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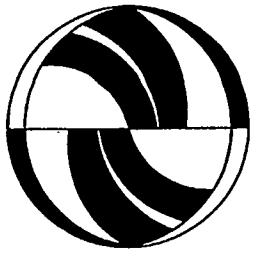

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Genevieve Giuliano

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New Directions for Understanding Transportation and Land Use

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Research policy and review 27. New directions for understanding transportation and land use

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Abstract. Theories of relationships between land use and transportation, and the empirical research conducted to test these relationships are reviewed. Recent empirical research seldom supports theoretical expectations. These results are explained by the changes in urban structure that have occurred over the past three decades. The paper concludes with some suggestions for revising the theories to represent conditions in contemporary urban areas better.

1 Introduction

The relationship between transportation and land use has been an enduring subject of both theoretical and empirical study (Fujita, 1984; Lerman et al, 1978; Meyer and Gomez-Ibanez, 1981; Meyer and Miller, 1984; Putman, 1975). Land-use-transportation relationships are not only key factors to understanding the nature and evolution of urban form, but also have important policy implications. Transportation investments are among the largest of public investments, and thus their anticipated impacts play a critical role in the public cost-benefit calculus.

Despite the rich and varied literature on this issue, the theoretical basis of land-use-transportation relationships has been subject to a variety of criticisms, and recent empirical research seldom supports theoretical expectations. In this paper I argue that these results suggest a reevaluation of existing theory and of the role of transport costs in location choice. In part 2 of the paper I present a brief overview of existing theory and outline its major weaknesses. Part 3 is a review of empirical research that illustrates these changing conditions, and part 4 provides some explanations for these findings. The paper concludes with some suggestions for rethinking the relationship between land use and transportation.

2 Overview of existing theory

Land-use-transportation relationships have been examined in the context of different paradigms. Two major streams may be distinguished: economic-behavioral and mathematical programming or network equilibrium. Economic-behavioral approaches are based on economic principles of utility and profit maximization (for example, Alonso, 1964; Mills, 1972; Muth, 1969). Land is allocated to different uses on the basis of factor prices, including transport costs. Accessibility is implicit in the theory; the value of location relative to opportunities is reflected in land prices. Mathematical programming models optimize flows for a given allocation of activities (for example, Boyce, 1980; Harris and Wilson, 1978), or allocate activities for a given fixed set of transport costs (for example, Herbert and Stevens, 1960), or for given transport characteristics (for example, Kim, 1983; Los, 1979). The economic-behavioral and mathematical programming approaches both predict a unique solution in which total costs are minimized. Since the programming models have only recently

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been empirically tested (Boyce, 1986; Boyce et al, 1987), the emphasis of this discussion is on the behavioral models.

2.1 *Residential location*

Residential location theory expresses household location choice as utility-maximization problem in which choice depends on land rent, transport costs, and the cost of all other goods. The basic model (for example, Muth, 1969) employs important simplifying assumptions: (1) the total amount of employment is fixed and located at the center of the city, (2) each household has one worker and only work-trip travel is considered, (3) housing is homogeneous (that is, location is the distinguishing factor), and (4) unit transportation cost is constant and uniform in all directions. The utility-maximizing location for a given household is the point at which the marginal savings of housing cost is equal to the marginal cost of transportation. Location theory gives rise to the familiar declining land-rent and density gradients as the value of access to the center is capitalized in land rent. The theory predicts decentralization in response to a reduction in transportation cost, as households consume more housing at greater distances. Land values reflect these shifts; the land-rent gradient flattens as the relative price of land closer to the center declines.

Most criticisms of residential location theory deal with the simplifying assumptions employed in the basic monocentric model, rather than with its substantive basis (for example, Muth, 1985). Criticisms of the theory can be categorized into three types: (1) those which add complexity but do not affect basic validity of the model, (2) those which affect the predictive ability of the model, and (3) those which affect the underlying assumptions. These are illustrated with the following examples.

2.1.1 *Monocentricity* Criticisms of the monocentricity assumption is an example of the first type. The assumption of a single employment center has been widely challenged, and several empirical studies have demonstrated the multicentered structure of metropolitan areas (Gordon et al, 1986; Greene, 1980; Odland, 1978). Relaxing the assumption of monocentricity adds to the complexity of the model, but does not affect its behavioral validity. Several polycentric models have been developed (for example, Hartwick and Hartwick, 1974; Ogawa and Fujita, 1980; White, 1976). Although they differ in many ways, these models are based on the trade-off between land rent and transport cost with respect to a given (unique) workplace location as in the monocentric model. The spatial outcome (where determinant) is similar to the monocentric case, with declining density gradients emanating from each center.

2.1.2 *Multiple centers and multiple-worker households* If the assumptions of monocentricity and single-worker households are both relaxed, a more serious problem emerges. Residential location theory can no longer define a unique optimal location solution, and the predictive ability of the model is challenged. For example, combined commute costs for a two-worker household are constant at any point along the ray connecting two workplaces. Therefore, all other things being equal, any location on the ray is equally optimal. Given that the most recent available census data suggest that the ratio of US workers to households with members of working age is about 1.5[1], the appropriateness of applying this theory to contemporary household location behavior is questionable.

[1] Ratio calculated from population and employment data in *Statistical Abstract of the United States, 1986* US Department of Commerce and Bureau of the Census, 1985.

2.1.3 *Capital stock durability* Residential location theory contains an implicit assumption of nondurable capital stock. With durable capital stock, responses to changes in parameters (for example, a change in transport cost) are difficult to predict and can lead to counterintuitive outcomes (Wheaton, 1982). Durability cannot be effectively incorporated in location theory because it implies a dynamic process, whereas the theory is deterministic and static. The inability of the theory to incorporate dynamic (historical) processes is a criticism of the third type; it is a fundamental shortcoming which brings into question the substantive basis of the theory itself (Batten and Johansson, 1987).

Criticisms of the traditional monocentric model are serious only when the utility of the model comes into question. The strengths of the model are its elegance and simplicity, and these have made it an ideal tool for urban policy analysis. The first category of criticisms does not materially reduce the utility of the model for analyzing urban phenomena. The second category limits applicability of the model, and the third category questions whether it is appropriate at all. Thus any assessment of the relevance of this model for urban anlaysis depends on the extent of the second and third types of criticisms.

2.2 *Employment location*

Three different employment location theories have been developed. Business location theory is an extension of residential theory described previously (Solow, 1973; Strotz, 1965). Employment location is a function of land rents, commuter costs, and all other costs. Since a reduction in transport cost results in lower land values at the center (that is, a flattening land-value gradient), the effect will be a centralization of employment.

Business location theory does not, of course, apply to market-sensitive employment (activities which require access to consumers). The classic theory of market-sensitive activities is central place theory, formulated by Christaller (1966) and Lösch (1954). It predicts the distribution and size of markets as a function of population and market-threshold requirements. The resulting distribution is that which minimizes total consumer transport cost and fulfills the minimum threshold requirements. Central place theory has enjoyed renewed interest in recent years because it predicts a multinucleated land-use pattern. For example, recent theoretical work has shown that profit-maximizing behavior by firms can give rise to a hierarchial multicentered city structure given certain assumptions (von Boventer, 1976; Carruthers, 1981).

Industrial location theory is based on minimization of total transport costs for production inputs and outputs for a given optimal level of production. This is the 'classical model' of location, first formulated by Weber (1928) and later developed by Hoover (1948), Isard (1956), and Moses (1958). This model applies primarily to manufacturing activities. Location choice depends on the relative costs of shipping inputs and outputs as well as on economies of scale in production.

These theories are quite different from one another. Each applies only to certain activities; there is no integrated theory that applies to all types of employment. In every case, however, transport costs play a key role. All of these theories have been subject to a variety of criticisms. Business location theory is subject to the same criticisms as residential location theory. Also, recent theoretical work has shown that location can be indeterminant in the industrial location model under some production conditions, even when transport costs are taken into account (Karlson, 1985).

These theories may also conflict with one another. For example, location theory predicts that a transportation improvement has a decentralizing incentive for

households, but a centralizing incentive for business. Centralizing business, however, creates an incentive for households to locate closer to the center. At the same time, market-dependent firms must follow the population. A transportation improvement enlarges the market area for such firms, allowing greater decentralization. Meyer and Gomez-Ibanez (1981) point out that these conflicts obviously make it impossible to predict the impact of transportation changes on urban form on the basis of location theory alone.

3 The empirical evidence

Evidence from empirical tests of location theory hypotheses demonstrates that the relationship between location and transport expressed in the conventional theories is generally not supported in contemporary metropolitan settings. Two types of empirical studies are presented here in illustration: studies of employment and household location behavior, and studies of land-use impacts of major transportation investments.

3.1 *Employment location*

Recent studies of employment location provide the greatest support for the conventional theories. Labor-force access is identified as an important or significant locational consideration at the *regional* level in several different studies.

A study of firms that had relocated from Milwaukee City to its suburbs between 1964 and 1974 showed that agglomeration economies and labor-force availability were the most significant factors explaining location choices for all industries. Estimates of the share of firms locating in a given municipality were generated via separate regressions for six different industrial sectors. Labor-force availability was measured by the number of workers in the sector located within a given radius of the municipality; agglomeration was measured as the sector's share of total employment within each municipality. Other access-related variables were significant only for construction and wholesale trade: distance from the Milwaukee CBD (central business district) was positively related to location choice, presumably reflecting demand for the cheaper land available in more distant suburbs (Erickson and Wasylenko, 1980).

The importance of access to the labor force was examined in a different way in a study of high-technology industry. Herzog et al (1986) hypothesized that, if access to a highly skilled work force is important and if highly skilled workers have special locational preferences, high-technology firms should locate in areas that reflect these locational preferences. Results showed that high-technology workers' locational preferences were not substantially different from those of other workers, but that these workers demonstrate a higher degree of geographic mobility. The authors conclude that considerations of human capital play an important role in location choice among high-technology workers, and that consequently metropolitan officials have little control over retention of specialized labor resources because of the relative unimportance of the specific attributes of local areas.

It could be argued that labor-force access at the metropolitan or regional choice level is an obvious requirement for any firm, and it does not adequately reflect transport (commute) cost considerations. Site-related access may be more relevant. If firms locate to minimize total costs, then, ceteris paribus, shorter commutes for workers are preferable. Herzog et al list the following factors that influence site choice (in addition to site availability and cost): labor-force characteristics, local taxes, transportation for workers, quality of schools, and proximity to recreational and cultural opportunities.

Similar results are presented in a British survey of relocating firms (Patterson and May, 1979). The surveyed firms varied greatly in size and age. Among manufacturing firms the following criteria for choice of location site were identified, in order of importance: site availability, site cost, labor-market accessibility, and site access. Other factors identified were the local political environment and personal preferences of location decisionmakers. Site cost and availability were considered the key factors that ultimately determine where the firm relocates.

These results suggest that labor force access is a significant factor in firm-location choice, at least at the metropolitan level. However, in addition to the trade-off between transport and land cost in the traditional theory, these studies suggest that transport cost may be traded for more favorable local development policies, more esthetically attractive locations, better schools and amenities, and a host of other factors.

3.2 *Residential location*

Recent studies of residential location also suggest a much more complex relationship between transport cost and location choice, but provide less support for the traditional theory. A comparison of actual commuting behavior in a sample of US and Japanese cities with that prediced by a monocentric location model showed actual commuting to be about eight times greater than the predicted value based on commute-cost minimization. Correcting for possible sources of bias (for example, employment decentralization, two-worker households) reduced the actual versus predicted disparity to a factor of about five. In contrast, a random location model overpredicted total commuting by only 25% for the same sample. These results question whether the trade-off between work trip and housing cost has any significant role in residential location decisions (Hamilton, 1982).

Other studies provie additional evidence that residential location is not adequately explained as a function of (fixed) job location. Simpson (1987) proposed a simultaneous model of residential and workplace location. Workplace location is expressed as a spatial job-search model, in which location choice is a function both of residential location (for example, the distance of potential job opportunities from home) and level of job skill. Residential location is expressed in the traditional form, with independent variables including workplace location and household characteristics. Empirical results with data from Toronto showed that the workplace-location equation had far greater explanatory power, whether estimated separately or simultaneously. Moreover, homeowners and those who were not heads of households (that is, those with less mobility) were found to be more sensitive to local employment conditions than were renters and household heads. These results suggest that residential location has a greater effect on job choice than job location has on residential choice.

Another study which used Toronto data focused on occupational status as a key location factor. Findings showed that different occupational groups have varying sensitivities to travel time, with income and other relevant factors held constant, and different preferences with respect to suburban residential location. The study also documented the existence of locational segregation between occupational groups, again with household income and demographic characteristics held constant (Miller and Cubukgil, 1981). These studies suggest that important location factors are not captured in traditional residential location models, and these factors may overwhelm considerations of transport cost.

Another way of testing the hypothesis that residential location depends on job location is by examining household relocation behavior. It has been argued that the high cost of relocation may be an important reason for suboptimal location

(Hamilton, 1982). Thus, when households move, the move should be closer to work, all other things being equal. An empirical analysis of household relocation in the Milwaukee area with data from 1962 to 1963 revealed a different pattern: the probability of moving closer to the workplace increases at a constant, then decreasing rate with distance from the workplace. Beyond some critical distance (approximately nine miles in this case) the probability approaches a constant value of about 0.8. *Below* some commute distance (about three miles) there appears to be no relationship between housing and job location (Clark and Burt, 1980). The implication here is that households may be indifferent to commute costs until these costs become significantly large, and that household preferences with respect to commuting are highly variable.

3.3 *Land-use impacts of transportation investments*

If transport costs play an important role in location choice, then transportation improvements should influence location choices. The basic concept underlying the relationship between land use and transportation is accessibility. Any significant improvement in the transportation system (for example, new highway or mass transit link) increases accessibility and reduces transport costs. Location theory thus predicts that the improvement in accessibility will be capitalized in land values and reflected in land-use changes responding to the shift in land value.

Numerous studies of the land-use impacts of new highways and mass transit lines have been conducted. (For a review, see Knight and Trygg, 1977; Lerman et al, 1978; Meyer and Miller, 1984.) Most of the work on the impact of rail took place in the 1970s in response to construction of the 'new generation' rail systems in San Francisco, Washington, DC, and Atlanta. Results of these studies showed that rail transit has had little impact on land values. Various explanations have been advanced for these findings. Local zoning practices and political attitudes that constrain intensification of development have been identified in some cases (Boyce et al, 1972; Knight and Trygg, 1977). It is also argued that the durability of capital stock implies long time lags in land-market response to changes in the transportation system, and that the methodological complexities involved in isolating the effect of any one factor on land values over several years make it unlikely that impacts can be measured, even if they do exist (Giuliano, 1986). Last, some would claim that rail systems do not have a significant impact on accessibility—they serve few origins and destinations, and they carry a very small share of the total number of trips in an area—and therefore should not be expected to affect land use (Hamer, 1976; Meyer and Gomez-Ibanez, 1981).

Highway investments are a different matter. Given that urban highways carry over 90% of all person-trips and a large proportion of all goods movement in the USA, it seems reasonable to expect that highway investments would generate significant land-use impacts if transport-cost considerations are important in location decisions. Two generations of highway studies have been conducted in the era after World War 2. The first studies were performed in conjunction with construction of the interstate highway system in the late 1950s through the 1960s, and the second series have been conducted during the present decade. The first-generation studies very consistently showed significant, positive land-value impacts of new highways, despite sometimes significant methodological weaknesses (Adkins, 1959; Czamanski, 1966; Mohring, 1961). In every case, these were studies of the first freeway constructed within the metropolitan area.

In contrast, the second-generation studies show no consistent relationship between highway improvements and land-use change. A national study of beltway (circumferential highways) impacts concluded that there was no consistent relationship

between the presence of beltways and land use. Rather, land-use impacts were dependent upon (1) overall local economic conditions, (2) access to medium-income or high-income residential areas, (3) availability of land to develop, and (4) favorable local zoning policies (Payne-Maxie Consultants, 1980). A recent study of highway impact which used Minnesota data reported comparable results: a positive long-term impact of highway expenditures (defined as an increase in local employment beyond the regional trend) was identified only for the Minneapolis–St Paul Metropolitan Area, and negative impacts were identified in the adjacent counties. These findings were attributed to the relatively greater capacity to absorb economic growth within the regional center (Stephanedes and Eagle, 1987).

Despite the lack of firm quantitative evidence, the conviction that highways affect land use remains. Several descriptive or historical studies have documented land-use development along freeways, noting the tendency for clustering around major interchanges and for linear development along freeway frontages (Baerwald, 1982; Erickson and Gentry, 1985; Muller, 1981). In these studies land availability, local public policy, and the durability of infrastructure were identified as factors that affect land-use impacts.

The empirical evidence presented above may be summarized briefly. Studies of the impacts of transportation investments document the expected theoretical relationships only in the case of the early freeways. Studies of rail impact, as well as more recent freeway studies, show no consistent relationship. Similarly, employment and household location studies both document the presence of other more important factors that affect locational decisionmaking. There are two possible interpretations of this recent evidence. The first is that the concept of trade-offs between transport cost and location choice continues to be valid, but the observed pattern is affected by other (random) factors. The second is that transport cost is no longer a key factor in locational decisionmaking.

Taken as a whole, the empirical record suggests that the second interpretation is more accurate. Transport cost is a much less important factor than location theory predicts. There are several possible explanations for these results, and they can provide guidance for the development of more appropriate theories.

4 Some explanations for the evidence

Contemporary metropolitan areas differ in many ways from the cities on which location theory is based. Some major differences are described here.

4.1 *Accessibility in contemporary metropolitan areas*

With development of a cheap ubiquitous transportation system and the decentralization both of residences and of businesses over the past thirty years, accessibility has been greatly increased in US metropolitan areas. The highway system is well developed, with linkages to the national interstate system as well as to the local system. Consequently, new facilities, even if large scale, have little *relative* impact when viewed from a regional perspective. Use of the transport system is also cheap in relative terms. Although turn-of-the-century streetcar commuters spent about 20% of their daily wages on the journey to work, for example (Hershberg et al, 1981), urban auto commuters today spend about 7%. The overwhelming majority of metropolitan residents enjoy a very high level of mobility for relatively little cost.

Assessibility has also been affected by decentralization of economic activities. With the commercial, manufacturing, and service activities dispersed throughout the metropolitan area, relative differences in accessibility have declined.

Contemporary metropolitan areas are perhaps better characterized by a homogenous activity and transportation surface than by the traditional negative density gradient.[2] The approximation of a homogeneous accessibility surface is not intended to preclude the existence of nodes or subcenters. Rather, in multicentered metropolitan areas, alternative locations have approximately equal access to the set of activity concentrations—which may themselves display a high level of homogeneity. Given these conditions, then, any number of locations are equally accessible, because locational differences have declined. The relative unimportance of access in locational decisionmaking is a logical outcome, as most location changes in contemporary metropolitan areas will lead to negligible changes in accessibility. That is, the changes in accessibility resulting from ubiquitous transportation systems and decentralization have led to new criteria for locational differentiation, for example, neighborhood characteristics, local public services, political attitudes, etc. Under these conditions, the empirical findings discussed above appear reasonable: once some basic level of accessibility has been fulfilled, it is no longer a primary consideration for either workers or firms.

4.2 *The costs of relocation*

Directly related to changes in accessibility is the issue of relocation. The long life and immobility of fixed capital makes relocation costs significant both for households and for firms. Relocation costs also include less easily quantifiable considerations: search costs for a better location, possible loss of key employees, and the information costs associated with reestablishing household activities in a new location. Relocation costs are thus a significant factor in any location-choice decision. Given these costs, it follows that the expected benefits of a new location must be at least as great as the cost of moving before a relocation will take place. If accessibility differences between alternative locations are small relative to relocation costs, accessibility considerations will not be sufficient to cause a move to take place. Therefore, at any given time, a large number of (rational) household and employment locations may in fact be 'suboptimal' with respect to transport cost. The importance of relocation costs has also been theoretically demonstrated in recent research. In his work on endogenous development of subcenters, Clapp (1984) has shown that no unique spatial equilibrium exists given positive relocation costs. Rather, relocation of a firm does not occur until the benefits of the new location are greater than the cost of moving.

4.3 *The scale of residential and employment development*

The scale of development has also increased dramatically in the era after World War 2. In the 1950s, the residential development industry consisted primarily of many builders developing small tracts as land parcels became available. In the 1980s, the industry is characterized by many fewer builders, and the 'typical' development is the planned community, which involves very large land parcels and is usually developed over several years. Similar changes have taken place in the development of industrial and commercial projects, evolving from individual buildings to vast industrial parks and mixed-use office centers. The consequences of these changes are twofold. First, the availability of large tracts of land becomes a critical factor. Such projects cannot be realized unless sufficient land is available, and large parcels are most likely to be found at the periphery of metropolitan areas. Second, land-use change is determined by fewer decisionmakers—and fewer decisions. Under these conditions, unique local characteristics, as well as the

[2] Studies of density gradients document the decreases in the slope over time (for example, Guest, 1975), and zero or positive gradients have been reported (Jackson, 1979).

unique preferences of decisionmakers, should play a major role in determining land use, once the necessary condition of land availability has been fulfilled.

4.4 *Changing structure of economic activity*

Much has been written on the changes within the economy over the past few decades (for example, Harris, 1985). The share of manufacturing activity has declined, and service activities have significantly increased. Integration of the economy has resulted in growth of national and international markets. How do these changes affect transportation and land-use relationships? First, the relative importance of transport cost in economic activity has declined as the transportation of information has been substituted for transportation of goods. Second, the market orientation of firms is shifting more heavily to national and international networks. Thus for many firms, access to the interstate highway system and to major airports may be far more important than relative access within the metropolitan area. The exceptions here are market-dependent activities which require access to an adequate consumer base. However, given an approximately homogenous population distribution (and homogeneous accessibility), it follows again that traditional access considerations may be relatively unimportant.

Agglomeration economies are also related to the structure of economic activity. Although both theoretical and empirical understanding of agglomeration economics continues to be limited, it does appear that agglomeration continues to be a significant force in location (Erickson and Wasylenko, 1980; Stevens, 1985). Given that the service sector is the fastest growing sector in the US economy and that agglomeration economies are associated with service activities, one might expect agglomeration forces to be very important in contemporary metropolitan areas. Several empirical studies document the concentration of economic activities in suburban areas, particularly (but not exclusively) around key highway intersections or airports (Baerwald, 1982; Erickson, 1983; Greene, 1980). A recent study of land values in the Dallas area showed proximity to subcenters to be a significant explanatory factor (Peiser, 1987). And downtowns in major US metropolitan areas continue to grow, though at a less dramatic rate than suburban areas.

In the presence of agglomeration economies, the role of transport costs depends on trade-offs between the benefits of agglomeration and the associated congestion costs. The historical record suggests that congestion is much less important: development intensification continues in the downtowns of some of the most congested cities (for example, Los Angeles, New York, San Francisco, Chicago), despite the absence of new transportation facilities, and traffic problems associated with the rapid growth of suburban subcenters have become major public policy issues (Cervero, 1986a; 1986b). It may be argued, however, that this trade-off is inefficient, because congestion costs are largely external, whereas agglomeration benefits accrue directly to the firm. In the absence of efficient pricing, then, excessive levels of agglomeration might be expected.

4.5 *Local preferences and public policy*

Local governments have the potential to control and influence land-use change. If strong community preferences are present, local jurisdictions can exercise zoning power to prevent or downgrade development despite favorable market conditions. They can also promote development through tax breaks, provision of infrastructure, financial assistance, and other incentives. Recent studies of highway and transit projects have demonstrated the critical role of community preferences (Knight and Trygg, 1977; Payne-Maxie Consultants, 1980). For example, specific instances of down-zoning around transit stations in response to local opposition have been documented in Washington, DC, and in the San Francisco area (Dvett et al, 1979;

Lerman et al, 1978). A variety of development constraints (for example, floor-area ratio maximums, building permit limits) have more recently been imposed in suburban centers in response to traffic congestion generated by rapid growth (Cervero, 1986a).

Contemporary metropolitan areas are characterized by multiple local jurisdictions, each representing different community goals and preferences. These jurisdictions may compete for development (or for no development) through exercise of regulatory power, and thus may have a significant impact on land-use decisions and consequently on urban structure. Given the scale of most contemporary developments, local government approvals are a key factor in the development process. If it is accepted that accessibility considerations are of declining importance in locational decision-making, it is only logical to expect local conditions to play a more significant role.

The explanations presented here suggest that existing theory does not capture major explanatory factors of land-use change in today's metropolitan areas. The available evidence shows that transport cost has decreased in importance as a locational consideration both for households and for firms. Briefly summarized, this change is primarily the result of the decentralization and a well-developed transportation system that have reduced differences in accessibility between locations. Local characteristics have correspondingly increased in importance because of scale economies in development, agglomeration economics, and regulatory influence of local governments.

5 New directions for revising the theory

In light of the discussion in this paper, it is necessary to identify concepts that both are more appropriate for these changed conditions and could lead to the development of a better theory. Some possibilities for residential and firm location are presented here.

5.1 *Residential location*

There are several ways to expand the traditional model to provide a more adequate representation of the household location-decision process. First, a temporal element might be added. In this case, transport cost would be measured as total household-commute costs over the expected tenure at a given location. The idea here is that households have some expectations about changes in job location (and job locations are distributed throughout the region), and the residential location decision is an attempt to minimize travel to these possible locations. That is, households may maximize access to possible employment opportunities over the expected housing tenure. Thus households with stable job histories should live closer to work than households with a high degree of job turnover, all other things being equal. Also, households with shorter housing-tenure (renters) should live closer to work than those with longer housing-tenure (owners).

Second, the 'all other goods' term in the traditional model could be treated more explicitly. Existing evidence suggests that neighborhood characteristics and access to activities other than work play an important role in location choice. National travel-survey data are also supportive. Total vehicle trips per US household increased by 6.4% from 1969 to 1983. During the same period, the share of work-related trips dropped by 15%, while the share of family and personal business trips increased by 27% (Klinger and Kuzmyak, 1986). Thus a more accurate model would incorporate access to services, recreational opportunities, etc in the calculation of trade-offs between transport cost and housing cost.

Third, a more flexible form of household utility with respect to transport costs may be considered. For example, households may be quite indifferent to increases in travel cost when total cost is low, but very sensitive to increases when total cost

is high. Given the relatively low unit cost of travel (in time and money) in metropolitan areas today, it is not unreasonable to assume that households would willingly trade off additional travel cost for considerations of residential choice, as long as the work commute is not made intolerably long.

There are many reasons why further research in these directions makes sense. First, locational characteristics are emphasized and the spatial variation in residential areas is taken into account. Second, access to activities outside work, which may be relevant to decisions about location choice are incorporated. Third, in light of the high mobility rate of US households, and given that housing is the single largest household investment, location choice may depend on expectations about rate of return. If so, more general location characteristics (for example, access to significant amenities, 'good' schools, etc) would be more important than access to a particular job site. Fourth, job tenure has also shortened in recent years; most workers change jobs several times over their working careers. Thus distance from a specific work site may be much less important than access to other potential employment opportunities. A recent analysis of residential land values in Los Angeles lends support to the concept of multiple-access considerations. Access to several different employment centers, as well as to the ocean, were found to be significant explanatory variables (Heikkila et al, 1989) for residential property values. Last, large-scale residential development might have reduced spatial variation in the housing market. That is, the variety of housing available in a given area must decline as housing tracts become larger, and thus the housing search area may of necessity increase. All of these considerations point to the declining relevance of commute distance as a key explanatory factor in residential location.

5.2 *Firm location*

The research reviewed here suggests that labor-force access continues to be an important factor in firm location. However, within contemporary urban areas, labor is ubiquitous, given the relatively even distribution of the population. Under such conditions any number of possible locations may be equally likely, and thus random events have a great influence. Combining this idea with the presence of agglomeration economies implies that initial events play a critical role in urban spatial structure, because once a location has been established, growth and concentration will follow. Simply stated, history matters in contemporary metropolitan development.

The importance of initial conditions or events has been recognized in a number of different ways. In his simulation study of central place theory, Carruthers (1981) demonstrated that the hierarchical structure of a linear central place system is dependent upon the initial location of the first firm and its characteristics, since subsequent firms locate in response to the locations both of other firms and of employees. A second example is an extension of the new urban economics model that explains the development of endogenous suburban subcenters. Subcenter development is based on the linkages between firms. As growth occurs and (dominant) firms relocate in search of more and cheaper land, other dependent firms will also relocate, thus generating a subcenter (Clapp, 1984). In this context, the location choice of the initial relocating firm determines the location of the subcenter.

A related theory of endogenous regional growth is based on the concept of local potential (Coffey and Polèse, 1984). In this model, the entrepreneurial ability of the local population (that is, the human capital) is the key development factor. Growth of local firms depends on the ability of local managers, and, to the extent that these firms expand while remaining under local control, continued local growth is assured. This model was used to explain regional economic differences; however, it is applicable to intrametropolitan growth as well. One might identify major firms or

institutions which dominate the local economy, and thus determine the subsequent location of additional economic activity. Similarly, aggressive 'growth-oriented' local governments may determine activity concentrations by attracting key firms to locate within their jurisdiction. The important point here is the endogenous nature of the process, that is, the extent to which local characteristics can direct and influence the urban development process.

If local factors play an important role, how does transportation affect development or firm location decisions? Obviously, transportation must have at least some indirect effect which is reflected in the need for firms to have adequate access to the labor market. This is nothing more than a restatement of the geographic concept of commute fields which have been used to define functional boundaries of urban areas (Berry, 1973). The urban field, or daily urban system, is defined by the maximum distance workers are willing to commute. In this case, however, the functional area may define the development potential of a given center. Once again, central place concepts seem relevant. All types of firms are in some way market dependent, as seekers either of consumers or of workers. The historical process of employment decentralization following population decentralization also supports this concept.

The role of transportation may be conceptualized in a couple of ways to reflect these conditions. Firms may treat transportation (or access) as a boundary condition or constraint. Some minimum must be fulfilled, but additional levels of accessibility have little value. This constraint-based concept implies that there is no unique spatial equilibrium with respect to land-use and transportation considerations—any number of locations may be equally acceptable, and the choice of location depends on other factors. Alternatively (to preserve the basis of the urban economic model), transportation may be considered a minor but still significant factor. Although agglomeration tendencies, land availability, and local institutions may be the major determinants for firms, transport or access considerations continue to have some relevance. In fact, these considerations may become more important as congestion increases.

6 Conclusion

The concepts presented here fit existing empirical evidence better than the traditional theory of land use and transportation. Research is necessary to develop and test these ideas more fully. The theoretical implications of treating transport in other ways should be explored. In the case of residential location, additional studies of household relocation patterns and household commute patterns could determine whether any of the alternative concepts presented here are appropriate. Simulation studies both of households and of firms may be useful as well. Stochastic processes, for example Monte Carlo simulations, could be used to test the influence of random factors on location. Last, detailed historical case studies should be conducted to identify key factors in the development process, with particular attention paid to changes in the transportation system. Case studies can isolate events or decisions which have materially affected urban structure, and thus provide guidance for generalizing land-use change and the role of transportation in the process.

The purpose of this paper has been to present some alternative interpretations of the relationship between transportation and land use. These interpretations are based on previous empirical research that calls into question some of the basic tenets of traditional location theory. The ideas presented here should provide direction for a better understanding of this complex relationship.

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