*th urban zone, and others are as those defined before. We then can see that this model is the same as the conventional interregional input-output model (*inter alia* Isard 1953) since it describes interindustrial relationships between two zones (or two regions in the conventional model) in a city (or in a region in the conventional model). Here, the subscripts c and r are dummy spatial scales, because only are one city and one region assumed.

Further, if a two urban zone - two city - one region case is assumed [see Table 2(a).3 and 2(b).3], neither the conventional 'intraregional' nor 'interregional' input-output model can be directly applied. In this case, following sets of relationships need to be identified: (1) intrazonal interindustrial relationships within city 1 and city 2; (2) interzonal interindustrial relationships between one zone in city 1 and one zone in city 2; (3) the interregional industrial relationships to the rest of the region (exclude city 1 and 2); (4) the relationships between the region and the rest of the world. A multizone multicity single region input-output model is then proposed in equation 3, in which c' shows the *c'*th city, and a new notation ($\mathring{A}^{n}{}_{jcr}$) is introduced, which, functioned as a balance factor, indicates the interrelationships between all the cities and the rest of the region (or between the urban areas and rural areas). The multizone multicity single region input-output table is shown in Table 2(b).3. $J^c{}_r$ (=2) shows that the number of urban zones in city c in region r (NB. R=1) are two, and C_r (=2) the number of cities in region r are two.

Finally, if a two urban zone - two city - two region assumption is made [see Table 2(a).4 and 2(b).4], a multizone, multicity, multiregional input-output table and model can be developed. In equation 5, the new notation ($\ddot{A}^n{}_{jcr}$), as a balance factor, indicates the amount of product produced in industry n in zone j in city c in region r flows to the rest of the region, the calculation of which is shown in equation (6) which is derived by aggregating through all the rest of regions. The subscript r' indicates the *r'*th region which here is not a dummy spatial scale any more. The number of regions in this assumption are two (R=2).

So far, the construction of the multispatial input-output model has been completed. However, some illusions need to be clarified. First, 'if it is necessary to construct such a multispatial input-output model', and second 'whether the superfluous notation can be cut off, and only the conventional interregional input-output model is applied'. As far as the first issue is concerned, we suggest such a model is very important to address interrelationships at multispatial levels, in particular, the identified study objects are two discrete zones but which have close economic links, for example, the interindustrial relationships between inner Leeds in the region of Yorkshire and Humberside and outer Birmingham in the region of West Midland. It may be argued that other spatial models such as spatial interaction and econometrics models can also be applied. However, the input-output may be the best one to account for interindustrial relationships and policy analysis. With respect to the second question, it is clear, from the above analysis, that the notation is not superfluous, and the conventional input-output cannot replace the multispatial input-output model even if all the 'superfluous' notation (i.e. zone, city, region) is cut off. From equation (2) (the conventional type input-output model) and (5) (the multispatial input-output table), Table 2(b).2 and 4, it can be seen the conventional interregional input-output model and table are only special cases of the multispatial input-output model and table. The condition of which the conventional input-output model is equal to the multispational input-output model is that <u>only if</u> multizone, one city and one region are assumed. Take the intermediate transaction flow as an example, if $Q^{nn'}{}_{jj'}$ is assumed for the conventional interregional input-output model, then

$$\hat{Q}^{nn'}_{jj'} \begin{cases} = Q^{nn'}_{jj'cc'rr'} & \text{when } c=c',\ r=r' \\ \neq Q^{nn'}_{jj'cc'rr'} & \text{when } c\neq c',\ r\neq r' \end{cases} \qquad (7)$$

which shows that the conventional interzonal input-output model is only a special case of a multispatial input-output model, that is when a one city - one region case is assumed. Since the MULIO module describes both continuous and discrete spatial scales, both internal and interregional relationships (to the rest of the region, to the rest of the world), '*it therefore enlightens and generates new insights for further development of regional input-output analysis*' (Jin 1991).

By operating the MULIO module, the following information can be provided: (a) gross output and input products; (b) intermediate products to a zone, to a city, and to the rest of a region; (c) the primary input product including imports, incomes and profits, and the final demands including exports, public and personal consumption; and (d) labour requirements by industry. However, the operation of the MULIO module may be insufficient to account for the overall urban economic, demographic and housing structures, without a consideration of other systems. For instance, the urban employment, unemployment, vacancy and housing construction structures and levels closely link to urban economic system. At the same time, the operation of other systems will cause feedback influence, through final demand, to the urban economic subsystem. This argument leads us to develop the other two modules for the multispatial social-demographic and housing systems.

IV. The Multispatial Socio-Demographic Module (SOCDEM)

Many models on demography have been developed, either as a component in demo-economic embedding modules (c.f. Batey and Madden, 1983), or as an important module in integrated frameworks (e.g. Isard and Anselin, 1982). The demo-economic modules are compact and consistent, however, they are too narrow to enable such variables as work force, dependent, population and journey-to-work flow which are key issues in demographic analysis to be embeded; The integrated Isard-Anselin framework deals with the changes of population of a system, it nevertheless focuses on the population natural growth and migration submodels. We hence attempt to construct a new module for the multispatial socio-demographic subsystem (SOCDEM) which can explicitly provide analysis of the changes of the socio-demographic subsystem, and incorporated into the GIMIMoC framework. The outline of such a module has been presented by one of the authors before (Wilson, 1989).

The SOCDEM module mainly treats the interactions between population and work force growth, origin and destination of employment, unemployment, labour requirement, vacancy and dependency at various spatial levels. These kinds of interactions are primarily embodied in the form of a table, termed the multispatial SOCDEM table (see Table 3), which describes three types of relationships: (i) the relationships between employment by social class and employment by industry; (ii) the relationship between population and work force growth and the actual employment; and (iii) the relationships between the change in labour requirement and the actual employment. All three relationships have multispatial features, which are, in turn, discussed below.

It is important to note, as discussed before, that this travel-to-work flow is occurred at multispatial scales which is not identical to the interzonal travel-to-work flow. The former one considers both continuous and discrete cases, and the latter one only deals with the continuous case.

The first type of relationship is, in fact, reflected from the travel-to-work flow. It is shown in Table 3, notated as $L^{mn}{}_{ijcc'rr'}$ (**L**) indicating the number of employees from a certain social class m living in a residential zone i in city c in region r who go to work in sector n' in industrial zone j' in city c' in region r'. The social class can be represented by skill level, ranging from manual to professional level; or by income, ranging from low income to high income. Industry can be subdivided, for example, as primary, manufacturing, public and private service. The actual origin of employees by social class can be derived from summing matrix **L** across the columns; and the actual destination of employees by industry can be derived from summing matrix **L** down the rows.

The second set of relationships are demonstrated in the columns labelled 2, 3, 4, and 6 in Table 3. Column 2 is the actual origin of employees by social class; column 3, notated $R^{n}{}_{icr}$, shows the work force of social class m in residential zone i in city c in region r, and column 6, $G^{m}{}_{icr}(\mathbf{G})$, is the total population by social class m in zone i in city c in region r. Both the work force and total population elements depend upon two straightforward models, which are affected by the economic activity rate (NB. here, defined as the ratio between the number of economically active person to the total population) and population growth rate (natural and migration change). The model for the work force can be written as:

$$R^{m}_{icr} = \hat{a}^{m}_{icr} G^{m}_{icr} \tag{8}$$

where:

$$G^{m}_{icr} = (\hat{o}^{m'}_{i'c'r'} + g^{m}_{icr})\ G^{m}_{icr(t-1)} \tag{9}$$

$\hat{a}^{m}{}_{icr}$ is the economic activity rate as defined before. The population's natural growth rate (birth rate - death rate) is expressed by $g^{m}{}_{icr}$. The migration rate from the social class m' in residential i' in city c' in region r' is expressed by $\hat{o}^{m'}{}_{i'c'r'}$.

Column 4, shown as $U^{m}{}_{icr}$, shows unemployment by social class m in zone i in city c in region r, which is calculated as difference between the workforce and the actual employment by social class by zone by city by region.

The third type of relationship is illustrated in rows 2, 3, 4, 5 and 6. Row 2 ($\underline{R}$) shows the actual employment by industry in industrial zone j' in city c' in region r' which is aggregated from the travel-to-work flows down the columns of the expanded travel-to-work flow shown in cell (1) (1). Row 3, notated as $E^{mn}{}_{j'c'r'}$, shows the number of employees by social class m required by industry n in industrial zone j' in city c' in region r'. It, in fact, reflects a certain productivity rate that mainly depends upon the economic system (the MULIO module). In other words, the labour requirement is the function of both the productivity rate and economic production level. A simple model can be expressed as in Equation (10):

$$E^{mn}_{j'c'r'} = \hat{e}^{mn}_{j'c'r'} \; X^{n}_{j'c'r'} \qquad (10)$$

where $\hat{e}^{mn}{}_{j'c'r'}$ is the productivity rate, and $X^{n}{}_{j'c'r'}$ is the economic production level determined by the economic system (the MULIO module). Obviously, a remainder can be obtained by subtracting the actual employment in row 2 (supply) from the labour requirement in row 3 (demand). This remainder, $V^{mn}{}_{j'c'r'}$, then indicates the number of vacancies existing in industry n in industrial zone j' in city c' in region r'.

Row 5, $SR^{mn}_{j'c'r'}$, shows the number of dependents supported by the employees working in industry n in zone j' in city c' in region r'. It implies a relationship between the support ratio and the actual employment, and, if we define $\underline{f}^{mn}_{j'c'r'}$ as the dependency rate in zone j' in city c' in region r', then the number of dependents can be derived from Equation (11):

$$SR^{mn}_{j'c'r'} = \underline{f}^{mn}_{j'c'r'} \, \underline{R}^{mn}_{j'c'r'} \tag{11}$$

The total population by industry is obtained by adding total employment and dependency. Finally, the total population summed across the industries has to be equal to the total population summed down the social classes. The SOCDEM table is then balanced.

The potential links between the MULIO module and the SOCDEM module become clear. The output data from the MULIO module (e.g. labour coefficient) can be incorporated directly into the SOCDEM module, and the output from the SOCDEM module will provide basic data for deriving exogenous factors such as consumption by employed, and unemployed and dependent persons, which are required by the operation of the MULIO module.

V. The Multispatial Housing Stock Module(HOSTOC)

The housing system is another important component which needs to be addressed. The HOSTOC module mainly focuses on the housing market condition at a variety of spatial scales, from which two submodels, the housing-demand and housing-supply, and the comparison outcome between the housing supply and demand, can be derived.

Housing-demand model Luce (1959) develops a housing demand model based on the assumption of that the probability for a individual to choose a certain house depends on the relative value of attributes and the level of other consumption. The type and location of the demanded houses and their interactions with urban economic and demographic subsystems, however, are not considered. Botman (1981) develops a complex housing forecasting system which explicitly allows for the potential interaction between the housing market and demographic and employment variables, whilst it only focuses on the Netherlands national housing system, the disaggregated spatial scales, in particular, the housing demand flow — that is the number of people who has type y house in urban zone i in city c in region r demand the type y' house in zone i' in city c' in region r' — are not concerned. We thus develop a multispatial housing demand model, in which the housing demand flow at multispatial levels, its interactions with those developed MULIO and

SOCDEM modules are included.

We begin with developing the housing demand flow model. Let us define $Y^{yy'}_{ii'cc'rr'}$ is the number of persons who at present are living in zone i in city c in region r demanding type y' house in zone i' in city c' in region r'; ${}^{d}N^{y}_{icr}$ is the number of persons who live in type y house in zone i in city c in region r; ${}^{s}N^{y'}_{i'c'r'}$ is the number of persons who likely sell type y' house in zone i' in city c' in region r', then a spatial interaction type of model, for instance, a double constraints spatial interaction model (c.f. Wilson 1973), can be developed to derive the house demand flow:

$$\hat{Y}^{yy'}_{ii'cc'rr'} = \hat{A}_{icr}\hat{B}_{icr}\,{}^{d}N^{y}_{icr}\,{}^{s}N^{y'}_{i'c'r'}\,e^{-\beta t^{yy'}_{ii'cc'rr'}} \tag{12}$$

where $\hat{A}$ and $\hat{B}$ are balance factors, and ß is a parameter.

${}^{d}N$ is the function of personal income, the size of household (population) and the travel cost, which is expressed as equation (13):

$${}^{d}N_{icr} = f\ (\hat{\imath},\ G,\ t, \ldots) = \Sigma^{Y}_{y'}\Sigma^{I}_{i'}\Sigma^{C}_{c'}\Sigma^{R}_{r'}\ \hat{Y}^{yy'}_{ii'cc'rr'} \tag{13}$$

${}^{s}N$ is a function of house price and regression parameter, which is equal to equation (14):

$${}^{s}N^{y'}_{i'c'r'} = f\ (p, \delta, \ldots) = \Sigma^{Y}_{y}\Sigma^{I}_{i}\Sigma^{C}_{c}\Sigma^{R}_{r}\ \hat{Y}^{yy'}_{ii'cc'rr'} \tag{14}$$

If an inverse average household size is defined as Θ (houses / per person), then the number of demanded houses by type by multispatial scales (${}^{d}H^{y}{}_{icr}$) can be derived from equation (15):

$$ {}^{d}H^{y}_{icr} = \Theta \Sigma^{Y}_{y'} \Sigma^{I}_{i'} \Sigma^{C}_{c'} \Sigma^{R}_{r'} \hat{Y}^{yy'}_{ii'cc'rr'} \quad (15) $$

It should be conceptually clear that the travel cost in equation (12) and (13) indicates the travel cost between the residential place (i) and work place (j), rather than the cost between one residential zone (i) and another zone (i'). However, as we argued before, the residential zone and work zone are usually mixed and the distinction between them are only for theoretical convenience, then the superscript (j') of travel cost can be replaced by (i'). In this way, the notation is compatible to the house demand flow.

It can be seen that the housing demand depends on the house demand flow, whilst the house demand flow (equation 12) links to both MULIO and SOCDEM modules through equation (13) and (14). The calculation of house demand depends on personal income from the MULIO and population from the SOCDEM modules.

<u>House stock supply model</u> Field and MacGregor (1988) suggest that the future housing stock depends positively on existing stock, improved houses; and negatively on existing and those likely become substandard houses, other losses,

second homes; and conversions, the calculation of which, however, to a large extend rely on the existing data or surveying. We propose that the house stock supply depends: (1) existing houses; (2) public new constructed and improved houses; and (3) private new constructed and improved houses, which can be expressed as equation (16):

$$ {}^{s}H^{y}_{icr(t)} = (1-d)\,{}^{s}H^{y}_{icr(t-1)} + {}^{a}H^{y}_{icr(t)} + {}^{b}H^{y}_{icr(t)} \qquad (16) $$

where

${}^{s}H^{k}_{icr}$ is the housing supply for type y house in zone i in city c in region r. Subscripts (t) and (t-1) in equation (16) shows the existing houses in time period t and t-1.

${}^{a}H^{k}_{icr(t)}$ is the public construction for type y house in zone i in city c in region r in time period t, which is a function of the public expenditure on housing construction and improvement.

${}^{b}H^{k}_{icr(t)}$ is the private housing construction for type y house in city c in region r in time period t, which is a function of the personal expenditure on housing construction and improvement.

d is a crude rate measuring the ration between the existing and new substandard houses and the total house stock.

It can be seen that the house supply submodel links to the final demand component of the MULIO module through public and private housing construction and improvement.

Comparing the number of demanded type y houses in zone i in city c in region r derived from equation (15) to the number of type y house stock derived from equation (16), the housing market condition for type y house in residential zone i in city c in region r ($B^{k}{}_{icr}$) can be obtained. Three conditions are then provided: (i) house stock shortage when demand is larger than supply; (ii) house stock surplus when housing demand is smaller than the supply; and (iii) house stock balance when the house demand is equal to the house supply, which are shown in equation (17):

$$B^{y}_{icr} = {}^{d}H^{y}_{icr} - {}^{s}H^{y}_{icr} \longrightarrow \begin{cases} < 0 & \text{surplus} \\ > 0 & \text{shortage} \\ = 0 & \text{balance} \end{cases} \tag{17}$$

It is likely that the housing market conditions will affect both the economic and socio-demographic systems, in that, the zone with more surplus and better houses may attract more migration than those zones with housing shortage. It is also recommended that such information may be useful for urban planners to make urban construction plans. New housing construction and improvement could be undergone whereas the house stock shortage for type y house (for instance, city council owned houses) in zone i in city c in region r exists.

VI. Integration and Interactions

The three modules for each identified system have so far been demonstrated. The next step is to integrate the three individual systems into a whole framework. This will involve two further issues: module articulation and solution.

Interaction. The module integration is achieved by specify the interactions between any pair of modules, as shown in Figure 2. The first one is the interaction between the MULIO and SOCDEM submodules. Moving from the economy to the demographic module, the labour coefficient (both direct and indirect) can be taken as the linkage between the two modules, which determines the labour requirement in the SOCDEM module. In the reverse direction (i.e. from the SOCDEM to MULIO module), the derived employed, unemployed and dependents will exogenousely influence the personal and public consumption level in the MULIO module. The second set of interaction occurs between the SOCDEM and HOSTOC module, most strongly represented in the direction of links from the SOCDEM to the HOSTOC set of modules, in that the changes of population (natural and migration) and household income will determine the housing demand. The reverse interaction may only be expressed as an attractive factor that influences migration. This reverse interaction is not as strong as the former one. The third set of interactions shows the relationships between the MULIO and HOSTOC modules. In the HOSTOC module, no matter in which submodel, the elements in both the housing demand or the housing supply, such as house stock demand (through personal income) and housing construction and improvement (through both the public and personal expenditure) are strongly affected by the MULIO system. However, the interaction from the HOSTOC to MULIO module is very weak. Thus the integration of the GIMIMoC is achieved.

Model solution. The completion of solving the (initial) GIMIMoC framework can be achieved by specifying the input and output relationships between each pair of modules. We suggest that the MULIO module be operated first because it generates the required information for both the SOCDEM and HOSTOC modules (see Figure 3). The output data from the MULIO module such as labour coefficient and gross output product determine the labour requirements in the SOCDEM module; and the personal income together with the size of population from the SOCDEM module influence the calculation of house stock demand and supply in the HOSTOC module. The outcomes from both the SOCDEM and HOSTOC modules such as unemployment, employment, dependents, housing construction and improvement expenditures, as exogenous factors, eventually determines the final demand level in the MULIO module.

From operating the GIMIMoC modelling framework, three main sets of output results can be derived, which are listed in Figure 4: the output results from operation of the initial GIMIMoC framework.

VII. In Summary

In this paper, the first stage of the whole modelling framework — initial description — has been developed. The main objective of the present model is to provide comprehensive information for further research, e.g. dynamic simulation. Three modules are then considered in the GIMIMoC framework. The MULIO module deals with the goods and service market, and the input-output analysis is applied to specify the interindustrial relationships. It is argued a multispatial input-output model needs to be developed to comprehensively account for the real world, to embody the interindustrial relationships at both continuous and discrete spatial levels. It is also demonstrated that the conventional input-output model is only a special case of the multispatial input-output model. In this case, the conventional input-output model cannot replace the multispatial input-output model.

The SOCDEM module describes the socio-demographic urban subsystem, in particular, the labour market. A multispatial SOCDEM table, together with the associated models are constructed. Since the comprehensive socio-demographic (employment, unemployment, work force, vacancy, labour requirements, dependents, population, migration) have been considered in this module, it is suggested to be either applied independently, or incorporated into the GIMIMoC framework.

In HOSTOC module, the house stock demand and supply models are developed. Special attention however is paid to the housing demand 'flow'. It is proposed that the demand flow is directed by the number of persons who demand and intend to sell their houses, and then the spatial interaction type of model is applied to describes such flows. The house stock situation is derived from comparing the number of demanded houses to the supplied houses.

The interactions in the GIMIMoC framework are reflected through both the internal mechanism and input and output relationships between each pair of the modules. The operation of the initial GIMIMoC framework is started from the MULIO model. Three sets of results are then output.

Since what this paper deals with is the first stage of the GIMIMoC, that is, to provide comprehensive information for urban analysis, we then suggest that the present GIMIMoC framework can link to three further researches: (1) as Figure 3 shows, a dynamic GIMIMoC needs eventually to be generated to account for the future urban economic, demographic and housing structures. A preliminary dynamic model has been developed (c.f. Jin and Wilson, 1991); (2) to provide essential information for policy-oriented models, for example, some of the results from GIMIMoC such as employment, unemployment, vacancy, dependents may be incorporated into the demo-economic modelling frameworks of Batey and Madden (1981) and Oosterhaven and Folmer (1985) to generate further impacts upon urban structures; (3) if a national spatial scale is considered, a CGE (Computable General Equilibrium) solution may be applied.

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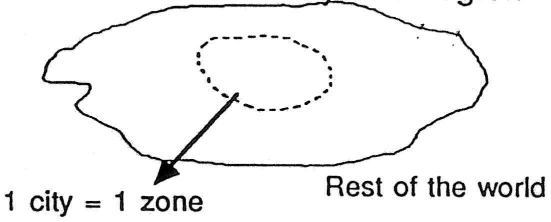
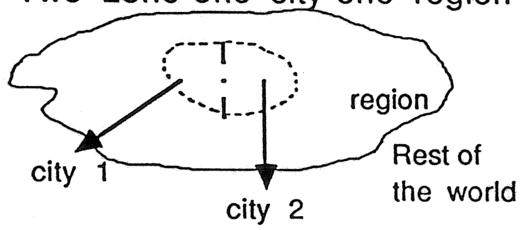
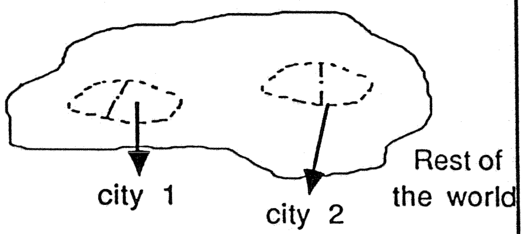
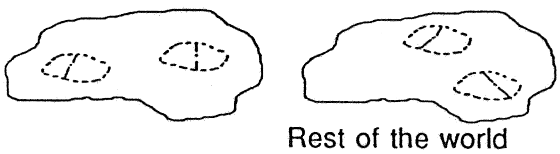
TABLE 1: The Assumptions and Labels at the Different Spatial Levels

	Total number	Label
People	M	m,m'
Sector	S	n,n'
Housing	Y	y,y
Zone*		
(a)	I^{c}_{r}	i,i'
(b)	J^{c}_{r}	j,j'
City	K_r	c,c'
Region	R	r,r'
Nation	ONE	1

NOTE:

* (a) and (b) are residential and industrial zones. A residential zone can be an industrial zone because of their mixed uses.

TABLE 2(a): Multispatial urban system and the associated input-output models

Assumed urban systems	Generalized Models
1. one zone-one city-one region 	An 'intra-region' model $X^n_{jcr} - \Sigma^S_{n'} Q^{nn'}_{jcr} = F^n_{jcr}$ (1) J=C=R=1
2. Two zone-one city-one region 	An 'interregional' model $X^n_{jcr} - \Sigma^S_{n'} \Sigma^J_{j'} Q^{nn'}_{j'cr} = F^a_{jcr}$ (2) J=2, . C=R=1
3. Two zone-two city-two region 	A 'single region multcity multizone' model $X^n_{jcr} - \Sigma^S_{n'} \Sigma^J_{j'} \Sigma^C_{c'} Q^{nn'}_{j'cc'r} - A^n_{jcr} = F^a_{jcr}$ (3) $J^C = 2$, $C_r = 2$, $R=1$ where, $A^n_{jcr} = \Sigma^S_{n'} Q^{nn'}_{j*c*r}$ (4)
4. Two-zone-two city-two region 	A multispatial model $X^n_{jcr} - \Sigma_n \Sigma_{j'} \Sigma_{c'} \Sigma_{r'} Q^{nn'}_{jj'cc'rr'} - A^n_{jcr} = F^n_{jcr}$ (5) where $A^n_{jcr} = \Sigma^S_{n'} \Sigma^R_r Q^{nn'}_{j*c*r}$ (6) $J^c_r = 2$, $C_r = 2$, $R=2$

Keys:

——— region

— — — city

—— · —— urban zone

TABLE 2(b): Multispatial input-output tables

Assumed urban system	Input-output tables

1. One zone-one city-one region

input \ output	1, ... S	F
1 . S		
P		

2.Two-zone-one city-one region

input \ output	Z1	Z2	F
	1,... , S	1,... , S	
Z1 1 S			
Z2 1 S			
P			

3. Two-zone-two city-one region

input \ output			C1		C2			
			Z1	Z2	Z1	Z2	ROR	F
			1,...,S	1,... , S	1, ...,S	1,... ,S	1,...,S	
C1	Z1	1 s						
	Z2	1 s						
C2	Z1	1 s						
	Z2	1 s						
ROR								
P								

4. Two-zone-two city-two region (multispatial urban system)

input \ output				R1				R2					
				C1		C2		C1		C2		ROR	F
				Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2		
				1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1...S	
R1	C1	Z1	1 s										
		Z2	1 s										
	C2	Z1	1 s										
		Z2	1 s										
R2	C1	Z1	1 s										
		Z2	1 s										
	C2	Z1	1 s										
		Z2	1 s										
ROR													
P													

where:

S: No. of sector.

P.F: primary input, final demand.

Z,C,R: urban zone, city, and region.

ROR: Rest of the region

TABLE 3: The Socio-Demographic Account Table at Different Levels for an Urban System* (SOCDEM)

			Region / City / Zone (1) $n_1, n_2, \ldots, S$	Actual employment (2)	Work force (3)	Un-employment (4)=(3)-(2)	Non-work Force (5)	Total population (6)=(3)+(5)
Region / city / zone	m_1, m_2, m_3, :, :, :, M	1	$L^{mn}_{ij,cc',rr'}$	$\hat{R}^{m}_{icr}$	R^{m}_{icr}	U^{m}_{icr}	NR^{m}_{icr}	G^{m}_{icr}
Actual employment	m_1, m_2, :, :, M	2	$\underline{R}^{mn}_{jc'r'}$	/	/	/	/	/
Labour requirement	m_1, :, :, M	3	$E^{mn}_{jc'r'}$	/	/	/	/	/
Job vacancy =(2)-(3)		4	$V^{mn}_{jc'r'}$	/	/	/	/	/
Dependents		5	$SR^{n}_{jc'r'}$	/	/	/	/	/
Total population =(2)+(5)		6	$G^{n}_{jc'r'}$	/	/	/	/	$G^{*}_{***} = G^{*}_{***}$

* See note in Table 2.

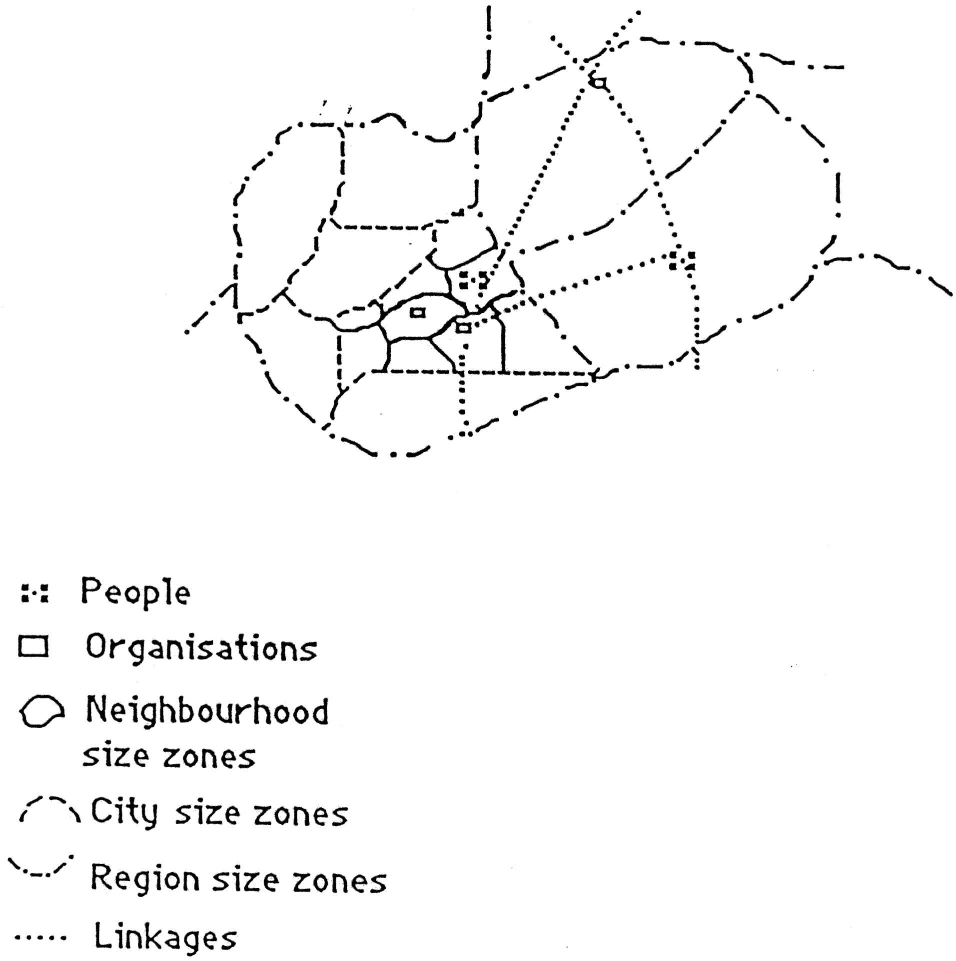
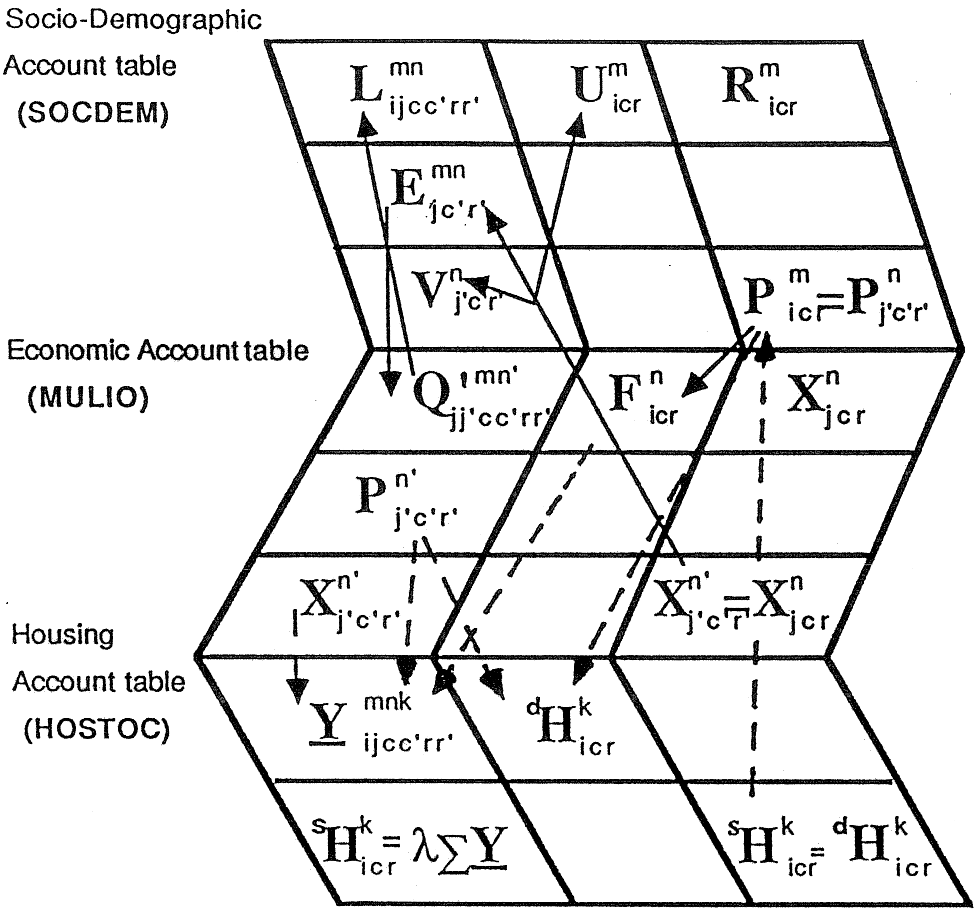


Figure 1: The multispatial multisectoral spatial systems (After Wilson, 1990)



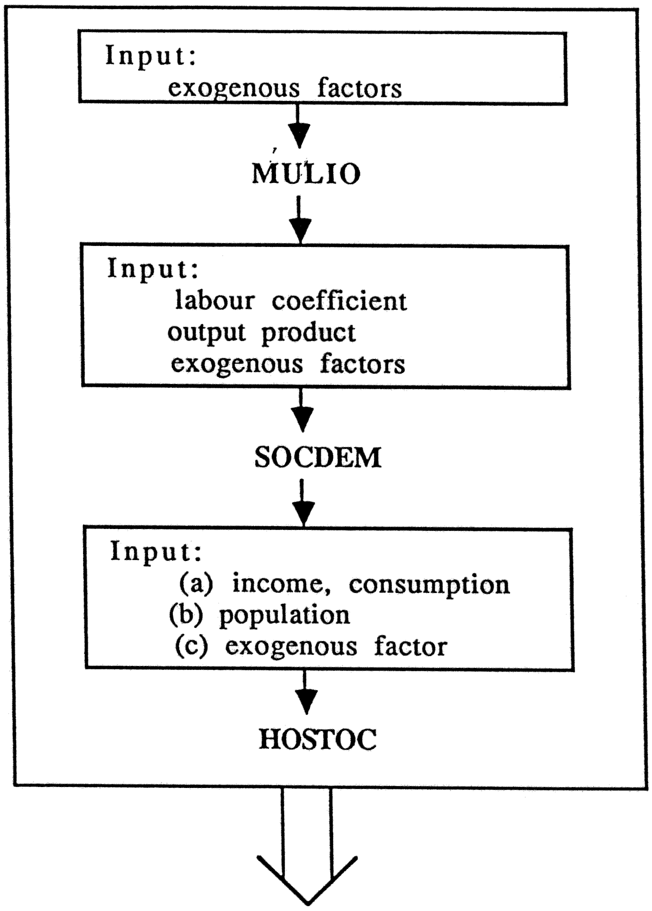
KEY:

Interactions between the SOCDEM and MULIO modules

Interaction between the MULIO and HOSTOC, and the SOCDEM and HOSTOC Modules

FIGURE 2. Interactions in the GIMIMoC Framework

I. Initial Stage



II. Dynamic simulaiton (JIN and Wilson 1991)

⋮

Figure 3: The solution procedure for the GIMIMoC framework

From the MULIO Module:

(1) Gross output and input product

(2) Public and private consumption

(3) Other final demand

(4) Personal income

(5) Trade flow to and from the rest of the region and the rest of the world.

From the SOCDEM Module:

(1) Populaiton by sector and social class

(2) Work force by social class

(3) Employment, unemployment by sector and social class

(4) Labour requirement by sector

(5) Dependents by social class

(6) Travel-to-work flow

From the HOSTOC Module:

(1) Housing demand flow

(2) The number of demanded houses by type

(3) The number of supply houses by type

(4) Balance situation

Figure 4: The output results from the operation of the initial GIMIMoC framework

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