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□ 論　文 □

도시토지이용과 교통에 관한 연속적 모형 : 지역경제성장과 도시공간구조와의 동태적 접근

A SEQUENTIAL LAND USE / TRANSPORTATION MODEL WITH EXTERNALITIES : LINKING THE DYNAMICS OF REGIONAL ECONOMIC GROWTH AND URBAN SPATIAL STRUCTURE

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목 차

ABSTRACT

1980년대 후기부터 교통정책의 우선 목표는 지역경제성장 자체가 교통문제를 스스로 해결할 수 있도록 하기 위하여 종래의 관리 중심의 정책은 다시 토지이용 정책으로 변화를 초래하였다. 오늘날 대도시는 개개 경제활동주체들의 동적인 경제 행태에 근거하여 분산구조를 띠고 있다. 이러한 동적인 경제행태에 미치는 요소들은 교통체계와 토지이용과의 상호연관성의 연구에 필수적인 지가, 인구분포, 통행행태등이다. 그러나 전통적인 단핵도시 모형은 대도시의 분산구조형태의 동적인 과정을 설명하는데는 한계가 있다. 본 연구는 대도시의 변천과정을 -도심 및 부심의 출현·소멸현상- 설명함으로써 도시교통정책에 필수적인 입지와 통행패턴에 대한 새로운 동태적 이론의 기초를 제공하는데 그 목적이 있다. 이를 위하여 지역경제

성장과 도시공간구조와의 동태적관계를 통합하는 토지이용과 교통의 연속 모형을 개발 · 응용하였다. 개발된 모형에서는 교통량에 따른 교통비용, 도시공간구조로 인한 외부효과들, 경제활동주체들의 비동질성, 이주비용, 그리고 집적이익등이 매기마다 내생적으로 결정되어 대도시의 공간구조 변화를 설명한다. 경제 활동주체들간의 상호물리적교류는 소득증대에 의하여 경제구조가 변함에따라 새로이 결정된다. 가상적 도시와 자료를 가지고 실험한 결과 비동질적인 경제주체들의 불균형적 성장이 장기적으로 도시구조에 영향을 미치며, 기본적인 경제행위에 따라 장기동태적인 과정을 통하여 나타나는 도시의 분산구조형태의 중요성을 보여주고 있다. 또한 교통비용의 변화에 따른 민감도분석을 통하여 모형의 실용성을 검정하였다.

1. INTRODUCTION

The dynamics of land use and transportation system interactions define the key aspects of transportation policies. This is also the most difficult aspect. Transportation policies intended to control traffic can only be properly evaluated in the context of activity patterns and land use. Contemporary metropolitan aeas are characterized by decentralized patterns of employment or population, i.e., by the presence of subcenters. Yet the emergence, growth, decline, and obsolescence of individual urban subcenters is part of a dynamic process resulting from simple economic behavior.

The purpose of this study is to formulate and apply an integrated model of the urban economic development process. The study is a theoretical approach to combined location—economic growth patterns. While the conventional monocentric model of urban economics has generated a number of useful insights (Muth, 1985), it is unable to explain the rise and fall of urban subcenters. The monocentric models built upon micro foundations are based upon on a number of unrealistic, simplifying assumptions about commuting and spatial structure. A more accurate nonmocentric model must show conditions under which policentrism might emerge, discussing where the centers may be located (Richardson, 1988). But, one of the least satisfactory features of regional analysis is the gulf between the studies of regional economic change and study of regional spatial structure. Recent regional economic analysis concerns empirical and theoretical developments in growth theory, econometric modeling, and input—output techniques; but are rarely concerned with spatial structure. Similarly, studies of spatial structure are generally undertaken in a static context seldom related to the process of regional economic change. We contend the sectoral composition of a region's economy exerts an important influence on the spatial structure of the region.

Interdependence (interactivity flows or traffic intensities) between activities is an important factor in the growth of regions. Interactions between agents makes the location decision of one agent dependent on the location decisions of other agents. Input—output relationships are important determinants of clustering both within and between activities. Interdependency is further influenced by standard structural transformations in the composition of demand, trade, production, and factor use in a developing economy.

Neoclassical approaches such as Fisher (1935) and Clark's (1957) development stages theory, Kuznets' (1957, 1966) modern economic growth theory, and Lewis's (1954) dual economy theory suggest that structural change is essentially a byproduct of economic growth. Based on these three underlying theories, Chenery (1960) develops general models of structural change that link changes in the composition of consumer demand to rising per capital income.

We contend that the process of metropolitan economic growth drives transformation in the spatial structure of the activity system. Our study depicts the dynamic of land use patterns, integrating Chenery's regional economic development processes into an activity location model. Structural transformations are revealed by nonproportional growth across sectors. Economic development production changes in input—ontput relationships that are translated into updated transshipment between activities.

Our research model is a simulation that account for interactions between

(1) a priori profitabilities,
(2) transport costs defined by a congesitive transportation network,
(3) externalities,
(4) relocation costs, and
(5) technological change.

These factors tractably explain the evolution of an urban economy, and effect of this evolution on urban structure.

This model can provide a theoretical framework to explain spatial processes and facts, that takes into account the complexity of the spatial and productive transformation process witin every context, and includes the functional and territorial ahcaracteristics of the economic process. The simulation results show how nonproportional growth of sectors influence the spatial patterns of economic activities over time, and demonstrate importance of decentralization as part of a dynamic process resulting from standard econimic behavior.

2. A SEQUENTIAL URBAN LAND USE / TRANSPORTATION MODEL

The sequential urban land use model developed here consists of two major components,

(1) a discrete programming model of the market for urban land and transportation, and
(2) an interactivity flow system that accounts for structual transformations resulting from economic development

Contemporary suburbs are interdependent, collectively comprising the metropolitan economy. This metropolitan economy is, in turn, part of a larger system of economics, engaging in trade with its hinterland, other metropolitan economics, and the rest of the world. At the same time, the metropolitan region is an economy with an evolving differentiation between suburds, each of which exhibits specifications in term of its activity characteristics.

Recognizing interdependencies is the principal means of integrating the regional economic development process into an activity location model. The model is initialized by an exogenous economic structure and spatial pattern. Given an initial spatial pattern, the characteristics of establishments change. These economic changes result in structural transformation and nonproportional growth across sectors. Given income elasticities for each sector and an existing set of input–output relationships, the structural transformation model endogenizes production levels and traffic intensities. Exogenous values in the discrete programming model describing seminet revenues, externalities, and relocation costs might also be influenced by production levels. Given these updates, the discrete programming model indentifies a new land use pattern. In the next time period, more economic structural changes are realized and the structural transformation model once again produces new traffic intensities.

2.1 The Market for Urban Land and Transportation

Urban spatial structure is the outcome of a process that allocates activities to sites. The process is principally one of transactions between owners of real estate and those who wish to rent or purchase space for their homes and businesses. These transactions are accomplished by the general rule of the market. We assume the urban area is divided into many discrete sites. These sites have different attributes. Each site belongs to an owner who is free to sell or lease his property. At the beginning of each transaction period, every establishment evaluates the merits of every site, and decides what price it would be willing to pay for access to each site.

The passage of time brings changes in the number and types of establishments bidding for access to locations. Existing establishments also change in terms of their characteristics. Households change in size, manufacturers acquire new production methods, and retailers shift product lines. Some sites change hands and some establishments move to new locations. As long as some establishments are moving, the pattern of accessibility and contiguity changes for other establishments. Even if site characteristics are fixed, these various changes accumulate over time to cause significant shifts in the matrix of site bids.

In most contemporary regional I–O tables, the structural coefficients represent interindustry trade flows. Recent developments in combining input–output and transportation planning models have made it possible to construct comprehensive urban and regional activity models. A metropolitan area industry activity model divides the local economy into identifiable sectors along two dimensions, product(or industry) and geography. Transactions representing interactivity linkages are indentified across industries and locations. A class of static formulations originated by Mills(1972, 1974a, 1974b, 1975 and extended by others (Hartwick and Hartwick, 1974, 1975; Kim, 1978a, 1978b, 1979, 1986; Moore and Wiggins, 1988, 1990; Moore and Seo, 1991; and Rho and Kim, 1989) has contributed much to the foundations of urban economic theory. The static perspective is that given a sufficient period of freedom from environmental shocks, any economic system will achieve an efficient configuration. Only a few dynamic models have appeared to account for the technical structure of land use change in the urban economics literature. But dynamic Mills heritage model can identify the optimal land use patterns resulting from exogenous, period－specific perturbations in an urban system's export levels.

Gordon and Moore II (1989) and Moore II and Gordon(1990) formulate a sequential programming model that simulates the spatial evolution of modern cities. Locators are assumed to make decisions from a ceteris paribus perspective (Moore II and Gordon 1990). By solving a series of linear assignment problems that track urban land use over time, their model presents a sequence of urban location decisions resulting from locator's efforts to maximize net revenues by mitigating congestion costs and other externalities (Moore II and Gordon 1990). Network congestion and other effects are endogenous in each period, but traffic intensities between all activities i and j are exogenous. In the current study, interactivity flow systems are conditioned on economic development patterns that include changes in the composition of demand, trade, production, and factor use as functions of per capita income.

2.2 The Discrete Programming Model

The arrival, departure, and ongoing bidding of activities constitute the principal mechanisms for spatial rearrangement. Unsuccessful bidders are consigned to a null site, or queue. Activities bid nothing for access to the queue, and there is no constraint on the number of activites that can locate there. To represent this process in a more complete way, Moore II and Gordon also introduce a nonbidding or null activity called "vacancy"that bids nothing for physical sites and can be assigned to any number of sites. When nonvacancy activities offer (sufficiently) positive bids for sites, existing vacancies are displaced.

Index activites from 1 to I and physical sites from 1 to M. Append an I+1st row accounting for vacancies, and an M+1st column corresponding to the null location, or queue.

The augmented matrix that results is A, an initial $[(I+1)\times(M+1)]$matrix of seminet revenues. At time 0, $A(0)=[a_{im}(0)]$is the profitability of plants i at m, ignoring externalities and transportation. That is, A(0) is the value to plant i of the attributes of site m independent of the locations of other plants.

The principal advantage of the solution procedure is that complex information about congestion and other externalities is assumed to flow from recent experience, allowing the sequential use of linear programs to emulate the decisions of locators. A flowchart describing this approach appears in Figure 1.

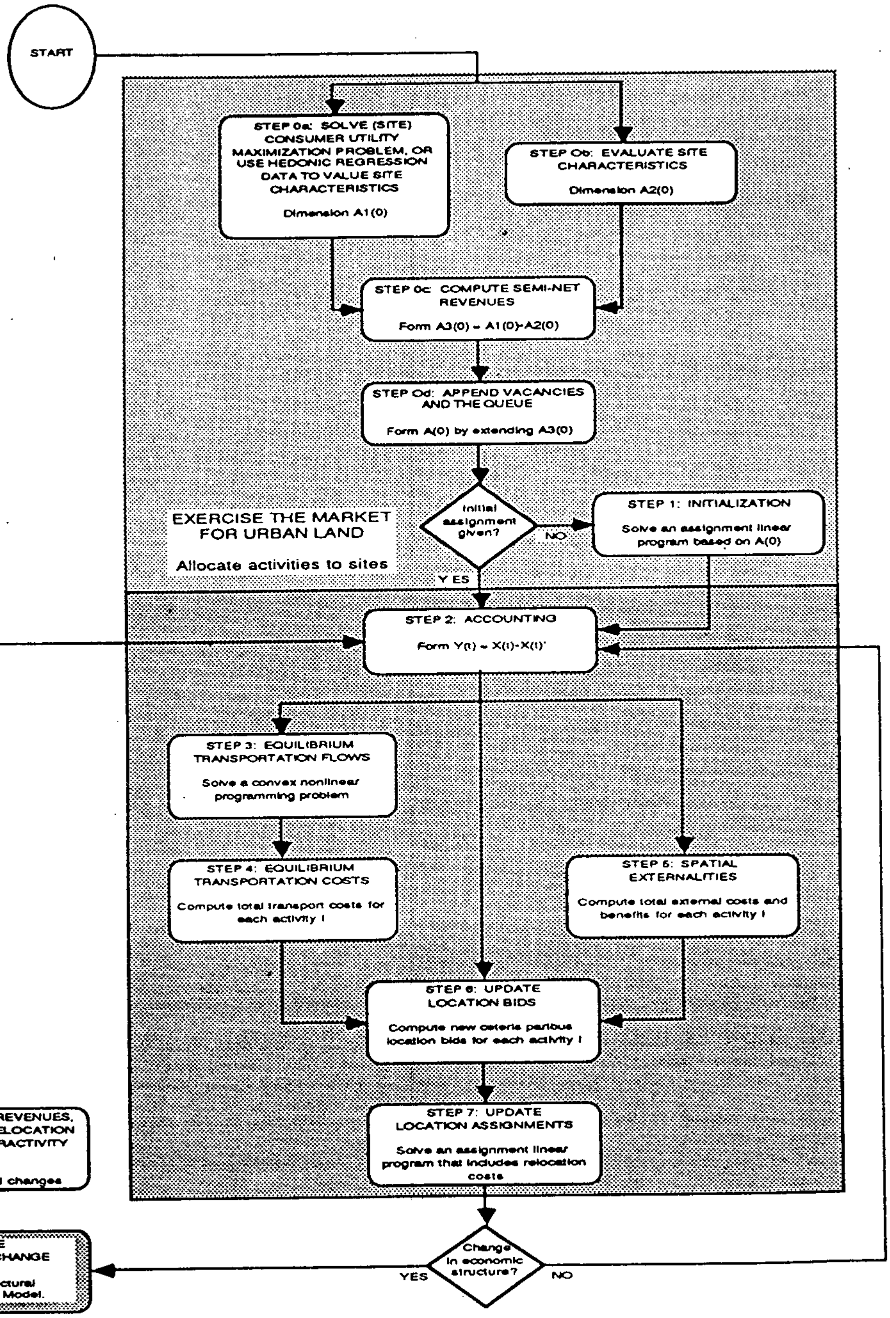


Figure 1 Algorithmic representation of the sequential urban land use model : An extended version of the Moore II and Gordon model(1990)

Step 3 and 4 are accounting for the endogeneity of travel costs and network assignment Given the matrix $Y(t) = [Y_{imjn}(t)]$ determined in Step 2; an exogenous matrix $F = [f_{ij}]$ consisting of traffic intensities between all activities i and j; an exogenous vector $c(f) = [c_k\{f_k(t)\}]$ consisting of flow-dependent congestion cost functions specific to each network link k; and the complete inventory of activity and vacant sites; the link-flow version of the user-equilibrium network assignment problem is solved and the user-equilibrium transportation costs ($C^*(t)=[c^*_{mn}(t)]$) associated with flows between activity i at site m and activity j at site n are determined.

$$Min \sum_k \int_0^{fk(t)} c_k(w)dw \tag{1}$$

$$S.t. \sum_{n=1}^{N} \sum_{m=1}^{M} \sum_{I=1}^{I+1} \sum_{j=1}^{J+1} Y_{imjn}(t) \cdot f_{kij}(t) = f_k(t) \tag{2}$$

$$\sum_{I=1}^{I+1} \sum_{j=1}^{J+1} Y_{imin}(t) \cdot f_{ij} = f_{mn}(t) \tag{3}$$

$$\sum_{autbound} \sum_{m=1}^{M} \sum_{I=1}^{I+1} \sum_{j=1}^{J+1} Y_{imjn}(t) \cdot f_{kij}(t) - \sum_{INbound} \sum_{m=1}^{M}$$

$$\sum_{I=1}^{I+1} \sum_{j=1}^{J+1} Y_{imjn}(t) \cdot f_{kij}(t) = f_{mn}(t) \tag{4}$$

$$f_{mn}(t) \geq 0 \tag{5}$$

where $f_{kij}(t)$ is the endogenous component of the flow between activities i and j that uses link k and $Y_{imjn}(t)=X_{im}(t) \cdot X_{jn}(t)$.

Step 5 is to determine the matrix of potential spatial externalities imposed by each activity j at (fixed) location n on each activity i at (variable) location m.

$$E(t)=[e_{ij}(\sum_{n=1}^{M} d_{mn} \cdot X_{jn}(t-1))] \tag{6}$$

Step 6 is key, updating each activity's location bid, Given $A(0) =[a_{im}(0)]$, the $[(I+1)\times(M+1)]$matrix of seminet revenues (identified in Step 0); $\chi(t)=[\chi_{jn}(t)]$, the $\{[(I+1)\cdot(M+1)\}\times 1\}$vector of optimal location from the previous time period (identified in Step 2); $F=[f_{ij}]$, an exogenous matrix of traffic intensities (interactivity folws) between all activities i and j (identified in Step 6 of Structural Transformation Model developed in the next chapter); $C^*(t)=[c^*_{mn}(t)]$, the (M x M) matrix of user equilibrium link costs (identified in Step 4); and $E^*(t) =[e^*_{imj}(t)]$, the$[I\times(I\ M)]$matrix of potential spatial externalities imposed by each activity j at (fixed) location n on each activity i at (variable) location m (identified in Step 5); the bid for each locator i prepares for each site m is updated based on each locator's seminet revenues and anticipated experiences at all locations. That is, compute the $[(I+1)\times(M+1)]$ matrix of location bids

$$A_{im}(t+1) = [a_{im}(0) \cdot v_i(t)/v_i(0)] - \sum_{j=1}^{I+1}$$

$$(\sum_{n=1}^{M} C^*_{mn}(t) \cdot f_{ij} X_{jn}(t)) + e^*_{imj}(t)] \tag{7}$$

where $v_i(t)$ is the value added by activity i in time period t as identified in the structural transformation model. Given fixed site characteristics, activities will still change their production levels as a result of changes in the cost of primary materials. Consequently, $a_{im}(0)$ is updated in each time period relative changes in the values added associated with each activity. The values $a_{im}(0) = 0$ if i is vacancy and/or m is the null site.

Step 7 is a market clearing operation. Given the matrix $A(t+1) = [a_{im}(t+1)]$, and an exogenous$[(I+1)\times 1]$ vector $R=[R_i]$ consisting of activity specific relocation costs; solve the following linear program.

$$Max \sum_{i}^{I+1} \sum_{m}^{M+1} [a_{im}(t+1)-R_i(1-X_{im}(t))] \cdot X_{im}(t+1), \tag{8}$$

$$S.T \sum_{i=1}^{I+1} X_{im}(t+1)=1, \tag{9}$$

$$\sum_{m=1}^{M+1} X_{im}(t+1)=1, \tag{10}$$

$$X_{im}(t+1)=1 \text{ or } 0, \tag{11}$$

where $\chi_{im}(t)$ is exogenous to time period t+1 (Moore II and Gordon, 1990).

Step 8 and 9 impose structural transformation associated with economic development on the location assigment model.

2.3 The Structural Transformation Model

2.3.1 Determinants of sectoral growth

The research model derives activity growth functions from a general equilibrium model that allows for changes in the composition of demand and in factor proportions. The general equilibrium models of Walras(1954), Leontief (1951), and Dorfman, Samuelson, and Solow (1958) customarily omit elements that would lead to persistent differences in growth rates. These elements include limited natural resources, changing factor supplies, nonhomogeneous consumption functions, economies of scale, and international trade. Accounting for imports, exports and intersectoral requirements defines four determinants of the level of production. These include three components of demand and one alternative source of supply. The accounting identity for this system is

$$X_p = D_p + W_p + E_p - M_p \tag{12}$$

where X_p is domestic production of commodity p, D_p is domestic final use of p, W_p is use of p by other producers, E_p is the export of p, and M_p is the import of p.

Intermediate demand W_p for a commodity p depends on output levels from the sectors using p, on the substitutability of other inputs for p, and on the variation in the relative prices of inputs. Based on previous work involving international comparisons (Houthakker 1957; Chenery and Watanabe 1958; Taylor 1969; Chenery and Syrquin 1980 and 1968), price effects are suppressed on the assumption that per capita income incorporates the effects of all these explanatory variables. Thus the function for intermediate use of commodity p is

$$W_p = \sum_k \alpha_{pk} \cdot X_k = \sum_k \alpha_{pk} \cdot (Q_k+M_k) \tag{13}$$

where the α_{pk} are input–output coefficients, X_k is the total output of commodity k, and Q_k is the sum to total intermediate purchases and value added in the production of commodity k.

Defining $\mu_p = \mu_p(Y)$ to be the proportion of total demand met by imported supply.

Structural change is often defined by sectoral shifts. which may include changes in any component of demand or value added by production. Alternatively, changes in structure can also be measured as sector specific deviations from proportional growth across sectors. Under assumption of proportional growth, equation (12) can be expressed for time t

$$\hat{X}_p(t)=\hat{X}_p[Y(t)]$$

$$=\lambda(t)\cdot X_p[Y(0)] \qquad (14)$$

where $\hat{X}_p(t)$ indicates total production of commodity p proportional to per capita income at time t(Y(t)), and

$$\lambda(t)=Y(t)/Y(0) \qquad (15)$$

is the proportionate increase in income between periods time 0 and time t.

In general, these proportional benchmarks will not be realized. Deviations from proportional growth can be expressed as follows

$$\triangle X_p(t)=X_p(t)-\hat{X}_p(t)=\triangle W_p \quad +\triangle D_p-\triangle M_p +\triangle E_p \qquad (16)$$

Thus, deviation from proportional growth in each sector can be traced back to deviations from proportional growth in intermediate demand, final demand, imports, and exports. Equation (16) implies several alternative decompositions of structural change that depend on import substitution, and the nature of changes in interactivity structure.

2.3.2 Specifying trajectories for the determinants of sector growth

The explanatory variables for the determinants of sector growth depend on the degree of openness of the economy, its trade pattern, and its rate of growth. The United Nations (1963) tested eight proxy variables for these factors in estimating growth patterns for individual industrial sectors. This and other studies of economic development patterns has led to the identification and measurement of a number of structural changes associated with rising income. As a result , income level has been used as an overall index of development as well as a measure of output. We employ income per capita as an explanatory variable on the assumption that per capita income incorporates effects of all other explanatory variables.

To investigate structural changes implied by sectoral deviations from proportional growth, we need to measure the income elasticities of domestic production X, domestic final demand D, exports E, and imports M for each sector p. Regression analysis provides a convenient vehicle. Regression has been widely used to compare and explain the uniform patterns of industrial growth measured by Chenery (1960), Kuznets (1966), Chenery and Taylor (1968), and Chenery and Syrquin (1975, 1980).

At the national level, economic development takes place in an enviroment in which trading opportunities and technology are constantly changing. The growth functions derived from cross sectional analysis describe the adaptation of countries at different levels of income to conditions of technology and trade existing at one point in time. Ideally these states indicate the path that a typical country would follow if its income increase so rapidly that conditions of trade and technology were relatively constant (Kuznets 1957, Chenery 1960).

Estimated income elasticities depend on the type of function fitted. The double logarithmic function is preferred for most international comparisons (Houthakker 1957; Chenery and Watanabe 1958; Taylor 1969;

and Chenery and Syrquin 1980 and 1986). Chenery (1960) and United Nations (1963) show that the logarithmic form fits the available data much better than a linear function for most sectors. Houthakker's (1957) findings support this assumption in the case of household consumption. We use linear logarithmic regression equations in which the value of each determinant of sector growth depends on per capita income. For example, the function for final domestic use per capita is,

$$\log(D_p) = \log(\beta_{p0}) + \beta_{p1} \cdot \log(Y) \qquad (17)$$

where β_{p0} is the initial state of final use of commodity p limited by data series, β_{p1} is an income elasticity for the consumption of commodity p, and Y is per capita income.

Consider the hypothetical regional economy summarized in Table 1. Based on updated estimates of domestic production X[Y(t)], domestic final demand D[Y(t)], exports E[Y(t)], and imports M[Y(t)] for each sector P; we will apply equations (12) and (13) to compute intermediate use W(t). The various phenomena associated with economic development can lead to technological changes within any and all sectors, and there are several ways these changes might be represented in the matrix of technical coefficients.

		Processing								Purchasing			
	Outputs / Inputs	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Households	Total Intermediate Use W_p	W_p /Total Output	Final Demand D_p	Exports E_p	Total Output X_p
Processing	Sector 1	1,000	1,500	100	200	500	600	1,400	5,300	0.838	600	500	6,400
	Sector 2	500	400	700	100	300	800	1,700	4,500	0.763	800	600	5,900
	Sector 3	700	200	800	100	500	300	500	3,100	0.775	600	300	4,000
	Sector 4	1,100	100	200	800	600	400	400	3,600	0.923	300	0	3,900
	Sector 5	400	0	100	1,400	300	200	900	3,300	0.825	500	200	4,000
	Sector 6	200	600	700	600	200	600	800	3,700	0.804	500	400	4,600
Payments	Households	1,600	1,800	700	500	700	900	100	6,300	0.875	900	0	7,200
	L_k Total Intermediate Purchases	5,500	4,600	3,300	3,700	3,100	3,800	5,800	29,800	▨	4,200	2,000	36,000
	L_k /Total Outlays	0.859	0.780	0.825	0.949	0.775	0.826	0.806	▨	0.828			▨
	v_k Value Added	700	1,200	400	200	600	600	1,200	4,900				▨
	v_k /Total Outlays	0.109	0.203	0.100	0.051	0.150	0.1340	0.167	0.136				▨
	Q_k $L_k + v_k$	6,200	5,800	3,700	200	3,700	4,400	7,000	34,700				▨
	M_k Imports	200	100	300	0	300	200	200	1,300				▨
	X_k Total Outlays	6,400	5,900	4,000	3,900	4,000	4,600	7,200	36,000	▨	▨	▨	36,000

Table 1 : A Hypothetical Regional Economic System

Viewed from this perspective, the fundamental problem is generic. Given new distributions for the row and column marginals of a matrix, the objective is to make best use of the information content in the new marginals. we rely on the biproportional adjustment method (Hewings 1977, 1982) used to updata input—output, migration, and trip interchange tables. Biproportional adjustment minimizes the I—divergence, i.e., the information gain, of the posterior array relative to the a priori array. Other approaches to the same problem include linear and quadratic programming, and variational inequalities (Nagurnry 1993). These approaches differ in terms of how distances between the a priori and posterior matrices are defined, and in terms of the algorithms used to address the constrained optimization problems that result.

Our use of biproportional adjustment does not provide an endorsement of one penalty function versus another. We do not presume to know if technological changes imply the creation of new technologies, or substitutions between existing technologies. Further, we do not know which adjustment procedure maps best to this mixed process of innovation and choice. We elect biproportional adjustment because the theoretical and computation aspects of the procedure are well understood, because the positivity of the initial array ensures the positivity of the unique solution to the problem, and because it operates directly on technical coefficients rather than on flows.

2.3.3. Disaggregating sectors into activities

Ideally, Leontief sectors are aggregations of activities producing a single product by similar techniques. Given the variety of products by typical plants, realizing a close approximation of this concept is impossible. In empirical interindustry studies, a productive sector corresponds to a grouping of processes and products that may differ in some respects. Still, an aggregate sector of porduction activities may be satisfactroy for a Leontief model even if the activites involved do not have uniform inputs of primary factors.

Table 1 describes flows between sectors, yet the discrete programming model identifies locators at the level of activities. Consequently, sector flows updated by the structural transformation model will have to be disaggregated into activity flows before the land use model can be applid. The rules used to disaggregate a sector into constituent activities can be traced back to the rules for consolidating the sectors of a detailed input-output table. The rules of consolidation involve simple summation of flows in a particular base period. LetX_{ij} denote the flow from activity i to j;let D_i denote the final demand for activity and let X_i denote the total output of activity i.

$$X_i = \sum_{j=1->j} X_{ij} + D_i \tag{18}$$

Generalizing to any period, let the input coefficient α_{ij} denote the quantity of input from activity i that is needed to produce one unit of output j.

$$\alpha_{ij} = X_{ij}/X_j \tag{19}$$

The flows between sector p and k consist of flows between several constituent activities i in sector p and j in sector k. At the sectoral level,

$$\alpha_{pk} = X_{pk}/X_k \tag{20}$$

Interactivity flows can be estimated from intersectoral flows by reversing the procedures implied by standard consolidation rules. If the activities defining a given sector have similar input-output characteristics, intersectoral flows can be disaggregated into an interactivity flows even if the activities vary with respect to the use of primary inputs. In terms of the abbreviated notation associated with Table 1, compute

$$f_{ij}=f_{pk}\cdot(X_{i\ \mathrm{in}\ p}/X_p)\cdot(Q_{j\ \mathrm{in}\ k}/Q_k) \tag{21}$$

where

$$X_p=\Sigma_{\mathrm{all\ activities\ } i \mathrm{\ in\ sector\ } p}\, X_i, \text{ and} \tag{22}$$

$$Q_k=\Sigma_{\mathrm{all\ activities\ } j \mathrm{\ in\ sector\ } k}\, Q_j, \tag{23}$$

More generally,

$$f_{ij}[Y(t)] = f_{pk}Y[(t)]\cdot\{X_{i\ \mathrm{in}\ p}[Y(0)]/X_p[Y(0)]\cdot Q_{i\ \mathrm{in}\ k}[Y(0)]/Q_k[Y(0)]\}, \tag{24}$$

where Y(0) denote per capita income in the base year.

2.3.4. Production technologies

Because urban land use configurations are characterized by capitial intensive land uses, input substitutions between land and capital are of special importance in an urban context. In this exercise, activities are classified based on the intensiveness of the land input. High, medium, and low land intensive activities correspond to low, medium, and high density land uses respectively.

2.3.5 Algorithmic specification of the structural transformation model

Step 0: Estimation of Income Elasticities for Determinants of Intermediate Purchases

$$\log D_p = \log D_p(t-n) + \beta_{pl}\log Y. \tag{25}$$

$$\log X_p = \log X_p(t-n) + \varphi_{pl}\log Y. \tag{26}$$

$$\log E_p = \log E_p(t-n) + \eta_{pl}\log Y. \tag{27}$$

$$\log N_p = \log N_p(t-n) + \gamma_{pl}\log Y. \tag{28}$$

Step 1: Identify base Period Transaction Table for All Sectors and Activities

Step 2: Define Income Growth Rates and Value Added Ratios for Period t

Given the per capita income levels Y(t) for each time period t and initial state Y(0), define an exogenous income growth rate $\lambda(t)=Y(t)/Y(0)$. In this exercise, we assume a 10 percent increase in per capita income per period. Define an exogenous value added vector $v_k(t)=v_k[Y(t)]$ for each sector k, and value added ratios $\omega_k(t)=v_k(t)/v_k(0)$.

Step 3: Calculate Intemediate Uses for Period t

$$W_p(t) = X_p(t) + M_p(t) - D_p(t) - E_p(t) \tag{29}$$

Step 4: Calculate Intermediate Purchases for Period t

$$L_k(t) = X_k(t)\,[1-\omega_k(t) - \mu_k(t)] \tag{30}$$

Step 5: Determine Technical Coefficients and Intersectoral Flows for Period t

$$f_{pk}(t) = X_k(t) * A_{pk}(t) \tag{31}$$

Given $A_{pk}(0)$,$W_p(t)$,$W_k(t)$, $A_{pk}(t)$ is updated via biproportional adjustment.

Step 6: Disaggregate Intersectoral Flows into Interactivity Flows for Period t

$$f_{ij}(t) = f_{pk}(t)\,[X_{p,i}(0)\,/\,X_p(0)]\cdot[X_{k,j}(0)/X_k(0)] \tag{32}$$

where $X_p(0) = \sum_i X_i(0)$ and

$$X_k(0) = \sum_j X_j(0).$$

In each time period, interactivity flows are derived from income levels. A flowchart describing this approach appears in Figure 2. Table 2 summarizes the inputs and outputs of the structural transformation algorithm in terms of the numerical information in Table 1.

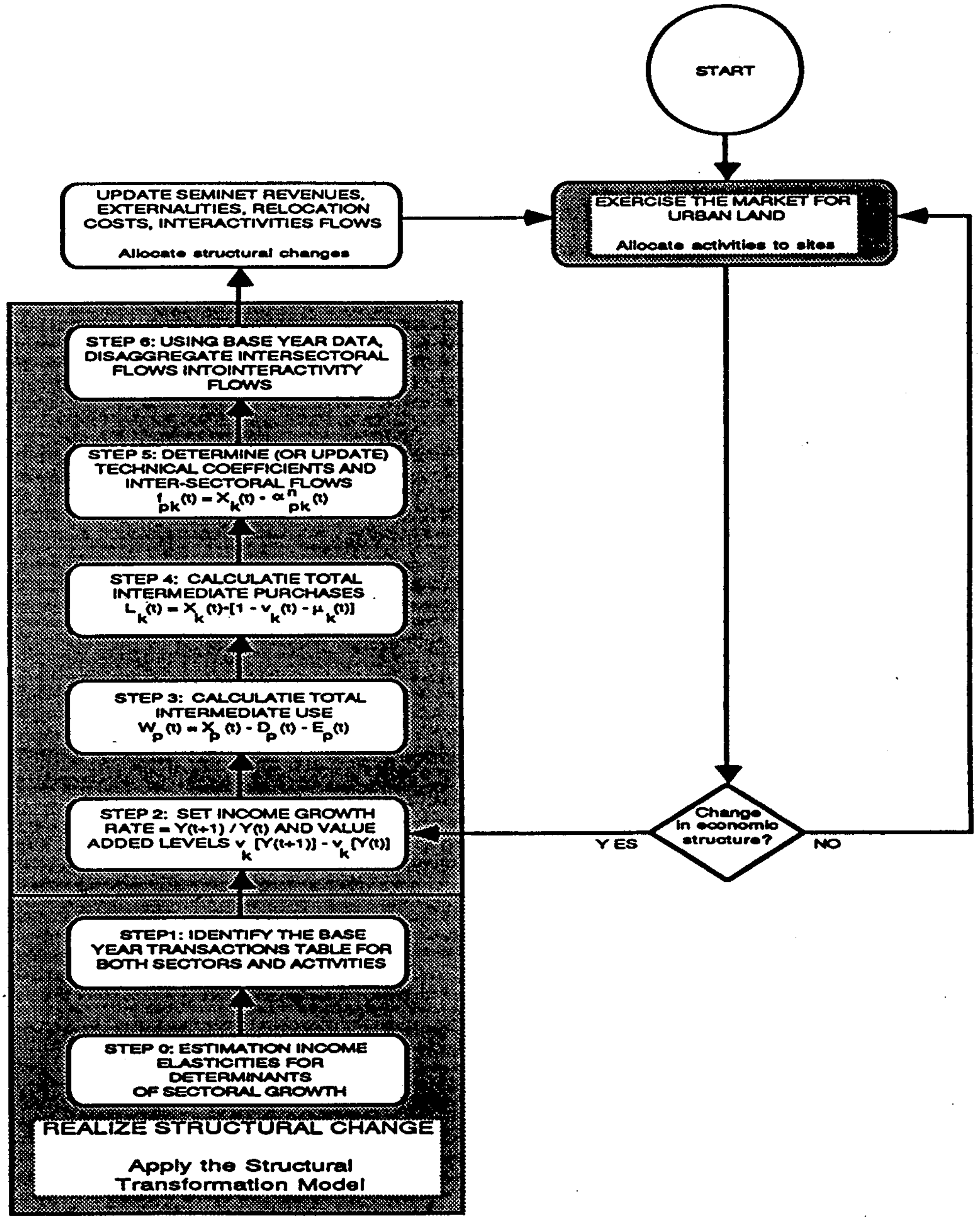
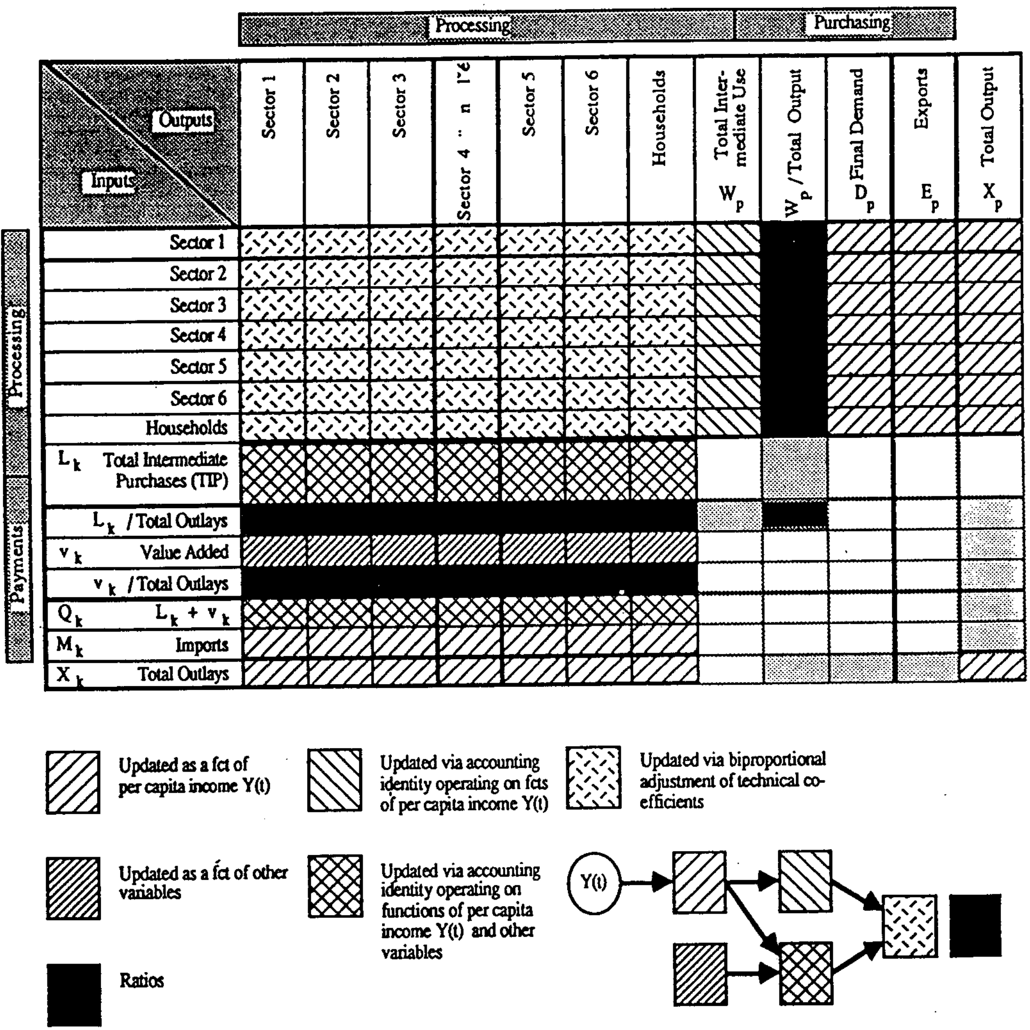


Figure 2 : Algorithmic representation of structural transformation model.

Table 2 : Exericising the Structural Transformation Algorithm on the Entries in Table 1.



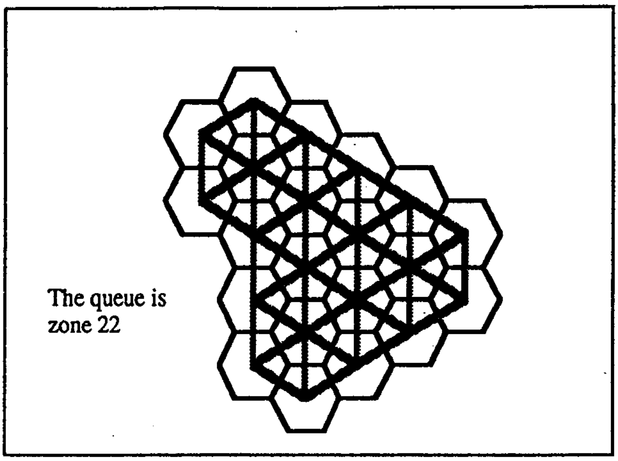
3. NUMERICAL APPLICATIONS

The simulation demonstrates the integrated model by investigating locational changes under conditions of economic growth. The results provide insight into the changes in the regional geography of advancing economies. Moreover, if this evolutionary approach can depict reality reasonably well, then this research may also help us to develop and test some useful empirical hypotheses.

3.1 Spatial Representation of a Hypothetial Metropolitan Region and a Hypothetical Regional Economic System

The hypothetical area is a metropolis based region consisting of an urban area and a periphery. The focus of the study is an urban area consisting of 21 hexagonal land use zones (Moore II and Wiggins 1988). The periphery is defined to be a dimensionless null site. Each physical site is initially occupied by and activity. The urban transportation system consists of aggregate links between zones. The network consists of congestive links connecting to nearest neighbors. The system is summarized in Figure 3. For user–equilibrium transportation costs, congestion functions are assumed to

A Transportation Network Connecting 21 Zones



Link Congestion Function
(BPR 4th Degree Polynomial)

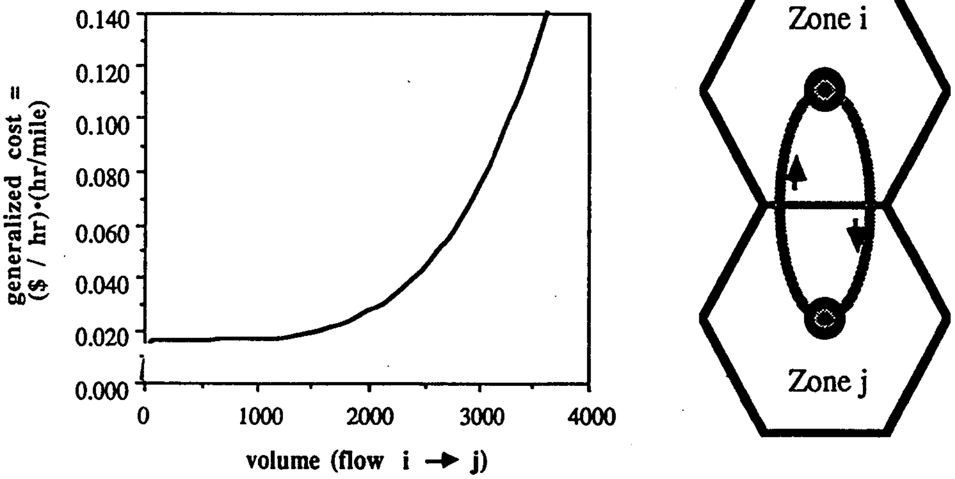


Figure 3 : A 21 Zone System and Associated Transportation Network

conform to the Bureau of Public Roads (BPR) fourth degree polynomial. In this function, we empolyed nonsymmetric matrix of generalized free–flow transportation costs given exogenously.

If a located activity is outbid by vacancy and retires to the queue, interactivity shipments involving this activity are assumed to be imported through the null site. Otherwise, the absence of a key production activity would present an infeasibility (Moore II and Gordon 1990). The null site is assumed to be a periphery through which import enter and exit the region.

The hypothetical regional economic system is previously explained in Table 1. Regional economy consist of six sectors and each sector has three activities based on their capital intensities.

3.2 Data Synthesis

Parameter values describing the economic growth patterns bearing on this research are drawn from the work of Chenery (1960 and 1980), Kuznets (1966), Chenery and Taylor (1968), Chenery and Syrquin (1975 and 1980). These studies provide income elasticities explaining uniform patterns of economic growth.

Exercising the assignment component of the model requires matrices describing seminet revenues, transportation link costs and capacities, external effects, relocation costs, and intersite distances. Precursor exercises rely on synthetic data, and the literature provides little empirical information relevant to the assignment component of this research. A more realistic description of an existing urban configuration is preferred. However, we rely on synthetic data for two reasons. While an empirical exercise would permit us to forecast the trajectory of a real metropolis, it would not further elaborate the function of the model. Also, we want this work to remain as comparable as possible to precursor efforts. Our synthetic data set is available upon request.

3.3. Results

3.3.1 Growth patterns

Development is often characterized by decline in the relative size of the manufacturing sector, almost always accompanied by a rising share of the service sector. Clark (1957) and Fisher (1939) argue that developing economies can be expected to move away from primary production activities toward service production. Because high income elasticities are associated with many service activities, it is argued that this sector only becomes large after the basic necessities are provided by the primary sector, and most demands for manufacturing goods are satisfied.

Such patterns imply nonproportional growth across sectors relative to increases in per capita income. The simulated ration of production growth rate to income growth rate is summarized in Table 3. The production growth rate of sector p is $\triangle X_p(t) = [X_p(t) - X_p(t-1)]/X_p(t-1)$. The income growth rate is $\triangle Y(t) = [Y(t) - Y(t-1)]/Y(t-1) =$

10 percent. The simulation produces significant differences across sectors in terms of deviations from proportional growth. Sector 2, a final primary production activity such as service, is the fastest growting sector. Sector 5, a primary production activity such as agriculture, is the slowest growing sector. Other sectors, such as manufacturing, fall in between these two extremes.

Table 3 : The Ratio of Production Growth Rate to Income Growth Rate :

SECTOR	TIME PERIOD t = 1	t = 2	t = 3	t = 4	t = 5	t = 6	t = 7
sector 1	1.508	1.542	1.574	1.605	1.636	1.665	1.695
sector 2	2.128	2.227	2.324	2.421	2.516	2.610	2.703
sector 3	1.863	1.939	2.016	2.094	2.172	2.251	2.331
sector 4	1.921	1.889	1.957	0.024	2.092	2.159	2.226
sector 5	0.716	0.704	0.693	0.682	0.672	0.662	0.652
sector 6	1.386	1.413	1.440	1.467	1.494	1.520	1.547
Households	1.069	1.073	1.076	1.079	1.081	1.084	1.087

Another phenomenon is the substitution of manufactured goods for primary inputs. The combination of rising purchases by other sectors, together with substitution of manufactured for primary commoditioes, produces rapid growth in the intermediate demand goods. The corresponding increase in manufacturing output above that implied by proportional growth accounts for the greater part of structural change associated with development. In the simulation, the average shares of intermediate use in total domestic demand increase from 0.828 to 0. 846. These increasing average shares of intermediate use imply an increasingly complex economic system. In addition, technological changes are implied by nonproportional growth in domestic demand, final demand, imports, and exports. These technological changes are summarized in Table 4.

A key development phenomenon is increasing use of intermediate industrial products. Lack of interdependence and linkage is perhaps the most typical characteristic of undeveloped economies. Increased use of intermediate inputs is characterizes an increasingly complex economic system. As economies develop, their productive structures become more roundabout in the sense that a higher proportion of output is sold to other producers than to final users. As with final demand, this phenomenon means a shift in output mix toward manufacturing and other sectors that use more intermediate inputs.

Table 4: Changes in Technical Coefficients.

		PURCHASING SECTOR						
TIME PERIOD	PRODUCING SECTOR	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Household
t = 0	sector 1	0.156	0.254	0.025	0.051	0.125	0.130	0.194
	sector 2	0.078	0.068	0.175	0.026	0.075	0.174	0.236
	sector 3	0.109	0.034	0.200	0.026	0.125	0.065	0.069
	sector 4	0.172	0.017	0.050	0.205	0.150	0.087	0.056
	sector 5	0.063	0.000	0.025	0.359	0.075	0.043	0.125
	sector 6	0.031	0.102	0.175	0.154	0.050	0.130	0.111
	Households	0.250	0.305	0.175	0.128	0.175	0.196	0.014
t = 1	sector 1	0.160	0.261	0.025	0.054	0.127	0.133	0.195
	sector 2	0.085	0.074	0.189	0.029	0.081	0.189	0.253
	sector 3	0.115	0.036	0.208	0.028	0.130	0.068	0.072
	sector 4	0.178	0.018	0.051	0.220	0.154	0.090	0.057
	sector 5	0.056	0.000	0.022	0.336	0.067	0.090	0.111
	sector 6	0.031	0.102	0.173	0.158	0.049	0.129	0.109
	Household	0.237	0.291	0.165	0.126	0.165	0.185	0.013
t = 4	sector 1	0.165	0.275	0.026	0.062	0.129	0.137	0.194
	sector 2	0.104	0.092	0.226	0.039	0.097	0.229	0.296
	sector 3	0.129	0.041	0.229	0.034	0.144	0.076	0.078
	sector 4	0.192	0.019	0.054	0.260	0.163	0.096	0.059
	sector 5	0.042	0.000	0.016	0.273	0.049	0.029	0.079
	sector 6	0.030	0.100	0.164	0.169	0.047	0.125	0.101
	Housedhold	0.205	0.255	0.139	0.120	0.140	0.159	0.011
t = 7	sector 1	0.167	0.281	0.025	0.068	0.129	0.137	0.191
	sector 2	0.119	0.107	0.254	0.048	0.110	0.261	0.330
	sector 3	0.142	0.045	0.247	0.041	0.156	0.083	0.083
	sector 4	0.201	0.021	0.056	0.296	0.169	0.100	0.060
	sector 5	0.031	0.000	0.012	0.216	0.035	0.021	0.056
	sector 6	0.029	0.098	0.155	0.177	0.045	0.120	0.095
	Household	0.181	0.228	0.120	0.114	0.122	0.139	0.009

3.3.2 spatial patterns

The simulation is initialized by an exogenous match between sites and activities. The subsequent sequence of patterns is summarized in Figure 4. Initially, six low density activities are outbid by vacancy.

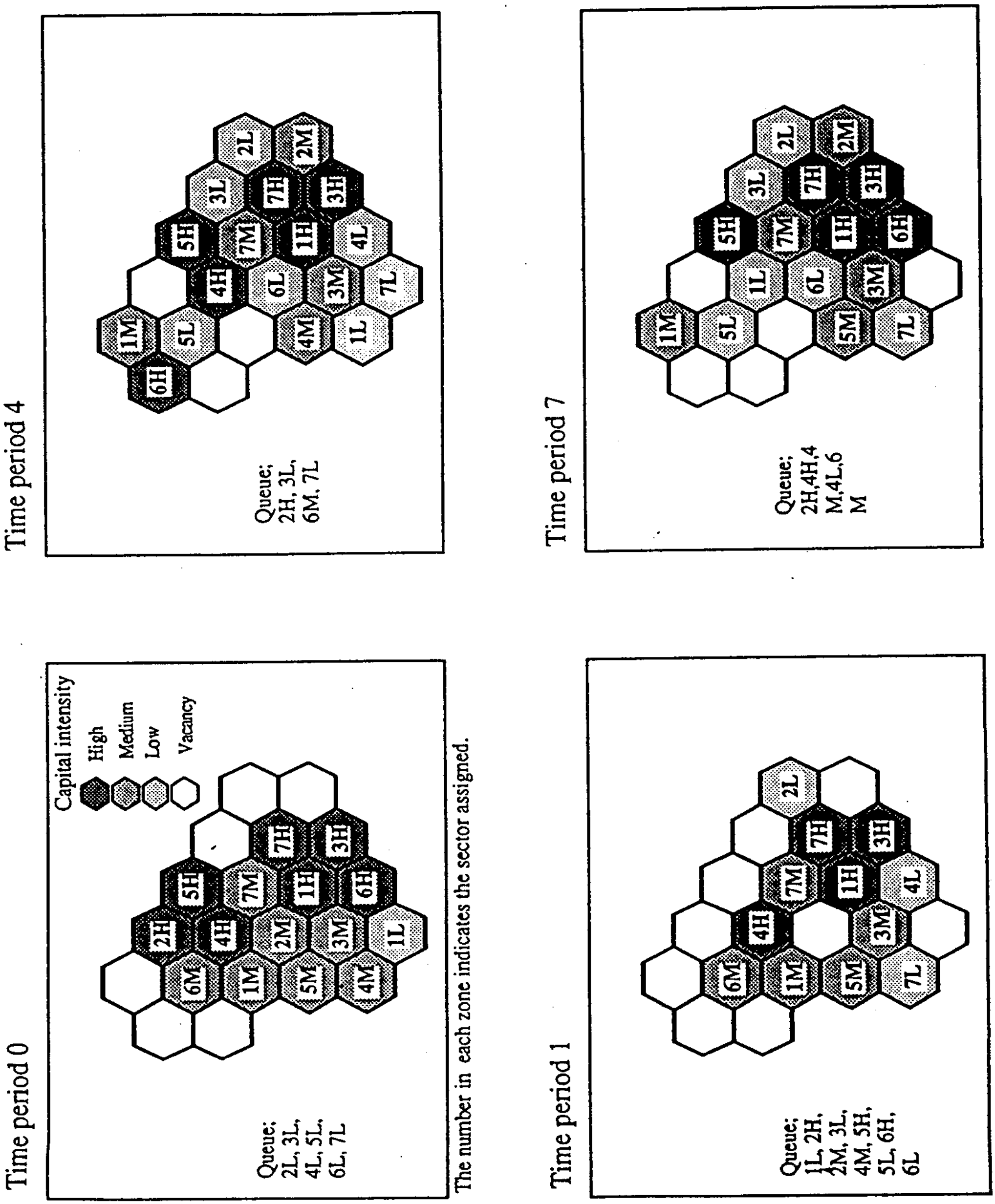


Figure 4 : Simulation Results for Periods 0, 1, 4, and 7.

In each period, seminet revenues, externalities, and activity specific relocation costs are modified in light of value added levels. Locators update their bids in response to the environmental externalities and congestion costs experiences in their current locations. Based on these updated bids, the assignment linear program generates new location patterns. Activities are displaced to the queue when they cannot generate a positive bid that is highest for any site. Not all locators relocate simultaneously. Some activities do not change their locations, where some relocate and persist for only a few time periods. Some activities exchange their locations. Vacancies are created frequently. After period 7, the simulation results stabilize. Relocations are still possible, but occur much less frequently. This result presumes no special site improvements or new investments in infrastructure.

3.4 Sensitivity Analysis: Transportation Costs

The research model provides an integrated treatment of regional economic change and spatial structure. Seminet revenues, externalities, and relocation costs are defined by production/location decisions. Input−output relationships change as a result of economic development processes, and these changes are translated into transshipments between activities. Transportation costs, including congestion externalities, play an important role relative to other system elements. If the unit transportation costs are too high, then changes in economic structure will dominate the activities' location decisions because each activity's total transportation costs ae rendered very sensitive to the changes in traffic intensities. Thus, it is important to determine whether unit transportation costs dominate other location factors.

We investigate four new scenarios in which free flow link costs are increased by 5, 10, 20, and 30 percent, respectively. The 5 and 10 percent increases in link costs induce no changes in the trajectory of location patterns. A 20 percent increase induces a few changes, the most conspicuous of which is a decrease in the number of vacancies. A 30 percent increase in link costs produces significant differences in locational patterns, and a more rapid convergence to stabillty.

3.5 Conclusions

In contemporary metropolitan areas, decentralization of activities is a dynamic process resulting from the interplay of simple economic behaviors. The model explained here demonstrates the locational behavior of activities in a system subject to economic growth. Changes in the spatial structure appear to be related to the locational characteristics of the economic activity; the characteristics of the economic environment; external economies and diseconomies, including the congestability of the transportation system; and relocation costs.

The collective results of these simulations and sensitivity tests demonstrate the utility of decentralization as a coping mechanism. Economic activities progressively relocate to decentralized locations to maintain access to each other. Gordon, Kumar, and Richardson (1988) contend that the relocation of activities within cities is guided by the desire to avoid congestion. Location of activities, intensity of land uses, means of production, origins, and destinations are all affected by the provision and pricing of transportation facilities, but an increase in transportation costs does not necessarily translate into centralization. Indeed, the simulation suggests that decentralization offers more advantage.

4. POLICY IMPLICATIONS

The evolution of a policentric spatial structure, either planned or spontaneous, is a reasonable response to the externalities associated with monocentricity (Gordon and Richardson 1993a). The subcenter location of jobs and populations alleviates the external diseconomies of urban scale without sacrificing the benefits of area wide agglomeration economies. However, government intervention often shows these spatial and political shifts toward policentric patterns. Instead of pursuing ambitious decentralization strategies, metropolitan planners tend to respond to local increases in urban growth, pollution, and traffic congestion. Consequently, resources are invested in infrastructure that exceeds prospective demand. Planners should promote the more efficient policentric structures critical to successful metropolitan growth, and avoid expensive interventions that might inhibit spatial restructuring (Gordon and Richardson 1993a).

The key issues are how, when, and, where to intervene. Gordon and Richardson suggest an appropriate scope for planning and regulatory approaches. The first step is to identify when public intervention is justified. The second step is to evaluate the conditions under which market based strategies are less practical than regulation. In most circumstances, planners should draw policy guidance from market approaches. Market based measures use economic principles to alter consumption or production decisions. These include the institution of market exchange mechanisms, or the establishment of prices that reflect true costs. For example, congestion pricing is a pricing system that corrects the market failure inherent in the passenger transport system. Tradeable emissions rights perform similarly in the case of production. Firms that must pay a market price for the right to pollute will not pollute unless the revenues availavle from production exceed the social cost of emissions.

Because of (perceived) uncertainty concerning the benefits associated with market based approaches, public authorities favor regulation. This reflects a lack of information. As information brokers, planners have a role in forecasting future phenomena. Multiperiod forecasts describing the benefits and optimal budgets of pricing strategies and investments are particularly important. Integrated models of the sort proposed here organize, process, and improve information concerning the anticipated impacts of policies and public investment decisions. By keeping the economic role of extenalities explicit, regulatory strategies can be compared to other approaches aimed at internalizing externalities.

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