TRANSPORTATION RESEARCH RECORD 1079

Land Development Simulation and Traffic Mitigation

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1986

Transportation Research Record 1079
Price $6.00
Editor: Lisette Chou
Compositor: Lucinda Reeder
Layout: Marion L. Ross

mode
1 highway transportation

subject areas
12 planning
15 socioeconomics

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Printed in the United States of America

Library of Congress Cataloging-in-Publication Data
National Research Council. Transportation Research Board.

Land development simulation and traffic mitigation.

(Transportation research record, ISSN 0361-1981 ; 1079)
1. Highway planning–United States–Congresses.
2. Transportation–United States–Planning–Congresses.
3. Land use–United States–Planning–Congresses.
I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 1079 380.5 s 86-28461
[HE355] [388.1'068]
ISBN 0-309-04073-6

Contents

A Dynamic Model of Urban Retail Location and Shopping Travel

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ABSTRACT

The evolution of the distribution of urban retail locations and the resultant shopping travel over time is simulated. The dynamic model developed incorporates a standard gravity formulation for interzonal travel demand with a linear programming formulation for the determination of the incremental zonal retail spaces that maximize net aggregate profits from retail sales. From one time period to the next link travel costs are updated as a function of the current flow, and zonal retail space development costs are updated as a function of the level of sales performance of the zone. The results of the simulations are in some cases counterintuitive, and illustrate the varied impacts urban development and transportation polices have on the spatial patterns of shopping activity and travel. Further possible extensions of the model, as well as practical applications, are discussed in conclusion.

During the last few years, the urban systems and transportation research community has given increasing attention to the dynamic modeling approach--the development of models in which time is an explicit variable. The reasons for this emerging trend include the inability of the traditional, static models to represent urban evolutionary changes, such as the decentralization of spatial patterns of urban activity (residential, commercial, etc.), the agglomeration of individual retail facilities into large-sized centers, sudden growth or decline of individual urban zones, and other similar contemporary urban phenomena (1).

In the dynamic modeling approach the nature of changes in the levels of system variables between individual time points (e.g., rate of change, oscillations, and instabilities), is as significant as the state of the urban and transportation system at given time points (e.g., trip ends, and interzonal flows), in cross-sectional analysis, for example. In particular, the existence and nature of equilibria for the system can be investigated as steady states, for instance, as a continuous evolution, rather than as individual, isolated points.

Several dynamic models of urban structure have recently been developed. Among these models are those of Wilson et al. (2), Allen et al. (3), and Mirchandani (4). The formulation of the first two models was based on a "logistic" mechanism of individual zonal activity growth. The third model was based on a variant of the "exponential smoothing" method of time-series forecasting applied to the matrix of origin-destination flows. In all cases, the spatial interaction is described by a gravity formulation.

Wilson's model focuses on the retail sector. However, subsequent versions addressed the agricultural, residential, and commercial sectors [Clarke and Wilson (5), and Birkin et al. (6)], whereas Allen's and Mirchandani's are comprehensive models that integrate several urban activities including retail, residential, industrial, and recreational.

The regional version of Allen's model adequately replicated the evolution of an area in Belgium between 1947 and 1970. The other models were not empirically validated, partly because of the difficulty of obtaining appropriate longitudinal data for the numerous variables in the models. Nevertheless, the findings of the various hypothetical simulations conducted with these respective models showed that a large variety of spatial patterns and types of temporal evolution can result from various parameter values, thereby translating different developmental scenarios and policies.

In particular, oscillations, cycles, and other similar forms of unstable behavior were observed in zonal activity levels over time. "Catastrophic" or discontinuous changes can also take place for certain critical combinations of parameter values, while bifurcations in evolutionary path may occur for others (7). Furthermore, random fluctuations in the levels of key variables (externally induced changes in the system's state such as major transportation facilities construction) have the potential to fundamentally alter, and over a long term, to cause an evolution of the system.

MODEL FORMULATION

The present model focuses on urban retail activity, and the associated shopping travel, as an individual component of a comprehensive urban and transportation system model. Consequently, the other activities (principally residential), are assumed to be given exogenously as the output of other submodels. The formulation of the model is based on two basic assumptions concerning supply and demand for shopping activity.

First, in keeping with the standard approach to travel distribution modeling, the spatial pattern of interzonal shopping travel from a Residence Zone i to a Shopping Zone j is assumed to conform to a gravity pattern. The attractiveness of an individual shopping zone is assumed to be proportional to the size of the zone, as represented by the square footage of retail space A_j. The trip production of a given zone is assumed to be proportional to the level of residential population in the zone P_i, which is exogenously input into the model. The disutility of shopping travel is represented by the interzonal

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travel time C_{ij}, which is itself a function of the link flow through the standard link performance function (8). The form of the spatial deterrence function is given as a negative expotential that conforms both to the entropy and the logit derivation of the gravity model (9). This is represented in Equations 1 and 2.

$$T^t_{ij} = \theta P^t_i A^t_j \exp(-\alpha C^t_{ij})/\Sigma_j A^t_j \exp(-\alpha C^t_{ij}) \quad (1)$$

$$P^t_i = P^{t-1}_i (1.05 + 0.1Z_1) + Z_2 \quad (2)$$

Note that it is assumed, as a simplification, that there is only one link connecting any couple of zones, so that there is no trip assignment component in the model. The level of retail sales in a given individual zone S_j is made proportional to the number of trip ends in the zone by the average amount spent on a shopping trip λ and the number of such trips per person per time period θ. This is expressed in Equation 3.

$$S^t_j = \lambda \Sigma_i T^t_{ij} \quad (3)$$

Second, the incremental allocation of zonal retail spaces over each consecutive time period is assumed to be such that it maximizes the future net aggregate profit resulting from retail sales (Equation 4).

$$\Delta A^t_j = A^{t+1}_j - A^t_j \quad (4)$$

This profit is the difference between incremental retail sales and the annualized cost of developing and operating a retail center in the given zone (Equation 5).

$$\Delta S^t_j = S^{t+1} - S^t_j = f(\Delta A^t_1 \ldots\ldots, \Delta A^t_j, \ldots\ldots \Delta A^t_n) \quad (5)$$

It is further assumed that incremental sales in a given zone can be predicted by multiplying incremental space by a growth factor, where the factor is equal to the ratio of incremental sales to incremental retail space in the previous period. Thus, the objective function is linearized as represented in Equation 6.

$$\mathrm{Max}\Sigma_j (\Delta S^t_j - C^t_j \Delta A^t_j) \simeq \mathrm{Max}\Sigma_j [(\Delta S^{t-1}_j/\Delta A^{t-1}_j) - C^t_j]\Delta A^t \quad (6)$$

Clearly this simplification is analytically convenient, and is probably closer to the manner in which retail space developers actually make their predictions of future sales activity than the analytically exact estimation, which is too intractable to be computationally practical.

In any case, the constraints on the incremental allocation of zonal retail spaces translate two sets of requirements. The first, at the individual zonal level, limits the retail space increase to the amount currently available in a zone given the ultimate zonal limits such as carrying capacities, and the amount of space used up so far in the zone. This results in Equation 7.

$$\Delta A^t_j \le L_j - A^{t-1}_j \quad (7)$$

where j equals 1, 2, ... n. The second constraint is at the level of the entire urban area, and requires that the total amount of retail space developed be made consistent with the residential population increase in the given time period by a coefficient of proportionality, which represents a developmental intensity with the dimension of a per-capita square footage of retail facilities (Equation 8).

$$\Sigma_j \Delta A^t_j \le \omega\ \Sigma_i \Delta P^t_i \quad (8)$$

Because the objective function, as well as all of the constraints, are linear in ΔA^t_j for the equations, the incremental zonal retail space allocation process can now be effected through the solution of a linear program represented by Equations 6, 7, and 8.

Equation 9 updates the unit costs of zonal retail space development (the cost coefficients in the Objective Function 9) as linear functions of the level of zonal retail sales relative to the level of sales at time t = 0.

$$C^t_j = C^o_j [1 + c(S^{t-1}_j/\bar{S}^{t-1})] \quad (9)$$

This translates the assumption that zonal rents, or land values, are directly affected by the financial performance of the zone. This equation in effect introduces the spatial dimension in the retail space allocation process. It also makes the factors of the evolution of the retail space system (and consequently that of the interzonal shopping travel), specific functions of time. Therefore, the model is inherently dynamic, and not simply a recursive one.

MODEL APPLICATION TO THE SIMULATION OF RETAIL SYSTEM EVOLUTION

The preceding model was programmed for execution by a microcomputer. The spatial system was a simple grid of 36 equally sized zones. The initial cost of travel between zones was represented by the travel time between zones under free flow conditions based on the euclidian distance between zone centroids. The number of time periods was set at 18, corresponding to 36 years. The preceding dimensions were dictated by the 128-K memory size of the computer.

The series of simulations consisted of a base case, together with various sensitivity analyses. The base case was represented by a population distribution at time t = 0, which was concentrated in the area's core (Figure 1). The respective retail space distributions at time t = 0 and t = 1 were also concentrated at the center of the area. Both t = 0 and t = 1 are required as initial conditions for the operation of the model because the coefficients of the objective function for any time period depend on the performance of the retail allocation space during the preceding period. Subsequently, the residential population growth was set at 5 percent

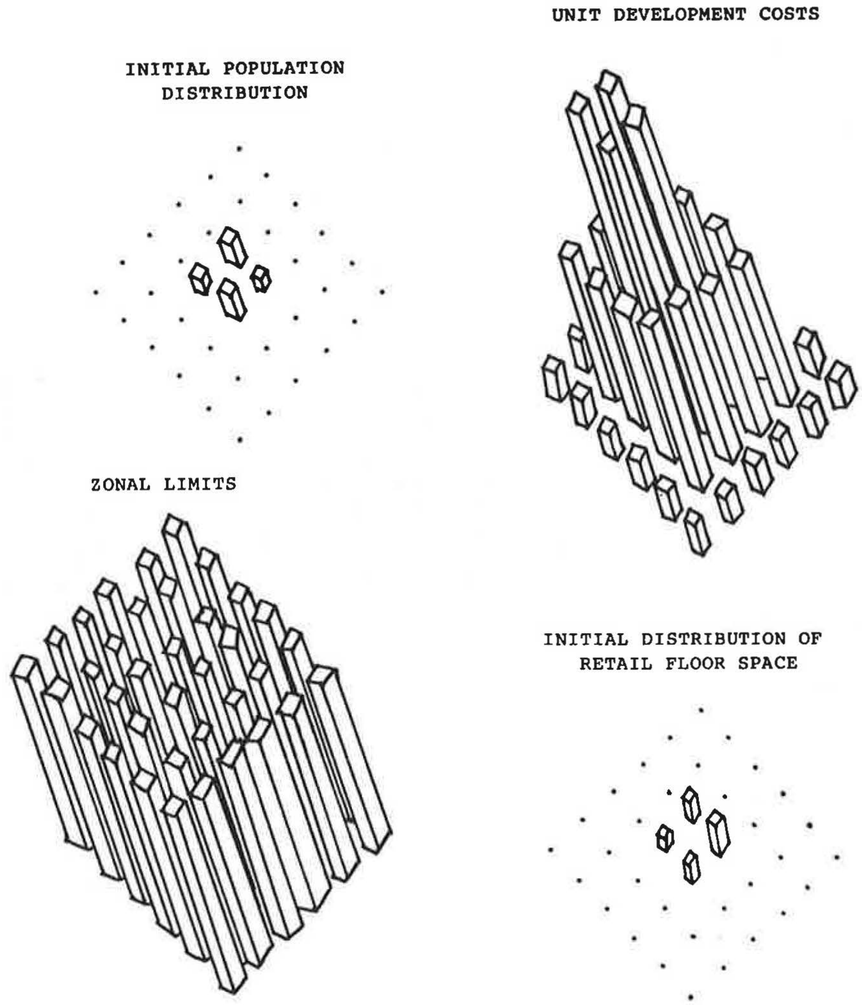

FIGURE 1 Initial conditions.

per period, plus random zonal differentials, as in Formula 2.

The initial zonal development costs were assumed to be highest in the inner ring of the four central zones and lowest on the area's periphery, with a medium level in the intermediate ring, and were roughly set equal to one-fifth the annual zonal sales revenue during the initial time period. Also, the limit on individual zonal retail space development was uniform for all zones, and set equal to 30 times the average zonal amount of retail space at time zero. Inflation was assumed to be nonexistent, or more precisely, it was assumed to affect both development costs and retail sales in the same manner so that all economic variables are in constant units over time.

The value of the parameter α in Equation 1, which measures the rate at which the level of interzonal shopping travel decreases with increasing distance (or which, in behavioral terms, represents the willingness of shoppers to travel long distances to retail facilities), was set at -0.2. This value results in a moderate distance decay effect, given the order of magnitude of the interzonal distances, ranging from 5 to 40 min.

The values of parameters a and b in Equation 10 represent the link performance function, and were set at the standard values for urban arterials of 0.15 for a, and 4 for b.

$$C^{t}_{ij} = C^{o}_{ij} \, [1 + a(T^{t-1}_{ij}/Cap_{ij})^{b}] \qquad (10)$$

Also, the value of coefficient c in Equation 9 was set at 1.0, thus implying an equality in the respective rates of increase in zonal sales, and in zonal cost of retail space development. The coefficient ω in Equation 8 was set at a value equal to the ratio between total population and total retail space at time t = 0, indicating a balanced retail development with respect to population growth.

Finally, coefficients θ in Equation 1, and λ in Equation 3, which in effect are scaling factors between the values of variables with different units of measurement, were both initially set at 1.0, thereby predetermining the order of magnitude of all the other variables.

RESEARCH FINDINGS

The results of the simulation of the base case just described are shown in Figures 2, 3, and 4. The evolution of the residential population distribution, which drives the evolution of the retail activity distribution, follows the expected pattern with residential levels increasing exponentially over time, and decreasing over space, away from the area's center. Concurrently, the distribution of zonal retail spaces shows that the location of retail development appears to alternate periodically over time between the area's core and its periphery.

Although absolute, the zonal retail spaces increase over time (as can be expected from the assumption that the area is in a growth mode), and the

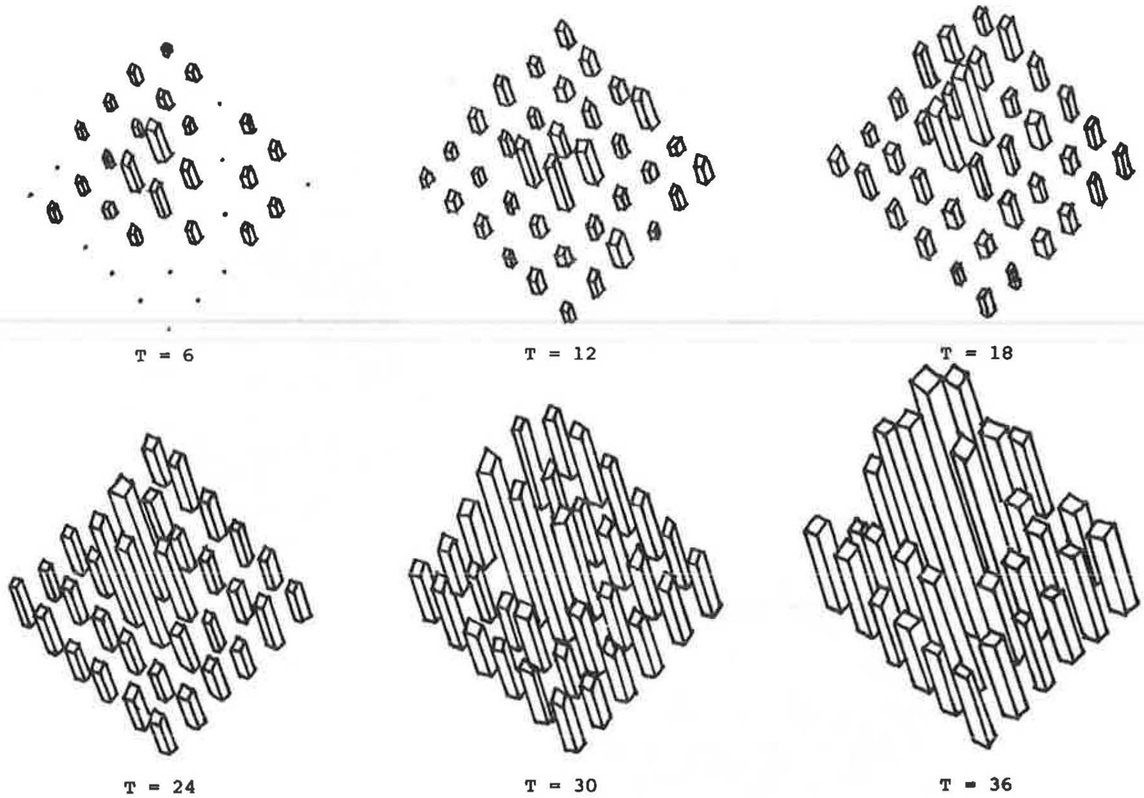

FIGURE 2 Evolution of the residential population distribution.

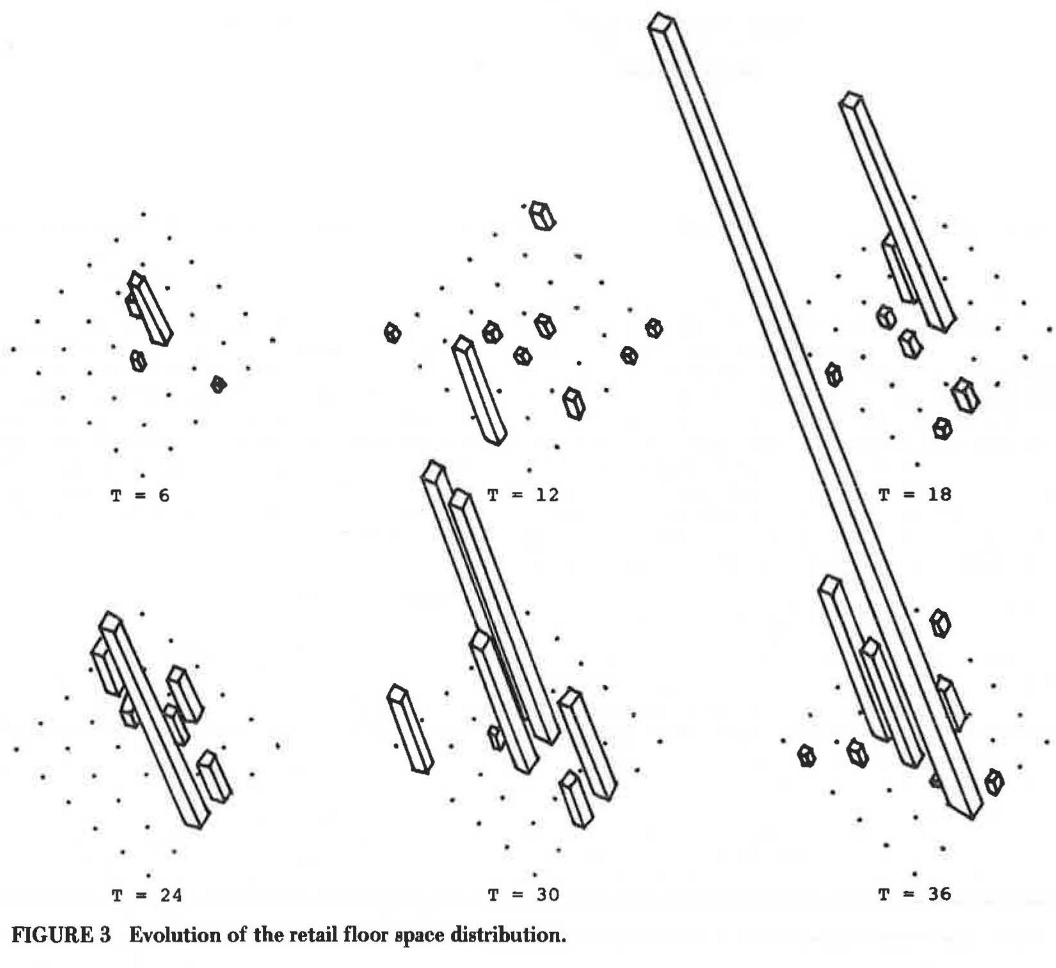

FIGURE 3 Evolution of the retail floor space distribution.

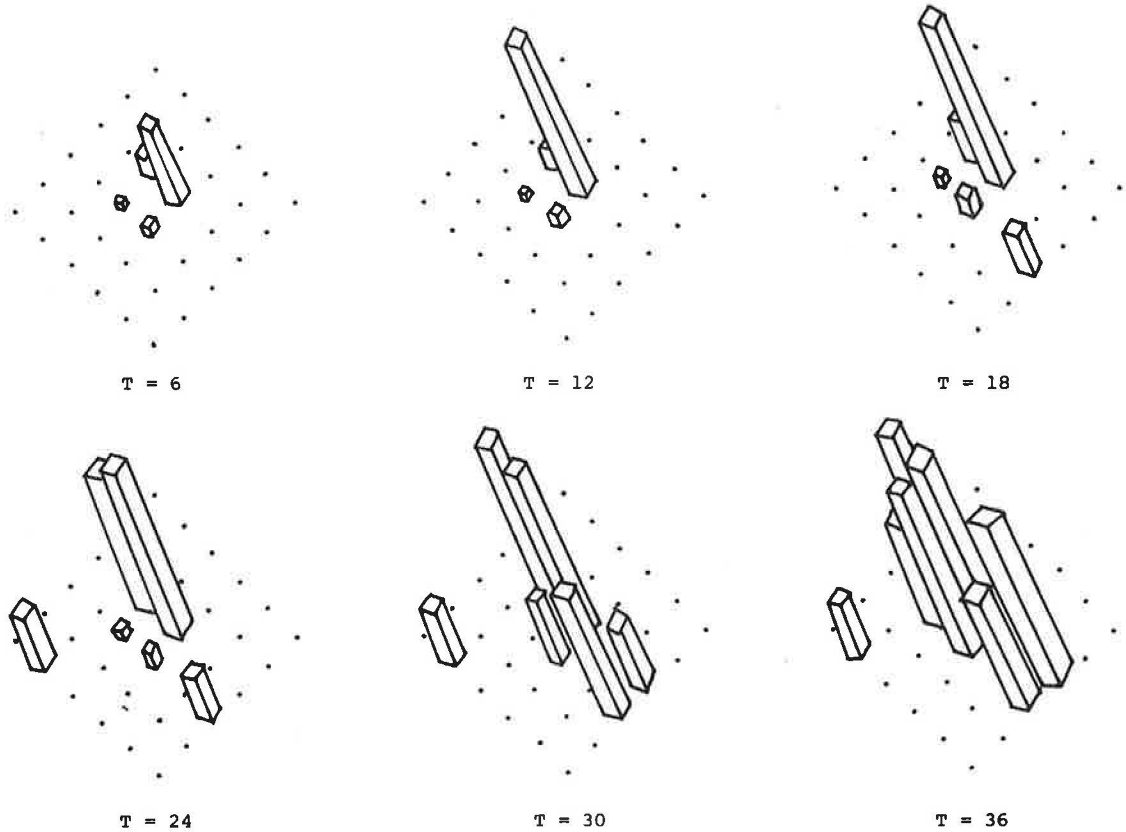

FIGURE 4 Evolution of the trip ends distribution.

level of retail activity (sales and shopping trip ends), in individual zones appears to oscillate. The characteristics of individual cycles in zonal activity appear to vary from zone to zone, as can be seen in Figure 5. For instance, Zone 19 shows a fairly steady cycle, whereas Zone 33 experiences an amplifying cycle. However, the period for most zones appears to be about 12 years (or six time periods).

It is worth noting that such oscillations in zonal activity levels have also been observed in all applications of the other dynamic models mentioned in the introductory section. However, oscillations in these models are expected as a standard feature of the output of systems of dynamic, nonlinear differential equations. In the present case, however, the dynamic component is provided not by a mechanistic law of evolution, but by an optimizing process of development.

In any case, such oscillations can be related to the multiple feedbacks between the zonal costs, activity levels, and the resulting zonal attractiveness to shoppers and developers. Specifically, when a zone's sales performance increases, its unit cost of retail development increases also. Consequently, the zone becomes less attractive to retail space developers. The zone may thus receive less development, in absolute terms, than other zones with lower levels of performance. In turn, this will decrease the attractiveness of the zone to potential shoppers, and consequently diminish its sales performance, until several periods later when the subsequent evolution of both the population and the retail activity spatial distribution might make the zone competitive again.

Concurrently with this unstable, cyclical behavior of zonal trips ends, the pattern of interzonal shopping travel flows also shows oscillations (Figure 6). For clarity only the six largest origin-destination flows are shown. The instability in zonal shopping trip ends is reflected in shifts in the type of interzonal travel pattern. Specifically, there appear to be two cycles of about 12 years each, starting with a primarily centripetal pattern at time t = 6, and becoming a purely centrifugal pattern at time t = 12, with a repeat from time t = 18 to time t = 24. At time t = 30, the major traffic flows are limited to the inner area, whereas at time t = 36, there is significant cross-town shopping traffic.

The implications of these oscillations in traffic volumes and origin-destination patterns are multiple, not only from the point of view of the operation of the retail facilities, but also for the operation of the transportation network. In particular, the fluctuations in level of trip ends in individual zones over time are detrimental to operational efficiency because they essentially imply underutilization of facilities at certain times, regardless of whether such facilities are retail stores, parking lots, or urban streets. Conversely, congestion will prevail at other times.

In the case of the retail sector, this problem may be alleviated through such temporary measures as adding or deleting personnel, short-term reconversion to other commercial activities, or other such business practices. Concerning the transportation network, such adaptations to fluctuations in travel demand may be more difficult to achieve, particularly given the relatively short period of the demand cycles, as described earlier. In any case, they will have significant impacts on traffic operations and control.

The next step in the analysis was to investigate the sensitivity of the foregoing results to changes in the urban conditions, as represented in the parameter values for the model. The first feature to be so varied was the value of the parameter α in

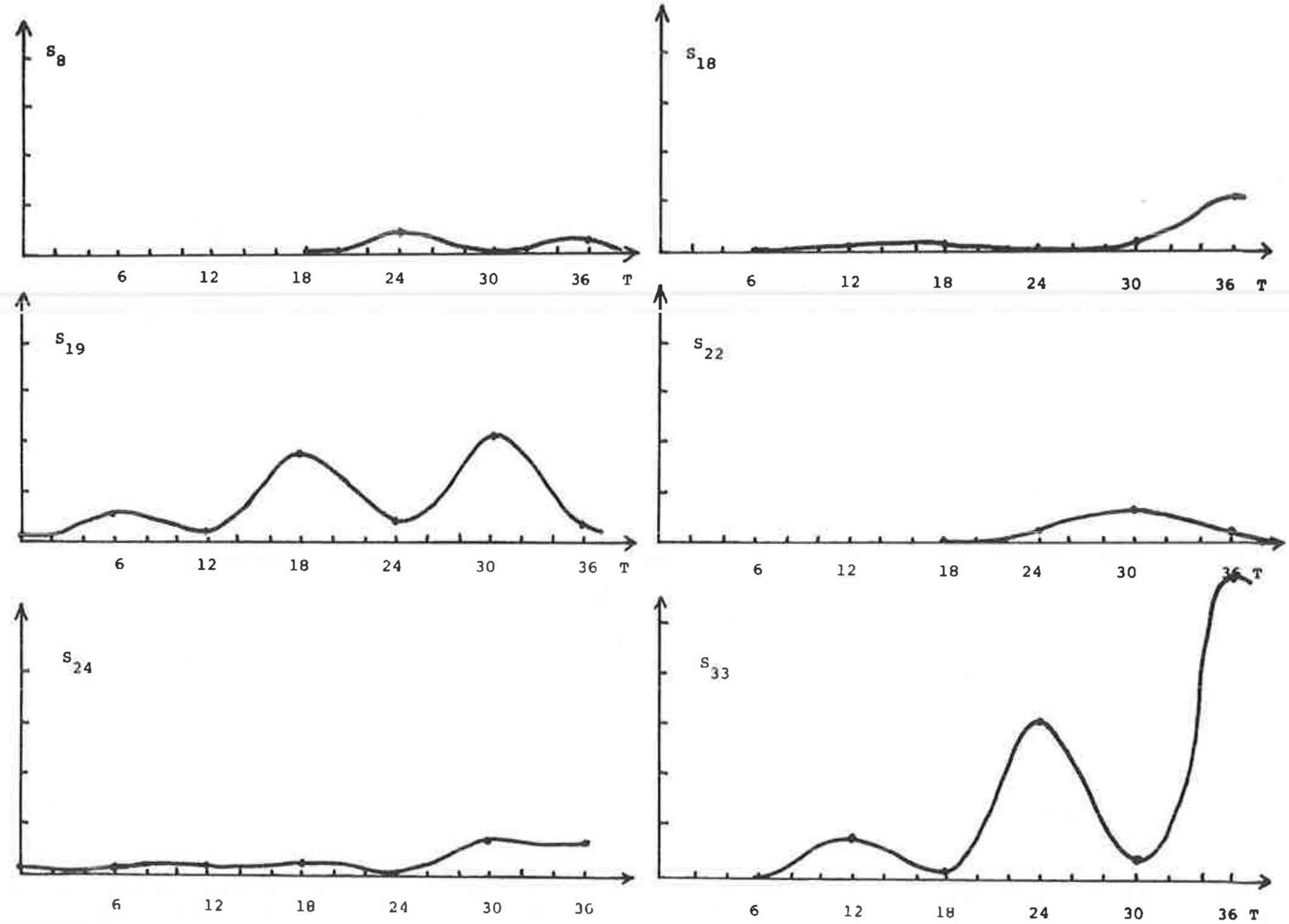

FIGURE 5 Evolution of trip ends levels in selected individual zones.

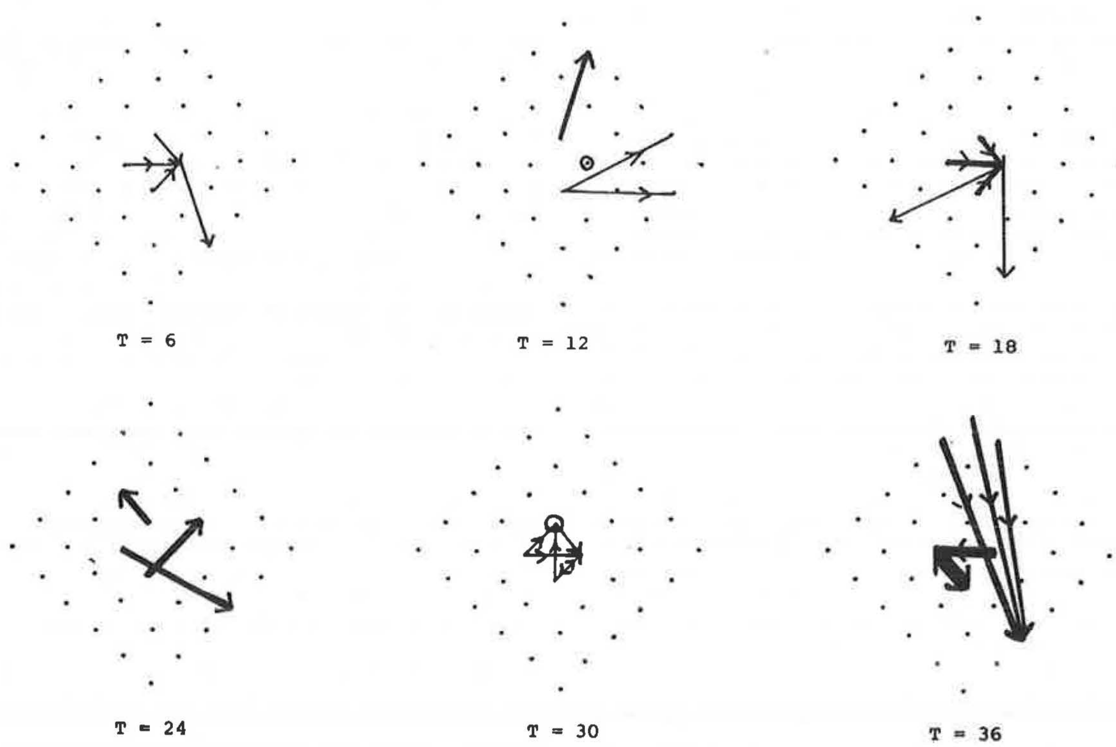

FIGURE 6 Evolution of the interzonal flows pattern.

Equation 1. This value was set at one-half its previous value of 0.2, translating a decrease in the spatial deterrence effect of distance on shopping travel, or equivalently, an increase in the willingness of shoppers to travel to distant shopping centers.

The results showed that in the first half of the simulation period, there were fewer dominant retail centers than before, but more of them in the second half of the period. Also, the average dispersion among retail centers remained about the same, although the pattern of interzonal shopping flows was changed, especially in the latter part of the period.

Another investigation was concerned with how increased levels of competition between both suppliers and consumers of retail activity affect the preceding results. The unit zonal development costs were thus made a steeper function of the zonal sales performance, while the travel time on individual links was made a faster rising function of the traffic flow. These changes can also be interpreted as increasing congestion levels in both the supply and demand sides. In numerical terms, coefficient c in Equation 9 was doubled, and the values of a and b in Equation 10 were set at 0.5 and 4.5, respectively.

The resulting evolution of the zonal and interzonal activity pattern showed that intrazonal shopping travel was prevalent in this case. Also, a more differentiated retail activity distribution, in the form of a dominant retail zone, together with more numerous secondary centers, emerged in the latter part of the period. In general, the development of the zonal retail spaces appeared to be somewhat more homogenous than those mentioned earlier.

The influence of the type of population evolution on retail system evolution was also investigated. Several patterns of population growth, including linear, and exponential, as well as different growth rates were used. Although the results are difficult to categorize in the form of simple, clear relationships, both zonal trips ends patterns and interzonal trip patterns were significantly affected.

Spatial irregularities in both the overall residential distribution and the residential evolution of individual zones are transmitted to the retail activity and shopping trip patterns in the form of greater temporal instabilities in their evolution. Furthermore, the characteristics of the initial residential population distribution had significant impacts throughout the period on both the type of trip ends, or interzonal trip patterns at given time points, and their characteristics of change over time.

CONCLUSION

An unlimited number of scenarios, beyond those discussed here, can be simulated in the same fashion, resulting in a wide variety of retail system evolutions. The interactions between the variables in the system are complex. Nevertheless, it is clear that some parameter values may lead to desirable configurations (e.g., a dispersed system of retail centers, or a radial pattern of shopping travel). Others result in detrimental configurations (e.g., center area congestion or rapid oscillations in retail sales).

Among the macroscopic factors of urban retail development and shopping travel that can thus be analyzed are: (a) the type of population growth or decline (e.g., residential densities, monocentric versus polycentric residential patterns); (b) basic economic activity distribution (e.g., inner versus peripheral, industrial decline); (c) zoning restrictions (e.g., developmental limits, land use policy); and (d) transportation network characteristics (e.g., layout, capacity, parking supply, and so on). In particular, the impacts of varying levels of congestion on the spatial structure of shopping travel have been investigated (10).

Among the microscopic factors of the retail system development are the behavior of the shopper (e.g., preferences for large retail stores, willingness to travel far, and so on); and behavior of the retail developer (e.g., willingness for taking risk).

One of the challenges of explorations of the type presented here is to categorize the results of such investigations in terms of clear, concise relationships between system parameters, and types of retail activity and travel system evolution.

The preliminary results illustrate a fundamental aspect of dynamic spatial analysis. Contradictory to the traditional standpoint, the evolutionary characteristics here are equally as significant as the cross-sectional information generated by the static, equilibrium-type urban structure models (magnitude and distribution of urban activities at given time points). This analysis highlights such dynamic features as oscillations in zonal trip level and interzonal trip pattern, evolutionary differences between individual zones, rates of growth or decline, long-term versus short-term characteristics, steady states, and so on. These dynamic impacts are as important to the evaluation of urban developmental policies as the equilibrium impacts predicted by static models. The importance of dynamic models lies in the fact that they alone can represent such impacts.

In conclusion, it might be appropriate to review briefly possible approaches for improving the described model. First, the dependency of the retail space allocation process on the other urban activities should be incorporated because all activities compete for the same limited urban space. This amounts to expanding the model by linking it with other models for residential (here assumed to be given exogenously), economic, or other activities, and incorporating the feedbacks between their respective variables (11). For instance, the amount of land available in a given zone would depend on the level of the other activities in the zone (relating to residential or office density). Also the cost of retail space development might be an increasing function of the percentage of remaining space suitable for development.

Another potential improvement in the present formulation would consist of the inclusion of additional economic variables, principally the zonal price of goods. This zonal characteristic should be important for most shoppers in their evaluation of zonal attractiveness. In turn, its value could be made a decreasing function of the level of zonal sales, reflecting volume discounts, and an increasing function of cost of retail development, reflecting the transmission of such costs to the consumer. These additional feedbacks among individual model variables might potentially give rise to other types of retail system evolution.

Another main area of development for the present model would be the allowance for a decline in zonal retail space. This might, for instance, be achieved by stipulating that the retail space for any zone with sales performance less than a specified level (e.g., a minimum rate of return), would be reduced by a given fraction (e.g., a failure rate).

Other refinements might in time be desirable, such as taking into account both multiple stops and multipurpose shopping trips, or nonhome-based trips, and other such complex aspects of urban travel behavior. Most important, the empirical validation of the results will have to be undertaken before dynamic models such as this can be used in practical situations. This task is subsequently dependent on the development of adequate longitudinal data bases, and the operationalization of a suitable calibration methodology (10).

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Expert Panel Method of Forecasting Land Use Impacts of Highway Projects

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ABSTRACT

The validity of expert panel forecasts of land use impacts of highway projects in small urban areas was evaluated. A panel was assembled consisting of individuals with backgrounds in different aspects of land use and forecasting. This panel of experts was asked to predict the changes that have occurred over the past 20 years from a 1965 perspective. The panel received information on each of the two case study cities, as well as brief descriptions of the projects. The forecasting instrument consisted of a map for each city and a questionnaire to elicit evaluations of 31 features of community development. Each feature was rated as to whether an impact would occur, whether the impact was negative or positive, and the magnitude of the impact and its importance. On the map the panelists predicted the areas in which residential, retail, service, and industrial impact would occur. The first round of this study was conducted in person and the second round was completed by mail. After the results from the second round were tabulated, they were submitted to a smaller panel in each of the cities for evaluation with respect to accuracy and usefulness.

A potentially important impact of any highway project is its effect on the spatial distribution of urban development. This type of impact is often referred to as a secondary land use impact in order to distinguish it from changes in land use that occur within the right-of-way. Secondary land use impacts are not direct consequences of the project, but result from modifications in access to parcels of land and from modifications in travel time between various points in the urban area. Secondary land use impacts have included regional shopping center developments, urban sprawl, and economic decline of central business districts. The reasons that highway projects cause impacts on land use have been well understood for at least 2 decades (1). However, existing techniques for assessing land use impacts are directed toward large freeway and rail transit systems in major urban areas. Little effort has been devoted to formulating techniques that could be used for assessing impacts of highway projects in or near small communities--the type of project that is now most often built.

The overall purpose of this study was to determine the applicability of existing techniques for assessing highway-related impacts in small communities. Existing techniques were categorized as (a) assessment by experts such as an expert panel or gaming simulation; (b) computer simulation; (c) statistical models; or (d) qualitative assessment such as a series of short questions, a checklist, or a cross-impact matrix. A representative technique was selected from each category.

The four selected techniques were evaluated by applying them to one or more case study projects in Wisconsin. The projects were completed between 10 and 20 years ago--long enough so that any changes in the development pattern of the urban area would be readily apparent. As best as possible, the techniques were applied as they would have been at the time of the projects.

Two types of validation were sought: (a) the forecasts from the techniques should correspond to actual patterns of development since the project was built, and (b) the techniques should not require more effort than would be justified by the quality and usefulness of the results.

One of the techniques examined and evaluated for usefulness in predicting secondary land use impacts of highways was an expert panel. This technique provides a contrast to other methods investigated in this overall study. An expert panel can handle intangible impacts, such as aesthetics, strength of government authority and attitudes of financial institutions, and extremely localized impacts, such as the development of a regional shopping center. These impacts are not easily assessed by mathematical models. In addition, an expert panel evaluation can assess intangible impacts with more comprehensive insight than can be accomplished with simple checklists. A structured expert panel appeared to have the following desirable characteristics: (a) expert knowledge and experienced intuition, (b) time efficiency, and (c) low cost.

PROMINENT METHODS OF EXPERT PANEL EVALUATION

Expert panel techniques include focus groups, gaming simulations, and structured expert panels. These have received considerable attention, both in the literature and in practice, because they are able to handle issues that are not easily quantifiable. It has been shown that human judgments based on these methods can enhance the process of land use forecasting.

Focus groups (2) allow a small number of participants (typically 6 to 10) to discuss a particular issue in an unstructured manner under the guidance of a skilled moderator. The early discussion is intended to be quite broad so that the participants will be more comfortable while interacting. Through

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interaction more spontaneous and possibly more honest comments will be made. When the group is assembled it is necessary to allow for diversity as well as similarity. If too much contrast is present it may stifle discussion. The expertise of the moderator is the essential element in a successful group. It is the responsibility of this individual to maintain the direction of the group on the subject under consideration. This task requires a high level of skill. Clear, unambiguous interpretation of the results is rarely possible because of the role of the moderator and the unstructured nature of this type of research. This technique would be useful at an exploratory stage but would not be suitable for detailed land use forecasting.

Simulations are simplified representations of larger, more complex systems. Three different types can be identified: (a) those that use computers exclusively (known as models), (b) those that use a combination of computer and human players, and (c) those that use only human players. Those simulations that use only humans to generate operations and calculate consequences are known as gaming simulations (3).

Games have three features: (a) explicit rules about how a goal is to be achieved with certain resources, (b) players' psychological orientation that the goal is valueless in itself, and (c) social consensus that the activity is inconsequential for the serious business of life (4). When games are used by decision makers in the real world, the third feature is naturally violated. A particularly representative game, which was influential in the development of the expert panel procedure that was evaluated in this paper, is the Community Land Uses Game (CLUG).

CLUG (5) attempts to predict how land will be used based on existing constraints. The players' objectives in this gaming simulation are to buy and sell land, to construct commercial and residential property, to put industries into operation, and to make a profit. CLUG most resembles a board game, complete with dice, markers, and play money. It is able to stimulate the interactive elements of conflict and cooperation, as well as strategic thinking. CLUG is designed to include 9 to 25 players who participate in 5 to 10 rounds of the basic game, plus additional experiments if appropriate. The game could easily occupy 20 hr or more of playing time. In this game there are some preestablished components, some left to chance (the roll of the dice), and others are open to negotiations and decision making.

Because of its simplicity, CLUG will not predict what will take place in the future, but will provide an arena for creating possible outcomes. Modifications can be made to better simulate different problems. An argument that can be posited against games such as CLUG is that results will be constrained and directed by the game's design. This is not necessarily undesirable if the limitation of the framework is clearly understood. CLUG can be valuable, but its chief virtue lies in education rather than prediction. Students of urban affairs or urban planning may be better able to anticipate real-world problems after playing CLUG.

One of the most familiar expert panel forecasting techniques is the Delphi method. The Delphi method (6) attempts to reach consensus through an iterative process. Delphi panels were first used to predict when events would take place. Rand Corporation has conducted several Delphi panels (7). Some of the areas investigated included scientific breakthroughs, automation, space programs, and future weapons systems.

For Delphi to attain the most reliable consensus of opinion held by a group of experts, intensive questionnaires with controlled feedback are used. After one round has been completed, the findings are tabulated and returned to the panelists. The panel-monitoring team may choose to provide this information verbally or may use a statistical technique to represent central tendency. Equipped with this additional information, participants may modify their original responses. The number of rounds is not prescribed, but generally three rounds are needed to gain consensus and show stability.

Delphi employs the services of several experts but interaction between them is discouraged. One of the most important features is that the panelists are unknown to each other. Anonymity is preserved by administering the questionnaire through the mail. With Delphi, a dominant personality or an individual with a particularly prestigious title would be unable to exert pressure, either consciously or unconsciously, on the other participating individuals.

The Delphi panel should consist of experts with varied backgrounds. In this way the forecast will benefit from the diversity of knowledgeable input. These experts are often individuals with many commitments; therefore, it is imperative to explain the expected amount of time that needs to be devoted to this activity. The time needed is not extraordinarily large, but individuals with full schedules need to be informed of the requirements.

Ervin (8) applied the Delphi method to regional industrial land use forecasting in Tennessee in the mid-1970s. This study was considered an abbreviated version, according to the author because only two rounds were conducted and no effort was made to arrive at a stabilized consensus of opinion. However, it did provide useful information. Because this set of panels was conducted for several industries, it was discovered that the relative importance of the various factors would vary from one industry to another and location factors were important to some industries but of little significance to others.

More recently Cavalli-Sforza and Ortolano (9) attempted to predict impacts of three alternative transportation projects in San Jose, California, by using the Delphi method. The impacted area was divided into four zones, and panelists made separate predictions for each zone. Regarding land use, specific forecasts were made with respect to expected population, number of single-family units and multifamily units, and number of commercial and industrial employees for 2 future years. The panelists were also provided this information for 1970 and 1975 so that they would have knowledge of existing trends. As the rounds progressed there was evidence of ranges tightening around the median responses.

The greatest difficulty experienced by Cavalli-Sforza and Ortolano was the amount of time needed to reach a successful conclusion. It took progressively greater periods of time to recover the questionnaires as the rounds advanced. The third round was completed 18 months after the inception of the study. Monetary compensation is one means of counteracting the problem. Of course, the most desirable solution is to bring together a totally committed panel from the beginning.

Cavalli-Sforza and Ortolano (9) were only able to conclude that the Delphi method functioned as expected. Because they had actually performed a forecast into the future, it was not possible to evaluate whether the results were reasonably accurate.

STUDY TECHNIQUE: STRUCTURED EXPERT PANEL

For this study it was desirable to combine several positive aspects of the techniques mentioned earlier.

An iterative questionnaire, like the Delphi method, formed the basis for the overall structure. However, it was believed that the technique would benefit from the informal setting, the personal input, the immediate feedback, and the guidance of a moderator, which are essential to focus groups. because land use is a spatial issue, the structured expert panel would also benefit from a map, like the one in CLUG. By drawing on these earlier methods, it was possible to develop a technique that could handle the full range of land use impacts.

Panelists were asked to rate the following 31 features of community development that could change because of a highway project:

- Employment in existing industrial park (manufacturing);
- Industrial employment elsewhere within the study area;
- Employment in regional shopping centers;
- Employment in community shopping centers;
- Employment in neighborhood shopping centers;
- Retail employment in the central business district (CBD);
- Employment in hotel and motel services;
- Employment in repair and cleaning services;
- Employment in advertising, management, consulting and legal services;
- Amount of regional post-secondary educational facilities (colleges and technical);
- Amount of local schools;
- Amount of regional health care facilities;
- Amount of local health care facilities;
- Service employment in the CBD;
- Employment in restaurant and fast food establishments;
- Total population;
- Amount of unoccupied housing units;
- Ability of local government to control land use through traditional measures (zoning);
- Length of average trip to work in miles;
- Amount of ridesharing;
- Amount of intercity travel for work purposes;
- Overall congestion in the study area;
- Congestion in the area of highway project;
- Aesthetics of area surrounding the highway project;
- Amount of development in communities near but not part of the study area;
- Amount of development in areas with incomplete utility service;
- Willingness of financial institutions to lend money for further land development;
- Land values near project (within 1,000 ft);
- Land values in the remainder of the study area;
- Tax base; and
- Utilization of existing parks.

The questionnaire was based on a modification of the Leopold technique (10), which asks respondents to rate both the magnitude and importance of an impact. Both ratings used category scales with 0 signifying no importance or no impact, and 10 signifying extremely important or extremely large impact. An example set of scales is shown in Figure 1. Panelists were also asked to record the direction of the impact (larger or smaller). Panelists were specifically not asked questions regarding the desirability of the impact. When no impact was recorded, panel members were told to explain this response.

In addition, maps were provided for each of the case study cities, Sheboygan and Wisconsin Rapids, so the locations of residential, commercial, industrial and service impact could be identified. These maps represent the cities as they existed in 1965 (Figures 2 and 3). The existing major road networks are featured together with proposed changes defined by a heavy dashed line and areas categorized as industrial, commercial, residential, open space, or park, and by the concentration of workers. The levels of soil suitability for septic tanks were defined. Also included were the locations of water and sewage plants, as well as schools, hospitals, and shopping centers. The maps were not divided into zones. Color pencils were provided for panelists to designate areas where significant changes in land use activity would occur. In addition, panelists were asked to show where a regional shopping center or a concentration of services might develop.

Because this study "predicted" events that have already occurred, it was necessary to choose individuals that had little familiarity with the case study cities. The prospective panelists were asked to rate their familiarity with six cities (including the two case study cities, and based on responses some otherwise highly qualified individuals had to be eliminated. A 13-member panel was recruited consisting of five experts in technical aspects of highway planning from the Wisconsin Department of Transportation (WisDOT), four university professors who specialize in community development, three community planners from separate agencies, and one real estate developer.

The panelists were provided a brief description of each city labeled only as City A and City B. The

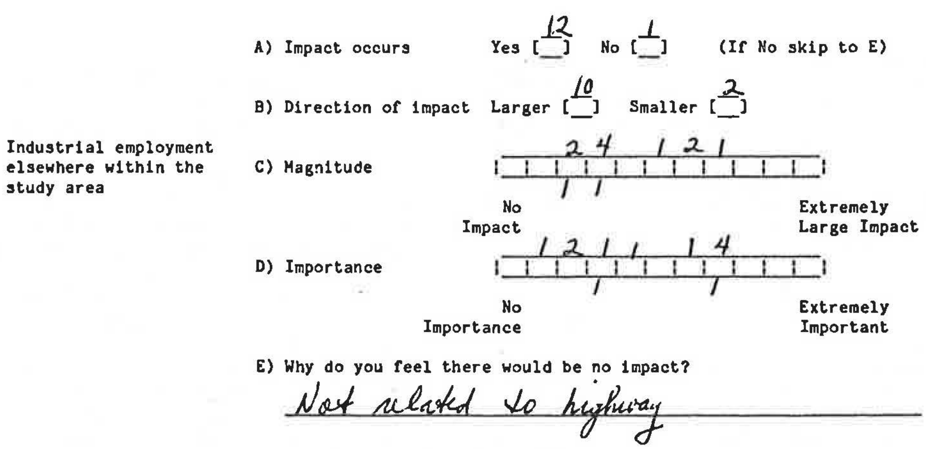

FIGURE 1 Example community feature with scales and first round summary.

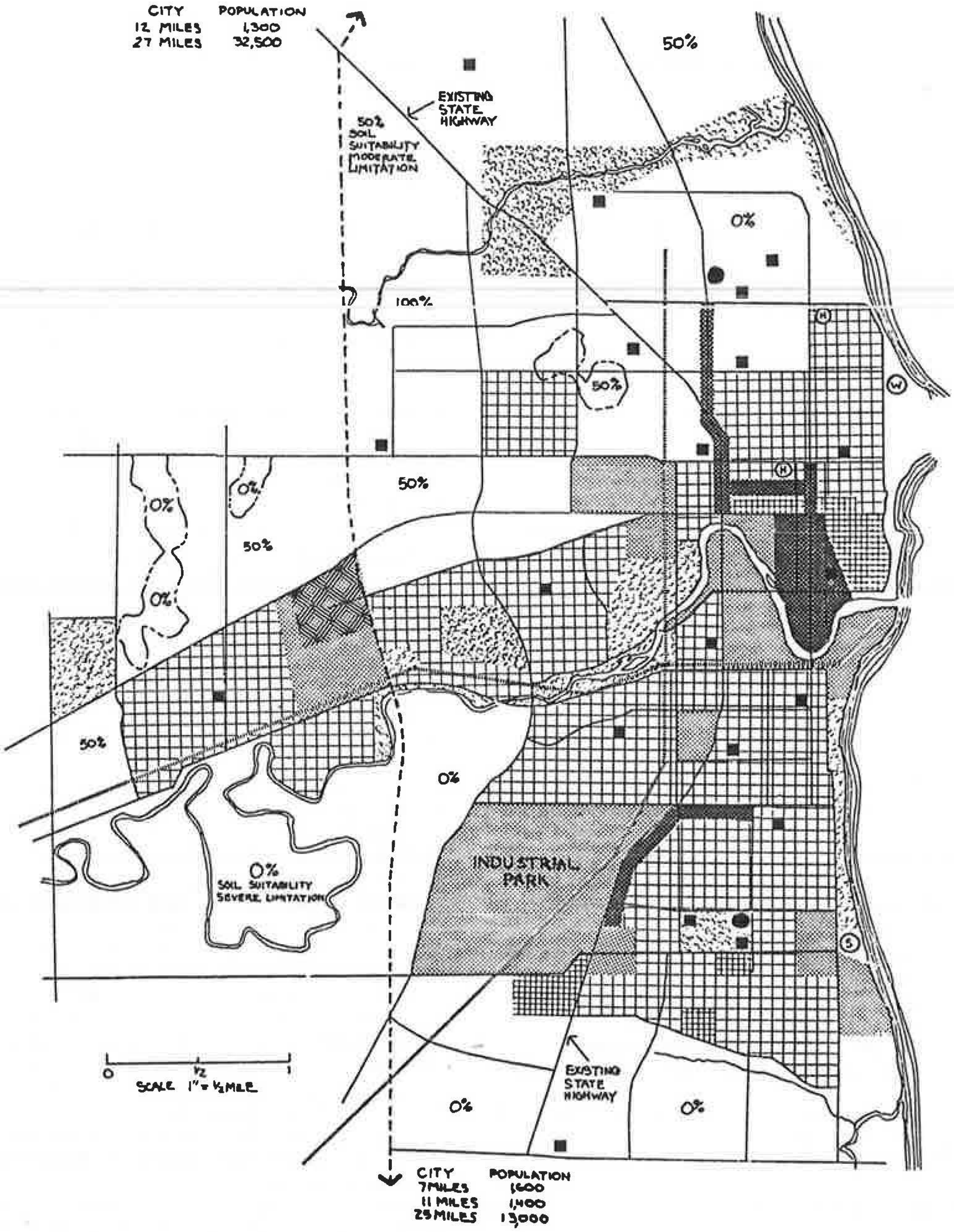

FIGURE 2 Expert panel's base map of Sheboygan.

descriptions contained information regarding size, government, economy, and concentration of employment. The project for Sheboygan was a freeway bypass, just west of the central city. The project for Wisconsin Rapids consisted of two events: (a) widening portions of an existing two-lane rural highway that is a major link in the state highway system, and (b) adding a bridge across the Wisconsin River so that traffic on this highway could bypass the CBD.

In the interest of expediting the first round, three sessions were held. Based on the location of panel members, one session took place in Madison, another group met in Milwaukee, and one individual completed the questionnaire for Round 1 in his Milwaukee office. The sessions were accomplished on three consecutive working days. Panelists were read a narrative of societal conditions in 1965 and given complete instructions for handling the features of the community development questionnaire and the map. A member of the study team was present to answer any questions, but the panelists were reminded not to interact. It was necessary to provide some clarification at each session, but the panelists were able to make their responses expeditiously.

Round 1 summarized responses for Round 2. The responses for Questions A, B, C, and D for each feature were tallied on a questionnaire as indicated in Figure 1. If the panelist believed that the community feature would be larger as a result of the project, the magnitude or degree of importance was recorded above the appropriate box on the questionnaire. On the other hand, if the community feature was judged to be smaller as a result of the project, it was recorded below the box. The reasons for no impact, given in response to Question E, were also recorded as shown in Figure 1. It was also necessary to provide a short addendum to the description of each city in response to questions raised by panelists at the time of the first round.

Composite maps for each land use activity (resi-

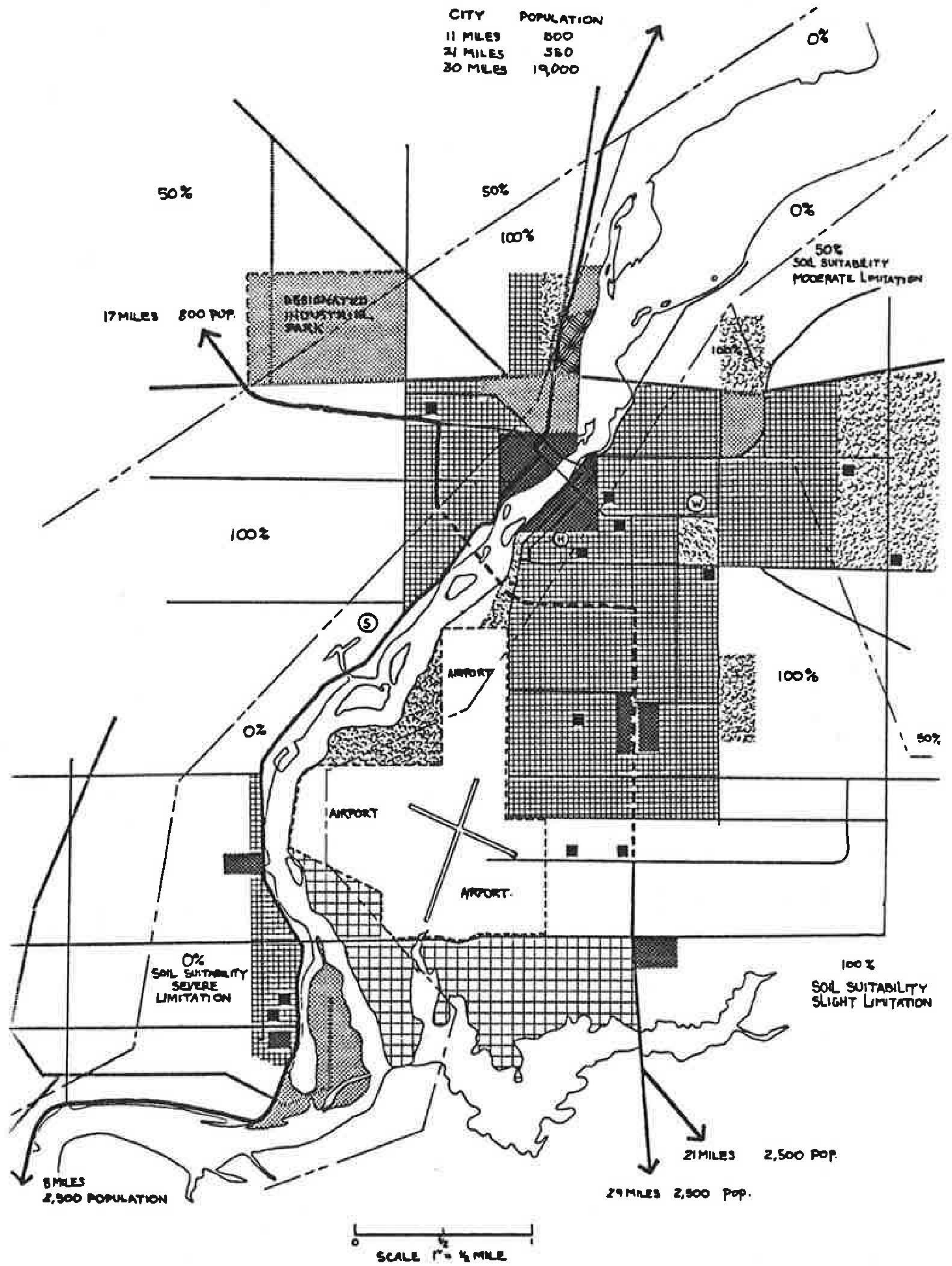

FIGURE 3 Expert panel's base map of Wisconsin Rapids.

dential, retail, service, and industrial) were developed from the information provided by Round 1. In the first round, panelists had one map on which they were to define the areas of impact for the different land use activities. In the second round, four maps were provided for each city, one for each activity, showing how all the panelists evaluated the areas of impact.

The second round, unlike the first, was conducted by mail. All the summaries compiled from Round 1 were mailed approximately 2 weeks after it took place. The following materials were provided for each city: general instructions; a features questionnaire with responses recorded; four maps showing the locations of impact on population, industry, retail, service (not retail); the original description of the city; and an addendum to the description with information requested by the panelists in the first round. The addendum for Sheboygan included a map showing planned interchanges.

In Round 2 panelists were asked to respond to exactly the same questions as they had previously answered. This gave them an opportunity to reevaluate their answers given the collective responses of the whole panel. Each of the maps now provided zones that could be selected as areas of impact. Panelists again used the color pencils to designate where impacts would occur. However, they were asked to show areas of positive impact in one color and areas of negative impact in another color.

In Round 2 the features of community development responses were tabulated in the same way as they had been in Round 1. Combined results of the map portion were produced by coloring zones to represent the number of panelists that said an impact would occur. Separate colors were chosen for: three to seven panelists indicating a positive impact would occur in a zone, more than seven panelists indicating a positive impact would occur in a zone, three to seven panelists indicating a negative impact would occur in a zone, and more than seven panelists indicating a negative impact would occur in a zone. The results in Round 2 displayed greater convergence and consensus than in Round 1, especially for Wisconsin Rapids.

EVALUATION OF THE FORECASTS

Because the panelists forecasted events that had already taken place, it was possible to evaluate the accuracy and usefulness of the technique. The results were presented to evaluation panels of local experts for review. These people had actually observed the changes that took place, and, therefore, were in the best position to assess the forecasts.

Separate evaluation panels were recruited for Wisconsin Rapids and Sheboygan. Each panel was made up of four individuals who were active in city planning or highway engineering. All evaluation panel members had lived in their respective cities for at least 20 years and were well aware of the impacts that their city had experienced. The evaluation panels were conducted according to the focus group technique.

The Wisconsin Rapids evaluation panel found the forecasting panel to be most accurate in predicting service and industrial impacts. Both the forecasting and evaluation panels agreed on the location of retail impacts, but the evaluation panel rated the magnitude and importance of retail impacts higher than the forecasting panel.

Overall, there was agreement about population impacts. However, some disagreements about population impacts occurred because the study team did not provide complete enough information to the forecasting panel; neither the maps nor the narrative provided any information about high water tables present in some potential growth areas. Also, the study team did not inform the forecasting panel about a large parcel of open land held by a local high school, which meant that the land was not available for residential development.

In Sheboygan the forecasting panel did not produce as strong a consensus as they had for Wisconsin Rapids. This made it more difficult to evaluate, but the Sheboygan evaluation panel agreed with most of the forecast. The closest agreement concerned the location of industrial activity. The forecasting panel was able to predict the development of a regional shopping center and to pinpoint its exact location. With only a few exceptions, there was agreement on the magnitude and importance of the 31 community features.

The evaluation panel in Sheboygan differed from the forecasting panel primarily on the map portion of the study. The location of retail (excluding the regional shopping center), service, and residential areas was only partially accurate. Again, the errors were traced to insufficient information being given to the forecasting panel. For example, access to areas near freeway interchanges was not fully described. The evaluation panel disagreed with the forecasted level of employment in community and neighborhood shopping centers and in some services. As in Wisconsin Rapids, the Sheboygan evaluation panel felt that the magnitude and importance of negative impact on retail in the CBD were stronger than forecasted.

Overall, the forecasting panel slightly underestimated the impacts in Wisconsin Rapids and slightly overestimated them in Sheboygan. Inaccuracies resulted chiefly from incomplete information. This does not indicate a serious flaw in the procedure. In this study it was necessary to reconstruct data from a much earlier year to be presented to a group of people who were unfamiliar with the cities. But when such an approach is implemented for a future project, the forecasting panel can and should include residents who would be much more informed about current conditions.

Both evaluation panels believed that the format of presenting maps and features of community development was useful. They had little trouble in understanding the forecasts, but tended to confuse measures of consensus as being measures of strength.

DISCUSSION AND CONCLUSIONS

A forecast using a structured expert panel can be conducted quickly and efficiently, and provides insights that only human expertise can supply. This study was completed in less than 2 months, once the instrument was developed. A structured expert panel is also a relatively inexpensive undertaking. Participants do not require sizable monetary compensation, and there is no costly equipment. A wide range of issues (including intangible ones), can be addressed. A strong consensus can be reached on difficult subjects; consequently, the results can be interpreted as more dependable than those of a single expert.

According to the evaluation panels, the forecasts were reasonably accurate and a good measure of agreement was present. Where the forecasts diverged from actuality, the divergence could usually be attributed to inadequate information presented to the panel. This problem could easily be avoided in actual practice because both more detail and respondents with greater knowledge of a particular city would be available. An ideal panel would consist of both local residents and outside experts. In addition, a limited amount of data could be collected between rounds if a strong need is indicated by the panelists.

The multiple-round format gave the panel a chance to request additional information, ask for clarification of information already provided, and to define their own zones for reporting impacts. In essence, the panel further refined the evaluation instrument as they completed the first round. A dynamic instrument is an important feature. It permits the panel to raise and evaluate issues that may have been overlooked by the study team and to discard issues it deems irrelevant.

It has been demonstrated that panelists are able to fully understand the development processes in cities the size of Sheboygan and Wisconsin Rapids. For small cities only a limited amount of information needs to be presented. Clearly, a panel could be overloaded with data when evaluating impacts in larger cities. However, it was not possible to determine from this study the maximum-sized city that could be evaluated with a structured expert panel.

It would have been possible to ask the expert panel to make projections for a future year (2010) but it would not have been possible to assess the accuracy of an expert panel for forecasting land use impacts. By projecting the present from 1965, accuracy could be tested. The experts did benefit from their own observations of other small cities over the previous 20 years. However, it is difficult to judge whether this knowledge unfairly strengthened the results of this study. Overall, this method of forecasting the present worked well and is recommended to others seeking to test forecasting techniques.

The first round of this study was conducted in group sessions to expedite the process. It would have been possible to conduct the entire procedure by mail, but long time delays would have resulted. The excessive time required to complete the San Jose study was considered problematical. If highway planners were to use this technique, such a time line would negate the usefulness of the findings. Although anonymity was violated by conducting the first round in group sessions, panelists were instructed not to discuss their opinions with other panelists. There was no evidence that this method of conducting Round 1 biased the results.

Traditionally, land use forecasting is done with a mathematical model. It is not the purpose of this paper to present an evaluation of that type of forecast. However, a Lowry-Garin model was used to forecast the impacts of the same project in Wisconsin Rapids. Results of the two methods can only be roughly compared. It was found that the expert panel produced a forecast that was very similar to that of the Lowry-Garin model, both in terms of size and location of impacts. Generally, the expert panel produced results with more texture but with less quantification.

Even though the results of an expert panel forecast are not quantifiable in the same manner as those produced by a mathematical model, they are not necessarily less reliable. Exposure to a vast array of sophisticated, computer-assisted techniques has created a natural tendency to rate these as most accurate. But a structured expert panel benefits from personal insight that would be difficult to incorporate into a mathematical model.

ACKNOWLEDGMENTS

The completion of this project was facilitated by data and information furnished by members of the central office and district staffs of the Wisconsin Department of Transportation. The authors thank the members of the expert panel, the two evaluation panels, and the Wisconsin Department of Transportation advisory committee. Agencies supplying data included the city of Sheboygan, city of Wisconsin Rapids, and Wood County. Special thanks are extended to Lynne Judd, principal contact at the Wisconsin Department of Transportation; Steve McEnroe, for preparing the graphics for the expert panel; Eric Hansen, for providing valuable criticism on all materials presented to the expert panel; Dan Pritchard, for suggesting the Wisconsin Rapids case study and organizing the Wisconsin Rapids evaluation panel; and Edward Beimborn, Director of the Center for Urban Transportation Studies. This research was sponsored by the Wisconsin Department of Transportation. The contract was administered through the Transportation Policy Studies Institute, University of Wisconsin--Madison.

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Safeguarding Suburban Mobility

ROBERT CERVERO

ABSTRACT

The suburban office boom of the past decade has flooded the outskirts of many metropolitan areas with unprecedented traffic, leading to major tie-ups that previously afflicted only downtown motorists. Some have forewarned that suburban congestion could become the dominant transportation issue in the late 1980s and 1990s. The congestion threat posed by rapid office growth on the metropolitan fringes is examined in this paper. The focus is on the roles of design, land use, and transportation management toward safeguarding suburban mobility. A national survey showed that extremely low densities and detached designs have rendered many new suburban office parks almost entirely dependent on the automobile. The absence of onsite consumer services, such as restaurants, as well as gross imbalances in the siting of jobs and housing along most suburban corridors have further reinforced workers' preferences for solo commuting. Some private-sector initiatives have been encouraging, notably ridesharing incentive programs, flextime work schedules, and cofinancing of needed infrastructure. Ordinances requiring developers to introduce such programs have also been enacted in several places around the country. Overcoming numerous institutional and logistical obstacles to traffic management in suburbia, however, remains a lofty, though not insurmountable, challenge.

Many American cities have witnessed an explosion of new office construction on their outskirts. Low-lying, campus-style projects are popping up in areas that only 10 years earlier were inhabited by cows and fruit groves. Combined with shopping malls, recreational theme parks, new subdivisions, and other mammoth land developments, outlying office centers are permanently reshaping the landscapes of suburban America.

The rapidity of suburban office development has been staggering. More than 80 percent of all office floor space in America's suburbs has been built since 1970 (1). By comparison, only 36 percent of all downtown office buildings have been built during the past 15 years. In some areas of the country, a tripling of current suburban office inventories has been projected by the century's end.

Although examples of the suburban office boom can be found almost anywhere, new construction has been particularly feverish on the fringes of rapidly growing sunbelt and western metropolises such as Atlanta, Dallas, Denver, Houston, and Orange County, California. Along Denver's southeast I-25 corridor, for example, a stretch dotted with office, high-technology, and business-executive parks, more office space has been produced than in all of downtown Denver (2). The suburban share of annual office construction in the Denver region has erupted from just 15 percent in 1970 to 73 percent in 1981 (1).

Even more mature eastern U.S. cities are undergoing visible suburban facelifts. In New York City, for example, the number of Fortune 500 firms headquartered in Manhattan dropped from 136 in the late 1960s to 65 in 1984 (3). Many have fled to neighboring Stamford, Connecticut, White Plains, New York, and Bergen County, New Jersey. By the late 1980s, more prime office space will exist in northeastern New Jersey than in midtown Manhattan (4).

The mobility implications of these recent trends are profound. As jobs continue to scatter along the urban fringes, regional commutersheds are taking on amoeba-like forms, fanning out as much as 100 mi in places such as Houston, Los Angeles, and San Francisco. No longer does the dominant commute pattern resemble the radial spokes of a wheel focused on a downtown hub. Rather, trips are becoming increasingly dispersed and crosstown in direction. In 1980, for example, more than 40 percent of all metropolitan work trips in the United States were suburb-to-suburb, compared with 20 percent between a suburb and central city (5). All signs point to a continued dispersal of regional trip-making in the future (6). Remarks one observer: "If present trends continue, suburban mobility--or rather the growing lack thereof--may well become the central transportation issue of the late 1980s" (7,p.285).

The scope of mobility problems brewing along many of America's urban fringes is examined in this paper. It draws on interviews of office developers as well as a 1984 survey of property managers from 120 of the nation's largest suburban office complexes. The 120 responses represent nearly 40 percent of 310 questionnaires sent out to managers of complexes with one-half million or more square feet of office floor space. Around two-thirds of the office centers surveyed were already completed whereas the remaining one-third were at varying stages of completion. Among the projects surveyed, the average office park had a labor force of 9,985 employees (standard deviation = 17,460), and contained 2.43 million ft^2 of floor space (standard deviation = 5.25 million), on a land parcel of 230 acres (standard deviation = 335 acres). Although difficult to generalize because of considerable sample variation, mammoth developments on the fringes of some of the largest metropolitan areas in the United States were largely captured in the survey.

DESIGN AND LAND USE CONSIDERATIONS

Project Scale and Density

The physical layout and land use composition of outlying office developments directly defines the kinds

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of traffic conditions that will exist, including the relative ease of site access, and even the modal preferences of employees commuting to and from work. Reasonably dense clusters of suburban employees are essential if public transit, private commuter buses, and carpools are to assemble trips without excessive route deviations and time delays. Although the service features of transit and vanpools, along with population densities at the residential ends of trips, are equally important, site design is the one area developers have direct control of.

Almost without exception, employment and land use densities of suburban business complexes fall far below those of their central business district (CBD) counterparts. The data in Table 1 reveal that, on average, floor area ratios (FARs), which is the gross floor space divided by total land area, for suburban office developments are roughly 1/25 of downtown FARs. This obviously reflects the difference in massing of CBD versus suburban office structures--downtown buildings usually reach towering heights on relatively small plots of land, whereas buildings in suburban office parks are typically low-rise on generous size land parcels. Within buildings themselves, suburban office employees generally enjoy twice as much elbow room as downtown workers: on average, around 380 ft^2 of gross floor space per worker in the suburbs versus 175 to 200 ft^2 in downtown settings. Thus, not only are downtown buildings much taller, but floor-by-floor use is more intense. The mammoth scale of most suburban office spreads is reflected in the final density measure given in Table 1. Generally, there is more than 30 times as much land area per worker in suburban versus downtown office settings, indicating that the advantages of space available to the worker at suburban workplaces are even greater once outside the building. In short, suburban office structures are much closer to the ground, as well as more spacious and remote, which results in extremely low employment densities.

Clearly, most contemporary office developments are predestined for automobile use. Particularly in the case of sprawling office parks where liberally spaced, horizontally scaled buildings dominate the landscape, the private automobile faces no serious competition to speak of. Where inwardly focused buildings stand adrift in a sea of surface parking, the pedestrian invariably faces long, laborious distances.

The overarching theme of recent suburban office park designs has been shaped less by utilitarian principles than by plain and simple aesthetics. Most developers hope that the emphasis on landscaping, spaciousness, and visual amenities will tip the scales in their favor in luring widely sought tenants, such as high-technology firms. Strict zoning codes and covenants only serve to reinforce the low-rise, wide setback profiles of most suburban office projects.

Building high-density, more village-like workplaces could go a long way toward attenuating the automobile's dominance in suburban work settings. Similarly, grouping buildings into community clusters, each well connected by walkways, trails, and plazas, could allow developers to maintain moderate densities while also encouraging nonvehicular circulation.

Current low-profile, physically fragmented office parks are by no means locked into this form in perpetuity. In several instances, sprawling complexes have been converted to denser, community designs over incremental phases. One notable example is the Denver Technological Center. This expansive 850-acre compound, first built in the early 1960s, has been transformed into a village-like development by architecturally integrating buildings using extensive walkways and traditional urban squares. Over time, the Technological Center's developers have proceeded to raise early suburban densities of FAR 0.25 to more urban densities of 1.0 to 2.0 (10). All future buildings will range from 4 to 24 stories, configured around campus clusters. Through a new design template, the Technological Center's metamorphosis from a suburban office spread to a fully integrated urban village has allowed it, in the words of the developer, to "survive and regenerate" (10).

Transportation Design Features

In addition to project scale and layout considerations, certain design treatments, such as the provision of convenient transit shelters and preferential parking, can influence the travel choices of suburban commuters. Although by themselves, such design details might appear to be trivial, their collective influences on mode choice can be equally important as more macrolevel design decisions.

One prominent feature of suburban office complexes is the abundance of free on-street parking. Currently, the average suburban office development provides 3.9 spaces per 1,000 ft^2, roughly one space per employee. A common practice is to overbuild parking beyond code requirements as a marketing strategy (11,12).

Providing bountiful, free parking can nevertheless be a costly proposition. A single parking space consumes roughly 350 ft^2 of real estate, and can cost from $1,500 to $3,000, including land (11). With today's liberal standard of nearly one space per worker, suburban parking lots can actually consume as much area as the buildings they serve. Sprawling lots also create long walking distances to building entrances, not to mention the isolating, patulous effects they have on building placements and access to street-side pathways and transit stops. The general rule of thumb for the maximum

TABLE 1 Comparison of Suburban and CBD Office Density Characteristics

	Suburban Office Complexes[a]				Approximate Difference Ratio of Suburbs to CBD
	Average	Low	High	CBD Range[b]	
Floor area ratio[c]	0.29	0.06	1.48	5.0-10.0 (varies widely)	0.04:1
Floor space per employee (gross ft^2)	380	140	970	175-200	2:1
Total land per employee (ft^2)	1,410	230	3,360	35-50	33:1

[a]Based on a national survey of 120 suburban office developments.
[b]See References 8 and 9 for sources.
[c]Floor area ratio represents gross floor space of all buildings divided by the total land area of the office development.

acceptable walking distance from a parking spot to an office's front door is about 300 ft. The national survey of 120 office parks revealed that in most cases walking distances tend to be far below this maximum: for more than two-thirds of the parks, average walking distances from parking lots to building entrances were under 100 ft, and for 95 percent of them, distances were shorter than 200 ft.

As an inducement to ridesharing, some suburban office developers set aside the most convenient parking spaces for carpools and vanpools. From the national survey, approximately 40 percent of all large-scale business parks currently offer preferential parking. On average, approximately 7 percent of all stalls are reserved for carpools and vanpools at these complexes, and the mean walking distance to building entrances for preferred parkers is slightly more than 50 ft.

Equally convenient terminuses for buses should also be designed into suburban work centers. Based on the national survey, around one-quarter of all suburban office parks currently have some type of onsite transit amenity, ranging from specially designated transit drop-off zones to the provision of plexiglas-covered bus shelters. The siting of convenient bus stops is particularly important if transit users are to receive a fair shake in relation to motorists. To date, they have not fared particularly well. From the survey, average walking distances between main building entrances and onsite bus stops are approximately 480 ft, more than 4 times as far as the average motorists has to walk. For office parks without any onsite transit services, the average walking distances from the nearest off-premises bus stop to the main building entrance is nearly two-thirds of a mile, roughly 30 times farther than most motorists have to walk. In a number of office park settings, access to offsite bus stops has been confounded by the presence of residential soundwalls, freeway interchanges, and other physical barriers. Overall, it is apparent that transit has been relegated by design to second-class status in many suburban work settings.

Land Use and Tenant Mix Considerations

Commuting practices of suburban office employees are influenced by more than just the immediate built environment. What takes place both inside and outside the physical confines of suburban office complexes, in terms of both land use and tenant mixes, usually affects worker commuting habits even more.

Over the past several decades, city planners have embraced the principle of land use mixing as a way of both enriching working and living environments and cutting down on vehicular trip-making. Opportunities for walking or cycling to work are greatly enhanced for employees who choose homes built either within or near an office or mixed-use compound. Jobs-housing balancing, then, is a potentially powerful means of safeguarding suburban mobility.

Currently, few suburban work centers in the United States have onsite housing. From the national survey, slightly less than 15 percent of suburban complexes with predominantly office functions have residential units for sale or lease on their premises. However, more than two-thirds of the survey respondents indicated that new housing construction was expected nearby, and approximately 62 percent believed that "a large amount" of housing already existed within 2 mi of their office site. Thus, many suburban office park settings could be characterized as having onsite provisions for housing, yet ample supplies close by. According to interviews, the overhwelming majority of suburban office developers believe that they have no responsibility for either building housing onsite or nearsite; rather, the general attitude appears to be that the marketplace will respond to the housing needs of office workers.

Nonetheless, there are a few outstanding examples of suburban office-housing intermixing. Table 2 gives 11 of North America's largest suburban office complexes that plan to have at least 1,000 or more residential units on their premises at buildout. Some of these projects, such as the City Post Oaks and South Coast Metro, represent large-scale, mixed-use complexes (7). These megacenters typically contain mid- to high-rise buildings along with massive concentrations of office workers and large resident populations

Some outlying communities have taken the integration of jobs and housing quite seriously. Costa Mesa, California, for example, requires developments such as the South Coast Metro (Table 2) to build residential units, either onsite or within the city limits, to house at least 20 percent of its workers. So far, 1,200 garden-style townhouse units have been

TABLE 2 Characteristics of Major North American Mixed-Use Office Developments at Buildout

Project and Metropolitan Area	Total Project Housing Units: Undetached Multifamily	Total Project Housing Units: Detached Single Family	Total Project Floor Space (%): Office[a]	Total Project Floor Space (%): Retail	Total Project Floor Space (%): Housing	Total Project Floor Space (%): Other[b]	Total Project Floor Space in Millions of Square Feet	Total Acreage	Mileage to Regional CBD
Los Colinas Urban Center, Dallas	4,000	1,000	55	10	10	25	11.7	960	15
Denver Technical Center, Denver	4,750	250	85	5	5	5	40.0	850	10
City Post Oak, Houston	6,000	0	70	14	8	8	30.0	1,200	6
The Woodlands, Houston	2,500	4,500	58	5	16	21	4.1	2,000	27
Playa Vista, Los Angeles	8,000	0	25	40	12	23	8.2	926	20
South Coast Metro, Los Angeles/Orange County	1,200	0	72	17	4	7	21.0	2,240	36
Warner Center, Los Angeles	4,000	0	61	23	8	8	7.6	1,100	25
Opus 2, Minneapolis	1,000	0	80	3	10	7	6.0	560	20
Harmon Meadows, New York/Newark	2,600	0	72	5	18	5	7.5	550	10
Chesterbrook, Philadelphia	3,400	370	20	3	56	21	5.5	995	17
Scarborough Town Centre, Toronto	4,000	500	54	20	17	9	5.5	330	15

Source: 1984 survey of office developments

[a]Office category includes traditional office, light industrial, and research and development (R&D) uses.
[b]Other category includes hotel, recreational, and institutional uses.

built within South Coast Metro. In other areas, however, there has actually been a public backlash against commingling housing and jobs in suburbia. In the Bay Area, for instance, developers of several large business parks were prohibited from constructing any housing onsite after areawide residents vehemently protested, fearing their neighborhood's image as a strictly zoned, upscale community would be tarnished.

Perhaps even more important than integrating homes and offices within a compound is the strategic balancing of jobs and housing at the subregional level, that is, providing enough homes within a 5-mi or more radius of all major employment centers. In many suburban areas, jobs and housing are in an alarming state of disequilibrium. Imbalances are particularly glaring around some of the nation's fastest growing suburban work centers. The ratio of employees to dwelling units stands at roughly 3:1 in Irvine and Santa Clare-Cupertino, California, 7:1 for City Post Oak, Texas, and 10:1 for the Westchester-El Segundo corridor of west Los Angeles, all of which have experienced phenomenal office growth over the past decade.

Clearly, the onus lies at the subregional level for balancing jobs and housing. Some progress has been made to date in coordinating both housing and job development. Both Costa Mesa and Santa Ana, California, for example, index incremental increases in allowable office and industrial floor space to housing availability. In both places, building permits for industrial and office construction are conditioned on adequate housing being provided for area workers.

Regardless of how many carrots or sticks are used to achieve equanimity in jobs and housing, there can be no guarantees that either average commuting distances will shrink or workers will begin abandoning their automobiles as a consequence. For one, although a numerical parity might be struck in a particular community, it will not necessarily be the case that those working in the municipality will occupy available in-town residences. At one suburban Los Angeles mixed-use megacenter, for instance, a recent survey conducted by project managers indicated that less than 10 percent of all residents living onsite or within several blocks of a complex actually worked there. It might very well be the case that some workers simply prefer a change of environment from where they spend their daylight hours to where they retire for the evening. Moreover, it is not clear that in cases in which housing has been provided onsite or nearby, that workers, many of whom earn clerical wages, can afford to purchase available units even if they wanted to. Finally, jobs-housing integration might also backfire by discouraging ridesharing and transit use. Building plentiful housing within a 3- to 5-mi zone of suburban office parks might result in commuting distances that are too far to walk or cycle, yet too close to efficiently organize carpools. Conceivably, the vehicle-miles traversed each day by 1,000 workers who live within a 5-mi radius of work and solo commute could exceed those of 1,000 coworkers who live 20 to 30 mi away and pool together in vans.

The need for fusing together suburban land use goes beyond job-housing integration. Unless restaurants, shops, and the like, are also sited close to employment centers, most suburban office workers will find it necessary to drive their own cars in order to access lunchtime destinations and run midday errands. From the national survey, the average distance from the geographic center of today's suburban office complexes to the nearest offsite retail establishment is 1.5 mi, clearly too far to walk during the normal 1-hr lunchbreak. Only a half dozen or so of the nation's largest suburban office complexes presently circulate shuttle buses between their complexes and nearby retail areas. Thus, the overwhelming majority of suburban office workers have to drive their own cars if they want to go anywhere at midday.

In recognition of the need to provide onsite consumer services, many suburban developers have begun integrating retail uses and ancillary functions into their projects. The national survey revealed that 42 percent of the largest office complexes currently have some supplementary retail or service function. By far, the most frequent type of onsite consumer function is eateries (40 percent of all respondents), ranging from formal restaurants to small delis. Other common onsite commercial activities include: convenience retail stores (17 percent of respondents), financial services such as banks (13 percent of respondents), assorted customer services such as gas stations (12 percent of respondents), and consumer merchandise shops such as clothiers (11 percent of respondents). Some of the larger-scale, mixed-use suburban work centers are given in Table 2.

THE ROLE OF SUBURBAN TRAFFIC MANAGEMENT PROGRAMS

Today a mixed bag of public programs and private initiatives are being pursued in the battle to stave off suburban traffic congestion. In contrast to the design and land use planning strategies just discussed, these efforts aim to change commuting preferences of suburban commuters and to creatively finance needed infrastructure. Programs that seek to modify travel demand typically involve the initiation of transportation system management (TSM) strategies, such as ridesharing and flextime programs. Financing programs, on the other hand, are generally supply-side and encompass both cooperative public or private cofunding, as well as legislative mandates to pay for subregional roadway improvements. As noted in the next paragraph, numerous obstacles (some social and institutional, others contextual), limit the effectiveness of many traffic management and funding programs in suburbia.

Before discussing the types of traffic management programs underway, current transportation supply and demand characteristics of suburban office complexes should be mentioned. Among the U.S. office developments surveyed, either controlled-access freeways or major four-lane arterials provided the primary access linkage to two-thirds of office parks' main entrances. Almost one-half of the office developers indicated a major freeway nearby, regardless of whether or not it served as the main thoroughfare leading into their complex. Around two-thirds of the respondents described current rush hour conditions on nearby roadways as either moderately or heavily congested. Nearly one-quarter believed traffic was fairly light, whereas 9 percent believed no access or circulation problems existed. Overall, it appears that as of the mid-1980s, most suburban office park settings are operating at tolerable congestion levels during peak hours, somewhere between 85 and 95 percent of roadway capacity. Because nearly one-third of the surveyed complexes have yet to reach buildout, and the vast majority expect higher future employment levels both onsite and nearby, traffic conditions can only be expected to worsen over time in many of these settings.

Transportation Management Associations and Ridesharing

Transportation management associations (TMAs), are effective coalitions for dealing with the knotty access problems found at many suburban work centers, especially ones that have poor transit services. Most associations, anywhere from 5- to 75-employer voluntary members strong, engage in a wide range of activities including: promoting ridesharing through computerized matching services, purchasing fleets of vans for employee pooling, underwriting internal shuttle services, financing areawide street improvements, and lobbying for suburban highway interests.

Despite the wide attention TMAs have received in transportation literature in recent years (13,14), according to the survey, only an estimated 4 percent of all large suburban office complexes nationwide currently support such programs. These complexes are found mostly in large suburban megacenters and areas that have critical masses of workers rather than along corridors with multiple small-scale office projects where they are often needed the most. Indeed, the cumulative traffic impacts of numerous loosely organized office and retail centers can be every bit as troublesome as large-scale megacomplexes. Among those developers currently involved with TMAs, the overhwelming majority believe their projects are more marketable as a result.

The most common activity of suburban-based TMAs is ridesharing coordination, although there are many more cases of individual employer-sponsored ridesharing campaigns. According to the survey, approximately 16 percent of large-scale office developments currently have some form of formal carpooling or vanpooling program. The majority of these have designated an employee as program coordinator, though most coordinators spend fewer than 10 hr per week on ridesharing matters. Statistically, the presence of a coordinator appears to be making a difference. The estimated share of employees pooling to work among all surveyed office parks was slightly less than 5 percent. Among those with coordinators, admittedly a small subsample, the share was 11 percent.

As discussed previously, the detached layouts and sheer enormity of many suburban office parks have discouraged ridesharing in many instances. Where few onsite consumer services, such as restaurants and banks, are available, the chances of successful ridesharing are even slimmer. The fear of being stranded without a car during midday is indeed one of the biggest deterrents to ridesharing in suburban work settings. A recent survey of 2,500 employees at the mixed-use South Coast Metro in Costa Mesa, California, for example, found that 45 percent needed their cars for personal reasons and 83 percent needed them to conduct business at least once a week. One way around this vehicular dependency problem would be to make company cars and idle vans available to rideshare participants during midday. To date, no TMA has sponsored such a floating vehicle program.

Transit and Other Market Strategies

Conventional fixed-route bus services are even less competitive with the private automobile in suburban office settings than vanpools. Densities on both residential and employment ends of suburban transit routes are often too low to make even a slight difference in areawide traffic conditions. In 1980, for example, while 8.0 percent of all 1980 journeys to work in U.S. metropolitan areas were via public transit, for commute trips made within suburbs the figure was only 1.6 percent (15).

For transit to realistically compete in sprawling suburban environs, major service reforms are called for. In light of the trend towards cross-haul commuting, radial downtown-oriented routes should, where possible, be converted into grid networks that use office parks, shopping malls, and other activity nodes as timed-transfer points. Perhaps even more important, flexible forms of mass transportation need to be fully exploited, such as shared-ride taxis and private buspools (16).

Allowing workers to arrive and depart at different times of the workday could help to spread out the rush hour crunch experienced along many suburban corridors. National survey results indicate that nearly 40 percent of all large suburban office developments have some form of modified work schedules: flextime, staggered work hours, or multiple work shifts. One of the more impressive programs is at the massive Warner Center mixed-use complex in the Los Angeles San Fernando Valley where over 3,000 employees of two large insurance companies presently enjoy flextime privileges. At both places, shifts begin and end every 15 min, from 6:00 to 9:00 a.m. and from 3:00 to 6:00 p.m. Surveys show that, given the chance, many workers have opted to arrive before the usual rush hours, take shorter lunch breaks, and leave work early, thereby accruing extra prime time daylight hours in the afternoon for themselves. However, several other suburban businesses around the country have scuttled their flextime programs because their office functions were considered highly time-interdependent.

Traffic Impact Ordinances

The threat of suburban gridlock has prompted an expanding roster of municipalities and county governments to introduce legislation aimed at either reducing vehicular trips or shifting funding responsibilities for roadway improvements to the private sector. Three major fronts of activity have been (a) trip reduction ordinances, (b) impact fee ordinances, and (c) parking reduction ordinances.

Trip Reduction Ordinances

These ordinances hold developers and employers to a stipulated phasedown in the percentage of solo automobile trips made to their establishments. They have been primarily passed in rapidly developing suburbs of California, including Placer County, Costa Mesa, and Pleasanton, although nearly two dozen other communities nationwide are seriously considering such legislation (4). To date, the most comprehensive, far-reaching trip reduction ordinance enacted is the one enacted in Pleasanton. Partly in response to concerns about the rapidly sprouting Hacienda Business Park, one of the largest office compounds nationwide, the city of Pleasanton passed the ordinance requiring all employers with 50 or more persons to institute various TSM programs, such as ridesharing, in order to trim peak trips by 45 percent, assuming that all workers would normally drive alone (17). Companies failing to comply with any parts of the ordinance would be subject to fines of $250 per day.

Table 3 gives both the advantages and disadvantages of the trip reduction approach. Compared to traffic impact programs, trip reduction ordinances grant employers a fair degree of latitude in dealing with their own specific mobility problems. These ordinances usually also apply to all large employers, and not just to the tenants of new developments. Because everyone is generally "in the same boat," they can promote intercompany coordination of ridesharing. Moreover, they respond to suburban mobility problems by attempting to modify travel behavior rather than increasing the vehicle-carrying capacity of thoroughfares. However, the true litmus test of a trip reduction ordinance is whether it can actually be enforced. In Costa Mesa, even though several large

TABLE 3 Advantages and Disadvantages of Transportation Ordinances in Suburban Settings

Type Of Ordinance	Ordinance Areas	Advantages	Potential Problems
Trip reduction	Placer County, Calif. Costa Mesa, Calif. Pleasanton, Calif. Fairfax County, Va.	Employer latitude Equitable Demand-oriented	Enforcement Survey errors Individual employer emphasis
Impact fee	Costa Mesa, Calif. Santa Ana, Calif. Irvine, Calif. Los Angeles, Calif. San Diego, Calif. Carlsbad, Calif. Fairfax County, Va. Montgomery County, Md.	Benefit assessment Pools fund for area improvements	Equity concerns Measuring per trip costs Tempo/timing problem Supply-side bias Possible jurisdictional gaps
Parking reduction	Los Angeles, Calif. Palo Alto, Calif. Orlando, Fla. St. Petersburg, Fla. Montgomery County, Md. Hartford, Conn. Bellevue, Wash.	Promotes ridesharing Cost savings to developer	Parking perceived as proven, risk-free and permanent Ridesharing considered risky Resistance from lenders Administrative problems

office projects have been approved over the past 5 years with specific TSM conditions attached, to date little progress has been made monitoring toward meeting conditions (18). Furthermore, because surveys of employee commuting are generally required only once every year or so, there is always a possibility of unrepresentative sampling. Some employers have expressed contempt about the peremptory tone of these ordinances, preferring instead programs based more on voluntarism. Finally, by focusing primarily on in-house efforts to cope with traffic, almost literally on a building-by-building basis, these ordinances could have the perverse effect of turning attention away from communitywide mobility problems.

Traffic Impact Fee Ordinances

A more common legislative approach to suburban traffic management has been the exaction of impact fees. Rather than assessing individual landowners based on their real property valuations, these ordinances collect monies according to how much traffic a future development will likely generate. By far, the largest number of traffic impact ordinances have been enacted in Southern California, though they can be found in Colorado, Florida, New Jersey, and around metropolitan Washington, D.C., as well (7).

The most ambitious impact fee programs today are found in Los Angeles County. In Los Angeles' Century City and Westwood Districts, both major centers of brisk office construction, developers pay a one-time fee of almost $1,000 for each afternoon peak trip generated on an average weekday. Moreover, in the booming Westchester area near Los Angeles international airport, an ordinance that exacts a one-time fee of $2,010 per peak hour automobile trip was recently passed. In all three districts, covenants affixed to land parcels bind all tenants to participate in TSM programs. Developers can receive credits against their fee obligation by introducing vanpooling, dedicating land for transit centers, and pursuing other mitigation programs.

The major advantage of impact fee ordinances is that they are based on proven principles of welfare economics (see Table 3); those who impose the cost of increased congestion should pay for whatever public improvements are necessary to correct them. Impact fees likewise appeal to many suburbanites' sense of equity; those benefitting most directly from the construction of freeway interchanges and arterial widenings should pick up the tab. Another major selling point is that impact fees generate a pool of funds for financing areawide, rather than just nearsite, transportation improvements. Thus, by establishing a trust fund, fee ordinances ensure that developers are responsible for more than just their own immediate problems.

However a number of stumbling blocks still stand in the way of wide-scale adoption of traffic impact legislation. One issue concerns equity. In almost all cases, fees are only passed on to new future projects. Residential and retail projects are often exempt from fee requirements. Some developers charge that they are being forced to pick up the bill for costly infrastructural improvements while previously existing establishments whose businesses contribute equally to traffic snarls pay nothing. Developers are not only concerned about others getting a free ride, but also about possibly having to pay for past traffic planning mistakes and oversights. Compounding matters even more is the inability to accurately gauge the true marginal cost of each additional rush hour trip generated by a new suburban project. Standard trip generation rates are often used, although most have been empirically derived from urban-like settings and do not necessarily reflect current or future suburban travel behavior.

Another problem with these ordinances is the mismatch between when impact fees are colleted and when actual improvements are made. Fees are usually assessed and collected before the issuance of building permits and occupancy certificates, and funds are accumulated in a reserve account for financing future projects. In several instances, this cash flow problem has been to the consternation of developers who have paid large sums of money to trust accounts only to see no actual roadway improvements implemented. Other potential problems with these ordinances are their distinct pavement and concrete, supply-side bias and the possibility that abstention of a single municipality from a subregional fee assessment program could leave crippling gaps in a major new thoroughfare system.

Parking Reduction Ordinances

In Los Angeles, Orlando and St. Petersburg, Florida, and several other communities around the country, ordinances allow developers to reduce expensive code-required parking as a quid pro quo for commitments to ridesharing. In both Florida communities, for example, builders have the option of contributing to a TSM fund in lieu of providing the usual four parking spaces per 1,000 ft² of office space (7).

To date, parking reduction ordinances have had little success in inducing developers to purchase employee vans instead of paved over parking lots. In Los Angeles the local ordinance allowing up to a 40 percent reduction in code-required parking has failed to attract a single taker during its inaugural 2 years (19). Many developers consider the trade-off of parking for vanpools simply too risky. Parking is widely perceived as a one-time, upfront investment with a proven track record. Moreover, it is a permanent fixture to the land. In contrast, suburban ridesharing programs are largely untested, require ongoing funding support, and are impermanent. A ridesharing program can fold at any time, either as a result of a sudden plunge in gasoline prices or changes in commuting preferences. Equally important, perhaps, is the fact that some banks and lenders have frowned on past attempts to introduce below-standard parking in suburbia, threatening to withdraw investment loans unless universally accepted parking levels are provided. Some developers have also avoided parking programs because of the lengthy delays in processing and approving requests as well as the absence of explicit criteria for evaluating success of ridesharing substitution.

Cooperative Agreements and Financing

Not all private developers have been coerced into financing offsite transportation improvements, and not all municipalities have chosen the ordinance route in battling suburban congestion. Increasingly, both parties are entering into ad hoc, cooperative agreements that spell out mutual funding responsibilities for offsite roadway improvements.

Based on the national survey, an estimated 68 percent of all suburban office developers have helped pay for offsite roadway improvements. More than one-half of these public-private coventures have involved cofinancing of areawide traffic control improvements, such as installing computer-controlled signal networks. Some of the largest private sector contributions for offsite suburban roadway improvements recorded to date are given in Table 4. Together, more than $300 million has already been spent on or pledged toward major infrastructure in the vicinity of 13 rapidly expanding office corridors in nine major U.S. metropolises. The most generous contribution to date has come from the developers of the Hacienda Business Park in Pleasanton where more than $80 million has been committed toward major freeway and arterial investments, as well as the construction of areawide pedestrian and cycling trails, residential sound barriers, and flood control canals (7).

The major advantage of cooperative financing to a developer is that, unlike trust fund programs, he has some direct control over how his contributions are spent. Through the process of negotiations, developers can usually secure guarantees that certain pet projects will be funded. The major drawback of the negotiated approach appears to be that in almost all instances to date, funding has gone to nearsite, rather than subregional, roadway improvements. The emphasis appears to be more on resolving front-entrance access problems than relieving the downstream effects of, for example, 50,000 new peak trips generated by a colossal employment center that just opened. Nearsite investments can contribute little to the vehicular capacity of an area if other regional improvements are not built in tandem. This lesson was brought to light in the case of a $9 million developer financing of a four-lane highway expansion in McLean, Virginia, that abruptly changes into a narrow two-lane road at the owner's property line (20).

CONCLUSIONS

America's suburbs certainly are not lacking in technical know-how for dealing with traffic congestion. An assortment of strategies (some design- and land-use-oriented, others involving creative institutional arrangements and financing), are viable candidates for safeguarding suburban mobility. Still, the effects of any one or two efforts are apt to be marginal, at best, over the long run. In tandem, however, the right cluster of design, land use, and transportation management tools could mark the difference between choked and free-flow travel conditions. In many suburban corridors, all it takes is a 3 to 5 percent reduction in peak hour traffic to free up clogged arteries and restore circulation. However, more will be needed than just additional capacity. Quick fixes that ignore more systemic problems such as jobs-housing imbalances are ultimately doomed for failure. What is called for is a

TABLE 4 Major Private Sector Contributions to Roadway Improvements Outside of Metropolitan CBDs

Metropolitan Area	Contributor	Amount ($000,000s)	Location and Types of Improvements
Denver	Joint Southeast Public Improvement Authority	23[a]	Highway upgrading in Southeast Denver area
Houston	West Houston Association	8.5	New four-lane arterial in West Houston
	Several Private Developers	2.3	New interchanges and ramps on Katy Freeway
Los Angeles	Private Developer	4.0	Assorted roadway improvements in Universal City area
	Private Developer	30[a]	Interchange ramps and signal upgrading in Westchester District
New York/Newark	Private Developer	11	Highway, bridge, and freeway off-ramp improvements in the Meadowlands
Orange County, Calif.	Private Developer	65[a]	Freeway, parkway, ramps, and signal improvements for Irvine Spectrum
	Private Developer	1.3	Traffic control in Newport Beach area
Philadelphia	Private Developer	2.0	Freeway interchange near the Chesterbrook Corporate Center
San Diego	Private Developer	57.5	New arterials, freeway overpasses, and signal upgrades for north county area
San Francisco	Private Developer	14	Freeway interchange, signal upgrade, and road widening in San Ramon
	Private Developers	85	Freeway interchanges, computerized signaling, soundwalls, and landscaping in Pleasanton
Washington, D.C.	Private Developers	22	New highway and overpass in Fairfax County and Tysons Corner area

Source: Survey results.

[a]Proposed private contribution.

more strategic planning approach whereby both public and private interests work together in crafting the right balance of design, land use, and traffic management programs tailored to specific suburban needs.

Any viable and lasting effort must also go beyond simply implementing a checklist of TSM and design improvements. Major institutional, political, and behavioral impediments have to be dealt with as well. Indeed, overcoming resistance to limits on suburban parking or the distrust some suburbanites have of mixed land uses pose far greater challenges than adding new freeway interchanges or generating computerized carpool matchlists.

One common denominator of nearly all successful suburban transportation programs to date has been the expanding role of the private sector. Whether through designing in-transit amenities or financing offsite roadway improvements, businesses and developers are emerging as leaders in the war against suburban traffic congestion. Most are more than willing to pay their fair share simply because they realize the long-term profitability of their investments hinges crucially on good access and liveable suburbs.

Overall, recent progress toward safeguarding suburban mobility has been encouraging, although much remains to be done. Clearly, heading off suburban gridlock in the years to come depends on both public and private interests working closely together, each levering its own resources and unique abilities toward this pursuit.

ACKNOWLEDGMENT

This paper was supported through a grant from the Institute of Transportation Studies at the University of California, Berkeley.

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Transportation Employment as a Source of Regional Economic Growth: A Shift-Share Approach

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ABSTRACT

The U.S. economy is experiencing major structural and regional adjustments as it develops into an information-oriented society. Traditional (heavy) manufacturing is threatened by overseas competition while young high technology and service industries are burgeoning. In addition, a major shift in population and employment is observed from Old North to Old South and to the West. Such economic and societal transformations can be expected to affect significantly the transportation economy. By means of a shift-share analysis, the changing size and distribution of transportation employment between 1969 and 1982 is documented. The Northeast and Midwest are losing competitive share in all two-digit standard industrial classification (SIC) transportation categories except transportation services. In this paper background is provided for regional theorists interested in regional configurations, transportation planners, and economic development specialists determined to capitalize on comparative advantages of their respective states and localities. The aim is to document, rather than explain, regional shifts in transportation employment.

The quest to determine relationships between transportation, investments, and economic activity has proven to be more complicated and intractable than originally conceived. Location theorists have demonstrated that transportation in the abstract is a major determinant in location decisions and urban or regional form (1,2). However, the impacts of investments in many basic forms of public works are indirect, subtle, and possibly variable over the growth stages of an urban or regional economy.

Attempts to demonstrate these relationships focus on one or the other side of the "chicken and egg" problem: Transportation investments affect economic growth, while economic activity spurs transportation development. Even if a complex model of simultaneous equations were built, findings would probably be inconclusive because of uncontrollable variables. Furthermore, the marginal productivity of infrastructure investment over the life cycle of regional economies is seldom considered. Research findings do suggest that in the early stages a highway network exhibits developmental stimulus, while in later stages it acts more as an agent of personal mobility (3,4).

In this paper a different approach is taken to the transportation-economy question by examining shift in the size and location of the transportation sector of the economy. The U.S. economy is at an advanced stage of sophistication in the sense that the transportation infrastructure and related economic institutions are well established. The distribution and spatial and temporal changes of transportation employment are of considerable interest to state and local economic development and transportation planning officials.

The purpose of this paper is to document regional shifts in transportation employment that result from, or possibly stimulate, regional shifts in U.S. economic activity, especially from North to South and West. The paper is only indirectly concerned with transportation investments as a measure of industry economic activity. Focus is on general economic activity in transportation that is driven, interalia, by regional economic vitality and the availability of prior and ongoing infrastructure investments.

From a theoretical viewpoint, this study adds to documentation of major regional and axial shifts now occurring in the U.S. spatial economy. For infrastructure planners and economic development specialists, it provides information on regions and states that are winning and losing in the transportation sector and where opportunities for growth in transportation employment might lie.

BACKGROUND

Approaches

Approaches to the study of transportation and economy have focused largely at the macro- or microlevels. Studies at the mesolevel such as that presented in this paper are in shorter supply.

At the macrolevel, cost of transportation considerations have been central to the formulation of location theories (1) and urban spatial structure models (2). Alongside this theory-building, numerous empirical studies explored transportation as a derived demand, dependent on economic activities, or as a determinant of new production possibilities and demographic change. Using multivariate statistical techniques, some generalizations for highway networks include the following:

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1. In the early stage of the development of a regional economy the highway network is insufficient to stimulate development,

2. In the second stage it is an agent for physical development, and

3. In the third state it shifts to becoming a mobility asset (3,4). Known as the "saturation shift theory," (5) these findings feature transportation as a shifting stimulus to economic activity over regional economic growth stages. Shifts are also observable in terms of the location and distribution of transportation employment in mature economies as discussed later.

At the microlevel much is known about the relationships between new transportation investment and economic development. Indirect local economic and developmental impacts of transit investment, for example, can be characterized and operationalized in computer impact models (5).

It is at the mesolevel that economy and transportation studies appear to be less abundant. Wheat pointed out in 1969 that little was known about whether superior transportation significantly influences manufacturing growth in small to midsized urban areas. Apart from his work in the early 1970s, little is known about a topic that has potentially far-reaching implications for highway and airport investment strategies to enhance economic development. The quest to position regions, states, and localities for economic opportunities and growth generates a need for semiaggregated or segmented data. This paper adds to this body of literature by segmenting growth in transportation employment subcategories for the United States using shift-share analysis.

Regional and Axial Shifts in the U.S. Spatial Economy

The Northeast and Midwest are losing out to growth in the Southeast, South, Southwest, and West. This is evidenced by population movements, as well as shifts in industrial location and employment. The Northeast always has been a net out-migration region. The sudden change in pace and destination of population movement beginning in the 1970s is significant. Although the West and Southwest show gains in population, dramatic growth appears in the South. This might be interpreted as a direct transfer from the Old North to the Old South (8).

Among the many factors hypothesized as contributing to this regional reorientation is the controversial notion that an axial shift is occurring in transportation movements. Vining et al. point to an obscure proposition that the natural grain of the U.S. landscape is north-south, and that high costs are associated with maintaining the principal east-west axis of the U.S. space economy (8). Given a weakening of conservative values and a liberalizing of institutions in the South after the 1960s, along with such physical improvements as air-conditioned comfort, the South has shown rapid growth since the mid-1960s.

Research Question

The central focus for inquiry is whether regional and axial shifts are having an effect on the spatial pattern of the transportation sector. Particular attention is given to north-south shifts in the share of transportation employment as indicated between the East North Central states of Illinois, Indiana, Michigan, Ohio, and Wisconsin; and the East South Central, and South Atlantic states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, and South Carolina). Six of the top ten trucking states are included in this group (9).

DATA

As is commonly the case in shift-share studies, this analysis uses employment data as an indicator of industry economic activity. For an industry such as transportation, in which many of the work elements are nonroutine, and thus dependent on human resources, employment is a sound surrogate measure of general economic activity. County business patterns are used for employment data. The advantages of these data are that data from this source are provided annually allowing selection of appropriate years for comparison, and employment data are available by standard industrial classification (SIC) to two or more digits by state. Disadvantages of these data are that they do not include railroad workers, single employed persons, and government workers (nonfederal) and that some definitions have changed during the past 20 years causing some discontinuities for trendline analysis (10).

The period 1969 through 1982 is used for the analysis because 1969 was characterized by strong economic performance and 1982 was characterized by poor economic performance. In business cycle terms, employment changes were thus computed between peak and valley years, which will tend to give a conservative estimate of growth rates. Data were compiled and analyzed on a year-by-year basis to confirm this conclusion.

Employment growth is compared for the following transportation-related industries:

- Total transportation, communications, and public utilities (SIC 4). See Table 1;
- Local and interurban passenger transit (SIC 41). See Table 2;
- Trucking and warehousing (SIC 42). See Table 3;
- Water transportation (SIC 44). See Table 4;
- Air transportation (SIC 45). See Table 5;
- Pipelines (SIC 46). See Table 6; and
- Transportation services (SIC 47) that include freight forwarding, arranging transportation services (including ticketing, railcar and motor vehicle rentals), weigh station, and regulatory activity. See Table 7.

For Tables 1 through 7, note that the County Business Pattern employment data is based primarily on the number of employees reported on U.S. Treasury Form 941 by single-establishment firms for the mid-March pay period each year. The employment figures do not include most self-employed persons or those employed by state and local governments and railroads. Consequently, figures derived from the course will be less than most other estimates of labor-force size.

METHODOLOGY

Shift-share analysis is an approach for identifying the differences in the rates of growth among two or more regions or states. The shift-share analysis specifies those parts of employment change within an industry that are attributable to (a) national total employment growth, (b) employment growth in the industry under analysis, and (c) a state's growth within a particular industry. The shift-share technique helps answer two basic questions about a par-

TABLE 1 Employment Change in Transportation, Communications, and Public Utilities Between 1969 and 1982 (SIC 41, 42, 44, 45, 46, 47, 48, 49)

Region, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to National Growth	Industry Mix	Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST							
New England	196,740	223,509	13.61	62,662	(13,595)	(22,291)	26,769
Maine	12,838	14,899	16.05	4,089	(887)	(1,141)	2,061
New Hampshire	10,009	14,177	41.64	3,188	(692)	1,672	4,168
Vermont	6,397	7,760	21.31	2,037	(442)	(232)	1,363
Massachusetts	106,569	113,047	6.08	33,942	(7,364)	(20,100)	6,478
Rhode Island	14,383	12,188	(15.26)	4,581	(994)	(5,782)	(2,195)
Connecticut	46,544	61,438	32.00	14,824	(3,216)	3,286	14,894
Middle Atlantic	842,916	822,101	(2.47)	268,469	(58,245)	(231,043)	(20,815)
New York	479,919	416,393	(13.24)	152,854	(33,162)	(183,218)	(63,526)
New Jersey	144,221	186,538	29.34	45,934	(9,966)	6,348	42,317
Pennsylvania	218,776	219,170	0.18	69,680	(15,117)	(54,169)	394
NORTH CENTRAL/MIDWEST							
East North Central	671,992	712,948	6.09	214,029	(46,435)	(126,639)	40,956
Ohio	173,756	183,251	5.46	55,341	(12,007)	(33,840)	9,495
Indiana	75,787	91,530	20.77	24,138	(5,237)	(3,158)	5,743
Illinois	231,183	227,890	(1.42)	73,632	(15,975)	(60,950)	(3,293)
Michigan	127,829	131,064	2.53	40,714	(8,833)	(28,646)	3,235
Wisconsin	63,437	79,213	24.87	20,205	(4,383)	(45)	15,776
West North Central	280,659	354,972	26.48	89,390	(19,394)	4,317	74,313
Minnesota	63,401	84,260	32.90	20,193	(4,381)	5,047	20,859
Iowa	38,352	45,413	18.41	12,215	(2,650)	(2,504)	7,061
Missouri	104,905	121,367	15.69	33,412	(7,249)	(9,701)	16,462
North Dakota	8,148	13,589	66.78	2,595	(563)	3,409	5,441
South Dakota	8,679	11,858	36.63	2,764	(600)	1,014	3,179
Nebraska	23,639	30,408	28.63	7,529	(1,633)	873	6,769
Kansas	33,535	48,077	43.36	10,681	(2,317)	6,178	14,542
SOUTH							
South Atlantic	503,877	728,426	44.56	160,485	(34,818)	98,882	224,549
Delaware	9,290	12,320	32.62	2,959	(642)	713	3,030
Maryland	66,700	74,122	11.13	21,244	(4,609)	(9,211)	7,422
Virginia	73,477	100,167	36.32	23,405	(5,077)	8,362	26,690
West Virginia	28,052	29,078	3.66	8,935	(1,938)	(5,969)	1,026
North Carolina	79,231	117,872	48.77	25,235	(5,475)	18,881	38,641
South Carolina	28,984	40,794	40.75	9,231	(2,003)	4,582	11,812
Georgia	84,901	133,486	57.23	27,041	(5,867)	27,415	48,585
Florida	133,242	220,585	65.55	42,438	(9,207)	54,110	87,343
East South Central	160,827	226,833	41.04	51,223	(11,113)	25,896	66,006
Kentucky	38,590	52,067	34.92	12,291	(2,667)	3,851	13,477
Tennessee	49,477	71,593	44.70	15,754	(3,419)	9,777	22,116
Alabama	49,775	68,783	38.19	15,853	(3,439)	6,595	19,008
Mississippi	22,985	34,390	49.62	7,321	(1,588)	5,673	11,405
West South Central	349,283	592,959	69.76	111,246	(24,135)	156,565	243,676
Arkansas	23,516	33,991	44.54	7,490	(1,625)	4,609	10,475
Louisiana	72,899	122,563	68.13	23,218	(5,037)	31,485	49,664
Oklahoma	48,326	72,427	49.87	15,392	(3,339)	12,048	24,101
Texas	204,542	363,978	77.95	65,147	(14,134)	108,428	159,436
WEST							
Mountain	133,072	249,399	87.42	42,383	(9,195)	83,139	116,327
Montana	10,477	16,231	54.92	3,347	(734)	3,141	5,754
Idaho	10,039	14,713	46.56	3,197	(694)	2,171	4,674
Wyoming	6,473	12,469	92.63	2,062	(447)	4,381	5,996
Colorado	41,272	77,931	88.82	13,145	(2,852)	26,366	36,659
New Mexico	15,047	25,124	66.97	4,792	(1,040)	6,324	10,077
Arizona	23,174	49,465	113.45	7,381	(1,601)	20,511	26,291
Utah	16,447	31,746	93.02	5,238	(1,136)	11,197	15,299
Nevada	10,143	21,720	114.14	3,230	(701)	9,047	11,577
Pacific	534,118	749,412	40.31	170,117	(36,908)	82,085	215,294
Washington	58,492	79,236	35.46	18,629	(4,042)	6,156	20,744
Oregon	39,156	51,815	32.33	12,471	(2,706)	2,893	12,659
California	410,162	573,658	39.86	130,637	(28,342)	61,201	163,496
Alaska	7,449	16,258	118.26	2,373	(515)	6,951	8,809
Hawaii	18,859	28,445	50.83	6,007	(1,303)	4,883	9,586
United States Industry Employment	3,703,344	4,626,875	24.94				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

TABLE 2 Employment Change in Local and Interurban Passenger Transit Between 1969 and 1982 (SIC 41)

Re ion, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to National Growth	Industry Mix	Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST							
New England	30,305	28,430	(6.19)	9,652	(18,535)	7,007	(1,875)
Maine	1,165	913	(21.63)	371	(712)	89	(252)
New Hampshire	1,044	1,539	47.41	333	(639)	801	495
Vermont	677	580	(14.33)	216	(414)	101	(97)
Massachusetts	18,556	15,119	(18.52)	5,910	(11,349)	2,002	(3,437)
Rhode Island	1,896	1,694	(10.65)	604	(1,160)	354	(202)
Connecticut	6,967	8,585	23.22	2,219	(4,261)	3,660	1,618
Middle Atlantic	135,936	74,500	(45.19)	43,296	(83,138)	(21,593)	(61,436)
New York	89,873	38,922	(56.69)	28,624	(54,966)	(24,609)	(50,951)
New Jersey	16,545	15,318	(7.42)	5,270	(10,119)	3,622	(1,227)
Pennsylvania	29,518	20,260	(31.36)	9,401	(18,053)	(606)	(9,258)
NORTH CENTRAL/MIDWEST							
East North Central	64,854	37,255	(42.56)	20,656	(39,665)	(8,593)	(27,599)
Ohio	13,509	5,560	(58.84)	4,303	(8,262)	(3,989)	(7,949)
Indiana	4276	3,064	(28.34)	1,362	(2,615)	41	(1,212)
Illinois	29,088	14,779	(49.19)	9,265	(17,790)	(5,783)	(14,309)
Michigan	9,316	4,101	(55.98)	2,967	(5,698)	(2,485)	(5,215)
Wisconsin	8,665	9,751	12.53	2,760	(5,300)	3,625	1,086
West North Central	21,978	19,454	(11.48)	7,000	(13,442)	3,918	(2,524)
Minnesota	8,172	8,101	(0.87)	2,603	(4,998)	2,324	(71)
Iowa	2,382	1,372	(42.40)	759	(1,457)	(312)	(1,010)
Missouri	7,706	5,799	(24.75)	2,454	(4,713)	352	(1,907)
North Dakota	592	-	-	188	(362)	-	-
South Dakota	510	737	44.51	162	(312)	376	227
Nebraska	1,580	1,086	(31.27)	503	(966)	(31)	(494)
Kansas	1,628	2,359	44.90	518	(996)	1,208	731
SOUTH							
South Atlantic	32,404	24,737	(23.66)	10,321	(19,818)	1,831	(7,667)
Delaware	1,004	1,350	34.46	320	(614)	640	346
Maryland	5,972	4,319	(27.68)	1,902	(3,652)	97	(1,653)
Virginia	7,984	4,910	(38.50)	2,543	(4,883)	(743)	(3,074)
West Virginia	1,938	1,158	(40.25)	617	(1,185)	(212)	(780)
North Carolina	4,644	3,264	(29.72)	1,479	(2,840)	(19)	(1,380)
South Carolina	1,240	-	-	394	(757)	-	-
Georgia	3,240	2,425	(25.15)	1,032	(1,982)	135	(815)
Florida	7,622	7,311	(4.08)	2,428	(4,662)	1,923	(311)
East South Central	10,996	7,102	(35.41)	3,502	(6,725)	(671)	(3,894)
Kentucky	3,747	1,475	(60.64)	1,193	(2,292)	(1,174)	(2,272)
Tennessee	4,054	3,049	(24.79)	1,291	(2,479)	183	(1,005)
Alabama	2,339	1,825	(21.98)	745	(1,431)	171	(514)
Mississippi	856	753	(12.03)	273	(524)	148	(103)
West South Central	17,459	15,452	(11.50)	5,561	(10,678)	3,109	(2,007)
Arkansas	1,041	791	(24.02)	332	(637)	55	(250)
Louisiana	4,038	3,686	(8.72)	1,286	(2,469)	831	(352)
Oklahoma	1,304	1,196	(8.28)	415	(798)	274	(108)
Texas	11,076	9,779	(11.71)	3,528	(6,774)	1,949	(1,297)
WEST							
Mountain	8,702	13,845	59.10	2,772	(5,322)	7,694	5,143
Montana	802	1,148	43.14	255	(491)	582	346
Idaho	674	735	9.05	215	(412)	258	61
Wyoming	341	524	53.67	109	(209)	283	183
Colorado	2,181	2,191	0.45	694	(1,333)	649	10
New Mexico	1,749	2,108	20.52	557	(1,069)	872	359
Arizona	1,188	3,773	217.59	378	(727)	2,933	2,585
Utah	1,160	-	-	369	(709)	-	-
Nevada	1,767	3,366	90.49	563	(1,081)	2,117	1,599
Pacific	37,328	34,753	(6.90)	11,889	(22,830)	8,366	(2,575)
Washington	3,569	2,917	(18.27)	1,137	(2,183)	394	(652)
Oregon	2,699	3,440	27.45	860	(1,651)	1,532	741
California	29,450	24,577	(16.55)	9,380	(18,012)	3,759	(4,873)
Alaska	517	-	-	165	(316)	-	-
Hawaii	1,610	3,819	137.20	513	(985)	2,681	2,209
United States Industry Employment	367,664	259,889	(29.31)				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

TABLE 3 Employment Change in Trucking and Warehousing Between 1969 and 1982 (SIC 42)

Region, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to National Growth	Industry Mix	Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST							
New England	54,502	50,354	(7.61)	17,359	(9,282)	(12,225)	(4,148)
Maine	4,018	4,098	1.99	1,280	(684)	(516)	80
New Hampshire	2,857	4,102	43.58	910	(487)	822	1,245
Vermont	2,134	2,144	0.47	680	(363)	(306)	10
Massachusetts	27,939	25,081	(10.23)	8,899	(4,758)	(6,999)	(2,858)
Rhode Island	4,528	2,633	(41.85)	1,442	(771)	(2,566)	(1,895)
Connecticut	13,026	12,296	(5.60)	4,149	(2,218)	(2,660)	(730)
Middle Atlantic	200,465	179,746	(10.34)	63,848	(34,139)	(50,428)	(20,719)
New York	81,510	61,803	(24.18)	25,961	(13,881)	(31,787)	(19,707)
New Jersey	53,532	54,801	2.37	17,050	(9,116)	(6,665)	1,269
Pennsylvania	65,423	63,142	(3.49)	20,837	(11,142)	(11,977)	(2,281)
NORTH CENTRAL/MIDWEST							
East North Central	232,237	222,020	(4.40)	73,967	(39,550)	(44,635)	(10,217)
Ohio	66,243	62981	(4.92)	21,098	(11,281)	(13,079)	(3,262)
Indiana	29,207	32,001	9.57	9,302	(4,974)	(1,534)	2,794
Illinois	75,199	65,760	(12.55)	23,951	(12,806)	(20,583)	(9,439)
Michigan	40,296	34,802	(13.63)	12,834	(6,862)	(11,466)	(5,494)
Wisconsin	21,292	26,476	24.35	6,782	(3,626)	2,029	5184
West North Central	90,646	114,923	26.78	28,871	(15,437)	10,841	24,277
Minnesota	18,925	23,922	26.40	6,028	(3,223)	2,192	4,997
Iowa	14,267	17,036	19.41	4,544	(2,430)	655	2,769
Missouri	33,850	36,062	6.53	10,781	(5,765)	(2,805)	2,212
North Dakota	2,004	4,536	126.35	638	(341)	2,235	2,532
South Dakota	2,828	5,032	77.93	901	(482)	1,784	2,204
Nebraska	7,738	11,587	49.74	2,465	(1,318)	2,702	3,849
Kansas	10,934	16,748	53.17	3,482	(1,862)	4,194	5,814
SOUTH							
South Atlantic	151,540	180,182	18.90	48,265	(25,807)	6,184	28,642
Delaware	2,986	2,340	(21.63)	951	(509)	(1,088)	(646)
Maryland	18,789	20,176	7.38	5,984	(3,200)	(1,398)	1,387
Virginia	21,800	25,624	17.54	6,943	(3,713)	593	3,824
West Virginia	7,058	7,831	10.95	2,248	(1,202)	(273)	773
North Carolina	34,585	41,239	19.24	11,015	(5,890)	1,529	6,654
South Carolina	9,532	12,341	29.47	3,036	(1,623)	1,396	2,809
Georgia	27,657	32,654	18.07	8,809	(4,710)	899	4,997
Florida	29,133	37,977	30.36	9,279	(4,961)	4,527	8,844
East South Central	54,893	75,433	37.42	17,483	(9,3488)	12,405	20,540
Kentucky	11,942	16,009	34.06	3,804	(2,034)	2,298	4,067
Tennessee	22,195	30,846	38.98	7,069	(3,780)	5,362	8,651
Alabama	14,685	19,379	31.97	4,677	(2,501)	2,518	4,695
Mississippi	6,071	9,919	63.38	1,934	(1,034)	2,948	3,848
West South Central	98,672	153,958	56.03	31,427	(16,804)	40,663	55,286
Arkansas	8,520	11,935	40.08	2,714	(1,451)	2,152	3,415
Louisiana	14,761	21,681	46.88	4,701	(2,514)	4,732	6,920
Oklahoma	14,342	24,081	67.91	4,568	(2,442)	7,614	9,739
Texas	61,049	96,261	57.68	19,444	(10,397)	26,165	35,212
WEST							
Mountain	36,823	61,601	67.29	11,728	(6,271)	19,321	24,778
Montana	2,974	5,104	71.62	947	(506)	1,689	2,130
Idaho	3,268	5,027	53.82	1,041	(557)	1,274	1,759
Wyoming	2,264	4,456	96.82	721	(386)	1,856	2,192
Colorado	12,398	16,624	34.09	3,949	(2,111)	2,389	4,226
New Mexico	3,440	5,431	57.88	1,096	(586)	1,481	1,991
Arizona	5,244	10,845	106.81	1,670	(893)	4,824	5,601
Utah	5,763	11,038	91.53	1,836	(981)	4,421	5,275
Nevada	1,472	3,076	108.97	469	(251)	1,386	1,604
Pacific	120,117	153,584	27.86	38,257	(20,456)	15,666	33,467
Washington	14,453	20,403	41.17	4,603	(2,461)	3,808	5,950
Oregon	12,774	15,664	22.62	4,068	(2,175)	997	2,890
California	89,111	112,286	26.01	28,382	(15,176)	9,969	23,175
Alaska	864	2,192	153.70	275	(147)	1,200	1,328
Hawaii	2,915	3,039	4.25	928	(496)	(308)	124
United States Industry Employment	1,039,380	1,193,397	14.82				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

TABLE 4 Employment Change in Water Transportation Between 1969 and 1982 (SIC 44)

Region, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to National Growth	Industry Mix	Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST							
New England	2,266	4,240	87.11	722	(88)	1,341	1,974
Maine	274	684	149.64	87	(11)	333	410
New Hampshire	95	164	72.63	30	(4)	42	69
Vermont	-	83	-	-	-	-	-
Massachusetts	1,284	2,650	106.39	409	(50)	1,007	1,366
Rhode Island	613	576	(6.04)	195	(24)	(208)	(37)
Connecticut	724	-	-	236	(28)	-	-
Middle Atlantic	46,452	37,544	(19.18)	14,795	(1,812)	(21,891)	(8,908)
New York	30,149	19,671	(34.75)	9,602	(1,176)	(18,905)	(10,478)
New Jersey	7,489	10,635	42.01	2,385	(292)	1,053	3,146
Pennsylvania	8,814	7,238	(17.88)	2,807	(344)	(4,040)	(1,576)
NORTH CENTRAL/MIDWEST							
East North Central	8,590	7,830	(8.85)	2,736	(335)	(3,161)	(760)
Ohio	4,144	2,916	(29.63)	1,320	(162)	(2,386)	(1,228)
Indiana	699	856	22.46	223	(27)	(38)	157
Illinois	2,584	3,204	(23.99)	823	(101)	(102)	620
Michigan	1,163	754	(35.17)	370	(45)	(734)	(409)
Wisconsin	-	-	-	-	-	-	-
West North Central	2,394	5,193	116.92	762	(93)	2,130	2,799
Minnesota	403	5,886	45.41	128	(16)	70	183
Iowa	53	-	-	17	(2)	-	-
Missouri	1,991	4,607	131.99	634	(78)	2,060	2,616
North Dakota	-	-	-	-	-	-	-
South Dakota	-	-	-	-	-	-	-
Nebraska	-	9	-	-	-	-	-
Kansas	-	126	-	-	-	-	-
SOUTH							
South Atlantic	25,007	31,323	25.26	7,965	(975)	(673)	6,316
Delaware	489	2,483	407.77	156	(19)	1,857	1,994
Maryland	8,421	6,071	(27.91)	2,682	(328)	(4,704)	(2,350)
Virginia	5,302	4,584	13.54	1,689	(207)	(2,200)	(718)
West Virginia	566	585	3.36	180	(22)	(139)	19
North Carolina	2,602	-	-	829	(101)	-	-
South Carolina	1,325	1,950	47.17	422	(52)	255	625
Georgia	1,044	1,935	87.07	333	(41)	617	909
Florida	7,860	13,697	74.26	2,503	(307)	3,640	5,837
East South Central	8,438	11,301	33.93	2,688	(329)	505	2,863
Kentucky	1,114	2,034	82.59	355	(43)	309	920
Tennessee	852	1,215	42.61	271	(33)	125	363
Alabama	4,463	5,163	15.68	1,421	(174)	(548)	700
Mississippi	2,009	2,880	43.35	640	(78)	309	871
West South Central	27,092	66,551	145.65	8,629	(1,057)	31,887	39,459
Arkansas	123	-	-	39	(5)	-	-
Louisiana	18,536	42,037	126.79	5,904	(723)	18,321	23,501
Oklahoma	77	244	216.88	25	(3)	145	167
Texas	8,479	24,270	186.24	2,701	(331)	13,421	15,791
WEST							
Mountain	-	-	-	-	-	-	-
Montana	-	-	-	-	-	-	-
Idaho	-	-	-	-	-	-	-
Wyoming	-	-	-	-	-	-	-
Colorado	-	20	-	-	-	-	-
New Mexico	-	18	-	-	-	-	-
Arizona	-	-	-	-	-	-	-
Utah	-	130	-	-	-	-	-
Nevada	-	-	-	-	-	-	-
Pacific	34,476	35,600	3.26	10,981	(1,345)	(8,512)	1,124
Washington	7,772	7,905	1.71	2,475	(303)	(2,039)	133
Oregon	3,679	3,783	2.83	1,172	(143)	(924)	104
California	22,014	22,775	3.46	7,011	(858)	(5,391)	761
Alaska	1,011	1,137	12.46	322	(39)	(159)	126
Hawaii	1,701	-	-	542	(66)	-	-
United States Industry Employment	160,906	205,878	27.95				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

TABLE 5 Employment Change in Transportation by Air Between 1969 and 1982 (SIC 45)

Region, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to: National Growth	Industry Mix	Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST							
New England	9,076	11,858	30.65	2,891	(540)	431	2,782
Maine	164	616	275.61	52	(10)	410	452
New Hampshire	128	-	-	41	(8)	-	-
Vermont	-	515	-	-	-	-	-
Massachusetts	8,095	9,125	13.84	2,576	(482)	(977)	1,120
Rhode Island	-	-	-	-	-	-	-
Connecticut	817	1,602	96.08	260	(49)	573	785
Middle Atlantic	71,402	71,408	0.008	22,742	(4,248)	(18,487)	6
New York	56,390	49,257	(12.65)	17,960	(3,355)	(21,738)	(7,133)
New Jersey	6,343	9,631	51.84	2,020	(377)	1,645	3,288
Pennsylvania	8,669	12,520	44.42	2,761	516	1,606	3,851
NORTH CENTRAL/MIDWEST							
East North Central	38,296	42,648	11.36	12,197	(2,279)	(5,567)	4,352
Ohio	4,920	6,588	33.90	1,567	(293)	394	1,668
Indiana	1,971	2,188	11.01	628	(117)	(293)	217
Illinois	24,043	25,520	6.14	7,658	(1,431)	(4,751)	1,477
Michigan	5,876	6,200	5.51	1,872	(350)	(1,198)	324
Wisconsin	1,486	2,152	44.82	473	(88)	281	666
West North Central	26,417	28,378	7.42	8,414	(1,572)	(4,881)	1,961
Minnesota	7,036	9,336	32.69	2,241	(418)	478	2,300
Iowa	741	755	1.89	236	(44)	(178)	14
Missouri	16,321	14,811	(9.25)	5,190	(971)	(5,737)	(1,510)
North Dakota	178	276	55.06	57	(11)	52	98
South Dakota	287	236	(17.77)	91	(17)	(125)	(51)
Nebraska	736	729	(0.95)	234	(44)	(198)	(7)
Kansas	1,118	2,235	99.91	356	(67)	827	1,117
SOUTH							
South Atlantic	60,481	90,909	50.31	19,263	(3,599)	14,763	30,428
Delaware	802	-	-	255	(48)	-	-
Maryland	1,419	1,907	34.39	452	(84)	120	488
Virginia	6,985	9,857	41.12	2,225	(416)	1,063	2,872
West Virginia	175	595	240.00	56	(10)	375	420
North Carolina	3,720	6,509	74.97	1,185	(221)	1,825	2,789
South Carolina	754	1,218	61.54	240	(45)	269	464
Georgia	14389	28,132	95.51	4,583	(856)	10,016	13,743
Florida	33,093	42,691	29.00	10,540	(1,969)	1,026	9,598
East South Central	9,251	14,634	58.19	2,946	(550)	2,987	5,383
Kentucky	1,258	2,077	65.10	401	(75)	493	819
Tennessee	3,028	8,824	191.45	964	(180)	5,013	5,797
Alabama	4,584	3,096	(32.46)	1,460	(273)	(2,675)	(1,488)
Mississippi	381	637	67.19	121	(23)	157	256
West South Central	30,383	48,512	59.67	9,677	(1,808)	10,260	18,129
Arkansas	339	1,059	212.39	1,088	(20)	632	720
Louisiana	2,976	8,031	169.86	948	(177)	4,284	5,055
Oklahoma	8665	3,714	(57.14)	2,760	(516)	(7,195)	(4,951)
Texas	18,403	35,708	94.03	5,861	(1,095)	12,538	17,305
WEST							
Mountain	13,637	27,027	98.19	4,343	(811)	9,858	13,390
Montana	398	697	75.13	127	(24)	196	299
Idaho	329	548	66.57	105	(20)	134	219
Wyoming	209	470	124.88	67	(12)	206	261
Colorado	6,933	14,903	114.96	2,208	(413)	6,175	7,970
New Mexico	866	818	(5.54)	276	(52)	(272)	(48)
Arizona	2,781	4,962	79.14	886	(165)	1,481	2,201
Utah	1,073	2,291	113.51	342	(64)	940	1,218
Nevada	1048	2,318	121.18	334	(62)	999	1,270
Pacific	79,175	91,251	15.25	25,217	(4,711)	(8,430)	12,076
Washington	7,124	8,684	21.90	2,269	(424)	(285)	1,560
Oregon	1,467	1,964	33.88	467	(87)	117	497
California	63,275	68,595	8.41	20,153	(3,765)	(11,068)	5,320
Alaska	2,656	5,655	112.91	846	(158)	2,311	2,999
Hawaii	4,653	6,353	36.90	1,482	(277)	512	1,700
United States Industry Employment	340,793	429,071	25.90				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

TABLE 6 Employment Change in Pipelines Except Natural Gas Between 1969 and 1982 (SIC 46)

Region, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to National Growth	Employment Change Related to Industry Mix	Employment Change Related to Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST	-	-	-	-	-	-	-
New England	-	-	-	-	-	-	-
Maine	-	-	-	-	-	-	-
New Hampshire	-	-	-	-	-	-	-
Vermont	-	-	-	-	-	-	-
Massachusetts	-	-	-	-	-	-	-
Rhode Island	-	-	-	-	-	-	-
Connecticut	-	-	-	-	-	-	-
Middle Atlantic	1,101	1,204	9.36	351	(132)	(115)	103
New York	174	146	(16.09)	55	(21)	(62)	(28)
New Jersey	127	212	66.93	40	(15)	60	85
Pennsylvania	800	846	5.75	255	(96)	(113)	46
NORTH CENTRAL/MIDWEST							
East North Central	1,637	2,073	88.28	351	(132)	754	972
Ohio	570	956	67.72	182	(69)	273	386
Indiana	135	165	22.22	43	(16)	3	30
Illinois	766	824	7.57	244	(92)	(94)	58
Michigan	166	128	(22.89)	53	(20)	(71)	(38)
Wisconsin	-	-	-	-	-	-	-
West North Central	1,352	1,2334	(8.73)	431	(163)	(386)	(118)
Minnesota	-	-	-	-	-	-	-
Iowa	174	-	-	55	(21)	-	-
Missouri	259	187	(27.80)	82	(31)	(123)	(72)
North Dakota	-	-	-	-	-	-	-
South Dakota	-	-	-	-	-	-	-
Nebraska	184	-	-	59	(22)	-	-
Kansas	1,093	1,047	(4.21)	348	(131)	(171)	(46)
SOUTH							
South Atlantic	485	343	(29.28)	154	(58)	(238)	(142)
Delaware	-	-	-	-	-	-	-
Maryland	-	-	-	-	-	-	-
Virginia	142	-	-	45	(17)	-	-
West Virginia	137	-	-	44	(16)	-	-
North Carolina	114	-	-	36	(13)	-	-
South Carolina	-	-	-	-	-	-	-
Georgia	485	343	(29.28)	154	(58)	(238)	(142)
Florida	-	50	-	-	-	-	-
East South Central	322	327	1.51	103	(39)	(59)	5
Kentucky	166	171	3.01	53	(20)	(28)	5
Tennessee	-	50	-	-	-	-	-
Alabama	-	65	-	-	-	-	-
Mississippi	156	156	0.00	50	(19)	(31)	0
West South Central	5,347	5,322	(0.47)	1,703	(643)	(1,085)	(25)
Arkansas	-	-	-	-	-	-	-
Louisiana	812	801	(1.35)	259	(98)	(172)	(11)
Oklahoma	1,980	-	-	631	(238)	-	-
Texas	4,535	4,521	(0.30)	1,444	(546)	(912)	(14)
WEST							
Mountain	690	420	(39.13)	220	(83)	(407)	(270)
Montana	133	43	(67.67)	42	(16)	(116)	(90)
Idaho	-	-	-	-	-	-	-
Wyoming	322	227	(29.50)	103	(39)	(159)	(95)
Colorado	-	966	-	-	-	-	-
New Mexico	235	150	(36.17)	75	(28)	(132)	(85)
Arizona	-	-	-	-	-	-	-
Utah	-	-	-	-	-	-	-
Nevada	-	-	-	-	-	-	-
Pacific	782	1,812	131.71	249	(94)	875	1,030
Washington	-	-	-	-	-	-	-
Oregon	-	-	-	-	-	-	-
California	782	1,812	131.71	249	(94)	875	1,030
Alaska	-	-	-	-	-	-	-
Hawaii	-	-	-	-	-	-	-
United States Industry Employment	15,522	18,599	19.82				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

TABLE 7 Employment Change in Transportation Services Between 1969 and 1982 (SIC 47)

Region, Division State	Employment 1969	Employment 1982	Percent Change	Employment Change Related to			
				National Growth	Industry Mix	Competitive/ State Share	Total*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NORTHEAST							
New England	4,329	11,428	163.99	1,379	3,887	1,833	7,099
Maine	-	346	-	-	-	-	-
New Hampshire	-	487	-	-	-	-	-
Vermont	109	344	215.60	35	98	102	235
Massachusetts	3,018	6,442	113.45	961	2,710	(247)	3,424
Rhode Island	276	571	106.88	88	248	(41)	295
Connecticut	926	4,071	339.63	295	831	2,019	3,145
Middle Atlantic	36,869	51,778	40.44	11,743	33,105	(29,938)	14,909
New York	29,043	35,436	22.01	9,250	26,078	(28,936)	6,393
New Jersey	3,291	8,395	155.09	1,048	2,955	1,101	5,104
Pennsylvania	4,535	7,947	75.24	1,444	4,072	(2,104)	3,412
NORTH CENTRAL/MIDWEST							
East North Central	13,493	30,483	125.92	4,298	12,115	577	16,990
Ohio	2,289	5,795	153.17	729	2,055	722	3,506
Indiana	644	2,129	230.59	205	578	702	1,485
Illinois	7,000	14,637	109.10	2,230	6,285	(878)	7,637
Michigan	2,809	5,327	89.64	895	2,522	(899)	2,518
Wisconsin	751	2,595	245.54	239	674	930	1,844
West North Central	4,919	10,388	111.18	1,567	4,417	(514)	5,469
Minnesota	1,226	3,390	76.51	390	1,101	673	2,164
Iowa	447	1,097	145.41	142	401	106	650
Missouri	2,616	3,979	52.10	833	2,349	(1,819)	1,363
North Dakota	135	283	109.63	43	121	(16)	148
South Dakota	101	256	153.47	32	91	32	155
Nebraska	900	-	-	287	808	-	-
Kansas	394	1,383	251.02	125	354	510	989
SOUTH							
South Atlantic	11,869	30,621	157.99	3,780	10,657	4,314	18,752
Delaware	-	585	-	-	-	-	-
Maryland	1,556	3,667	135.67	496	1,397	218	2,111
Virginia	873	3,376	286.71	278	784	1,441	2,503
West Virginia	143	-	-	46	128	-	-
North Carolina	977	2,470	152.81	311	877	305	1,493
South Carolina	360	1,878	421.67	115	323	1,080	1,518
Georgia	2,836	3,895	37.34	903	2,546	(2,391)	1,059
Florida	5,267	15,335	191.15	1,678	4,729	3,661	10,068
East South Central	2,123	5,157	142.91	676	1,907	452	3,034
Kentucky	443	1,191	168.85	141	398	209	748
Tennessee	647	2,152	232.61	206	581	718	1,505
Alabama	901	1,368	51.83	287	809	(629)	467
Mississippi	132	446	237.88	42	119	153	314
West South Central	7,186	25,588	256.08	2,289	6,452	9,661	18,402
Arkansas	146	650	345.21	47	131	326	504
Louisiana	2,415	4,657	92.84	769	2,168	(696)	2,242
Oklahoma	474	1,179	148.73	151	426	128	705
Texas	4,151	19,102	360.18	1,322	3,727	9,902	14,951
WEST							
Mountain	1,458	8,751	500.21	464	1,309	5,519	7,293
Montana	92	404	339.13	29	82	201	312
Idaho	84	504	500.00	27	75	318	420
Wyoming	44	-	-	14	40	-	-
Colorado	600	3,263	443.83	191	539	1,933	2,663
New Mexico	86	513	496.51	27	77	322	427
Arizona	331	2,062	522.96	105	297	1,328	1,731
Utah	198	1,078	444.44	63	178	639	880
Nevada	67	927	1,283.58	21	60	778	860
Pacific	17,687	47,354	167.73	5,633	15,881	8,153	29,667
Washington	1,644	5,403	228.65	524	1,476	1,759	3,759
Oregon	770	2067	168.44	245	691	360	1,297
California	13,576	35,501	161.50	4,324	12,190	5,411	21,925
Alaska	-	649	-	-	-	-	-
Hawaii	1,697	4,383	158.28	540	1,524	622	2,686
United States Industry Employment	102,117	226,328	121.64				
United States Total Employment	56,348,479	74,297,252	31.85				

Source: U.S. Bureau of the Census, U.S. Department of Commerce, Census of County Business Patterns. Washington, D.C.: U.S. Government Printing Office.

*Total is computed by subtracting the 1969 from the 1982 Employment figures. Consequently, total figures may vary slightly from the figures obtained by summing National Growth, Industry Mix and Competitive/State Share.

ticular industry for a particular region or state. Is the state increasing or decreasing its share of national employment for each industry (shown in each table as Competitive/State Share)? Does the state have an enhancing or impeding industry mix relative to the nation as a whole (shown as Industry Mix)?

In Tables 1-7, Columns 1, 2, and 3 give the raw data for each region and state. Column 4 displays the percentage growth rate in employment. Data for all nine geographic diversions and 50 states are given in each table. National employment data and percentage change for the particular industry (SIC) and for U.S. total employment is provided on the last two rows of each table.

Columns 5 through 8 designate the employment growth according to Items 1, 2, and 3 listed at the beginning of this section. First, changes in overall national employment may be treated as a reflection of business conditions (Column 5). For example, if national employment increases it will, to some extent, contribute to growth in specific industries and regions. The opposite effect would be translated by sluggish or declining national employment.

Employment in an industry may be increasing or decreasing independently from national employment trends and, consequently, may be viewed as a second component affecting employment changes in a region. Column 6 shows the increment in employment above or below that in Column 5 attributable to the national growth rate of the particular SIC. This is known as industry mix. A large negative number in this column, relative to other states, indicates that that state has above average concentration in a national slow-growth industry.

Finally, a region or state may have particular attributes that make it more or less attractive than other areas for a particular industry. Because the areas being compared in this study are primarily the states, this component is called the state share. The state share is a reflection of how competitive a state is in the specific industry being examined. Column 7 shows the increment in employment above or below that in Column 6 attributable to how a particular state's SIC growth rate varies from the national growth rate for that SIC. By comparing the signs and absolute values of the growth components in Columns 6 and 7 it is possible to discern whether growth or decline in a particular region or state is attributable primarily to concentration of the industry or to the economic performance of that industry in the specific region or state.

The methodology also allows for the identification of high-performer regions and states. Two criteria are used to screen for high-performer states: (a) the competitive share (Column 7) must be at least equal to the national growth component (Column 5), that is, growth in competitive share must be comparable with growth resulting from the national economy; and (b) absolute growth in employment (Column 8) must be at least 2 percent of absolute growth for the industry nationally.

RESULTS

Major Employment Trends in Transportation

Table 8 displays the national growth rates for all the SICs under consideration. Except for transportation services (SIC 47), at 121.64 percent, the transportation sector had a slower growth (24.94 percent) than national employment growth (31.85 percent). Local and interurban passenger transit (SIC 41) had a negative growth of -29.31 percent. The remaining industry growth rates ranged from 14.82 percent (trucking and warehousing) to 27.95 percent (water transportation).

TABLE 8 National SIC Growth Rates

Negatives	Change 1969-1982 (%)
All U.S. employment	31.85
SIC 4—Total transportation communications and public utilities	24.94
SIC 41—Local and interurban passenger transit	-29.31
SIC 42—Trucking and warehousing	14.82
SIC 44—Water transportation	27.95
SIC 45—Air transportation	25.95
SIC 46—Pipelines	19.82
SIC 47—Transportation services	121.64

Source: U.S. Bureau of the Census, U.S. Department of Commerce. Census of County Business Patterns. U.S. Government Printing Office.

Growth rates by industry and by geographic region are given in Table 9. For SIC 4 (transportation, communications, and public utilities) growth rates in the Northeast and North Central regions were considerably lower than those in the South and West. In general, this pattern repeats itself for SICs 41, 42, and 45. Some variation can be observed in water transportation (SIC 44) where the growth in New England, West North Central and West South Central was outstanding. For pipelines (SIC 46), very high growth rates in East North Central and Pacific can be observed. However, both these transportation industries are unique to particular subregions of the United States and neither are major employers. SIC 47 (transportation services) also varied from the general pattern in that New England and East North Central displayed growth more nearly comparable with the South and West.

These broad patterns are shown in Table 10. Here growth rates are shown by three indicators: D for absolute decline, 1 for above industry rate, and 0 for below industry rate. High growth geographic divisions--those with five or more 1s--are all found in the South and West.

Shift-Share Discussion by SIC

Because of the unique characteristics of employment in local and interurban passenger transit, water transportation, and pipelines, the following discussion concentrates on SICs 4, 42, 45, and 47 using the shift-share Tables 1, 3, 5, and 7.

The results of the shift-share analysis for SIC 4 appear in Table 1. All states enjoyed some growth in transport-related employment during the study period, with the exceptions of Rhode Island, New York, and Illinois (Column 8). The shift-share analysis shows that growth in the East North Central was due entirely to national growth (all negative figures in Columns 6 and 7). While all states "lost" employment in Column 6 because the transportation sector grew more slowly than total national employment, only in the New England, middle Atlantic and East North Central did most states "lose" employment due to declines in the state share. Moreover, the middle Atlantic and East North Central regions had by far the lowest percentage increase (-2.47 and 6.09 percent, respectively) in transport-related employment. In short, the East North Central states were not competitive with the East South Central, West South Central or South Atlantic states. During the study period growth in transport-related employment resulted in more absolute employment in the South Atlantic states than in the East North Central. Indiana and Wisconsin were the best-performing states within the East North Central states. However, the large majority of states in the South Atlantic, East and West South Central regions ex-

TABLE 9 Growth Rates by Region and SIC[a]

	SIC 4	SIC 41	SIC 42	SIC 44	SIC 45	SIC 46	SIC 47
Northeast							
New England	13.61	-6.19	-7.61	87.11	30.65	–[b]	163.99
Middle Atlantic	-2.47	-45.19	-10.34	-19.18	0.01	9.36	40.44
North Central							
East North Central	6.09	-42.56	-4.40	-8.85	11.36	88.28	125.92
West North Central	26.48	-11.48	26.78	116.92	7.42	-8.73	111.18
South							
South Atlantic	44.56	-23.66	18.90	25.26	50.31	-29.28	157.99
East South Central	41.04	-35.41	37.42	33.93	58.19	1.51	142.91
West South Central	69.76	-11.50	56.03	145.65	59.67	-0.47	256.08
West							
Mountain	87.42	59.10	67.29	–[b]	98.19	-39.13	500.21
Pacific	40.31	-6.90	27.86	3.26	15.25	131.71	167.73
Industry nationwide	24.95	-29.31	14.82	27.95	25.90	19.82	121.64
All U.S. employment	31.85	31.85	31.85	31.85	31.85	31.85	31.85

Source: U.S. Bureau of the Census, U.S. Department of Commerce. Census of County Business Patterns. U.S. Government Printing Office.

[a]Percentage of change from 1969 to 1982.
[b]No data available.

TABLE 10 Simplified Growth Rates by Region and SIC

	SIC 4	SIC 41	SIC 42	SIC 44	SIC 45	SIC 46	SIC 47
Northeast							
New England	0	1,D	0,D	1	1	–[a]	1
Middle Atlantic	0,D	0,D	0,D	0,D	0	0	0
North Central							
East North Central	0	0,D	0,D	0,D	0	1	1
West North Central	1	1,D	1	1	0	0,D	0
South							
South Atlantic	1	1,D	1	0	1	0,D	1
East South Central	1	0,D	1	1	1	0	1
West South Central	1	1,D	1	1	1	0,D	1
West							
Mountain	1	1	1	–[a]	1	0	1
Pacific	1	1,D	1	0	0	1	1

Note: D = absolute decline, 0 = below industry growth rate, and 1 = above industry rate.
[a]No data available.

perienced growth at almost twice the rate experienced in Indiana and Wisconsin.

Of all transportation employment categories, local and interurban passenger transit (SIC 41) suffered most between 1969 and 1982 (Table 2). The middle Atlantic and East North Central regions were hit hardest with changes of -45.19 and -42.56 percent, respectively, compared with the national rate of -29.31 percent. Relative to the southern states, the state share (Column 7) is worst for the Northeast and Midwest, indicating loss in competitive position.

This loss in competitive position is repeated for trucking and warehousing (SIC 42) in Table 3. In absolute terms, the East North Central region retains the highest absolute employment. However, with a growth rate of -4.4 percent, major losses occur. This is dramatized by contrasting Michigan's employment decline from 40,000 to 35,000, with North Carolina's gain from 35,000 to 41,000.

In Table 5, air transportation (SIC 45), two East North Central states perform above the national industry average, but on balance the Midwest loses competitive share to the South and West. Furthermore, in absolute terms, South Atlantic air transportation employment exceeds that for the East North Central; in relative terms the South Atlantic states have performed far beyond the East North Central states.

Finally, Table 7 shows the only bright spot for the Northeast and Midwest. Its transportation services (SIC 47) show a healthy growth rate of +125.92 percent, not far behind the East South Central and the South Atlantic, all performing ahead of the national average of +121.64 percent. Transportation services depend on sophisticated transportation networks, intermodel facilities and good computer and telecommunications systems. The Northeast and Midwest probably retain a strong technological and institutional endowment with their science-based industries, technical labor force, and built communications systems. The South and West would appear to have comparatively less advantage in this area of transportation employment.

In summary, the general pattern of Table 1 tends to persist at all two-digit levels, with some exceptions. That pattern is job loss in all regions due to industry mix, and further loss in the Northeast and Midwest due to state competitive share. Transportation services are the highest growth part of the transport sector. However, the general trend shows a loss in competitive share from North to South and West even though, in absolute terms, employment remains highest for many SICs in the North, because of industrial concentration.

High-Performer States

With the use of the heuristic method described at the end of the Methodology section, Table 11 displays states that are high performers under each SIC. Several Northeast and Midwest states perform well in single SIC categories. However, the bulk of high-performance cases cluster in the South and West, particularly the West South Central and Mountain regions. Most noticeable states repeatedly performing well are Arizona, Colorado, Louisiana, Oklahoma, and Texas.

TABLE 11 High-Performer States

	SIC 4	SIC 42	SIC 45	SIC 47
Connecticut				X
New Jersey				X
Wisconsin				Marginal
Minnesota				Marginal
Virginia				X
North Carolina			X	
Georgia	X		X	
Florida	X			X
Mississippi		X		
Tennessee			X	
Louisiana	X	X	X	
Oklahoma	Marginal			
Texas	X	X	X	X
Colorado	X		X	X
Arizona	X	X	X	Marginal
Utah	Marginal	X		
Washington				X
California				X
Alaska			X	

INTERPRETATION OF RESULTS

These data show that transportation employment has grown slower than the national average for the period 1969 to 1982. All two-digit SIC categories reflect this pattern except transportation services (SIC 47), which grew at +121.64 percent compared with a total national employment growth of +31.85 percent. Even air transportation employment grew slower than U.S. total employment. This may point to structural changes within the transportation industry, where information, coordination, and networking are becoming relatively more important. Such a trend raises economic policy questions such as how can a region or state capitalize on the services growth component of the transportation industry. Superior transportation services are probably closely tied to established institutional arrangements and sophisticated communication and computer systems capability--which again indicates the interrelationship of telecommunications and transportation surfaces. Telecommunications may be more of a complement than a substitute in the transportation growth equation.

The data suggest that regional shifts in the U.S. spatial economy are reflected in the changing distribution of employment in the transportation sector. While the Northeast and Midwest regions combined still surpass the South and West for transportation employment in absolute terms, growth rates in the latter two regions far exceed the former. This poses a threat to traditional transportation states in the frost belt. For example, Illinois, Indiana, Michigan, and Ohio are among the top 10 trucking states. The growth rate in the East North Central region for trucking and warehousing (SIC 42) was -4.4 percent, whereas directly south of the East South Central it was +37.42 percent. The competitive position of the New England, middle Atlantic, and East North Central in transportation employment is clearly under threat.

While not confirming an axial shift, these data are congruent with the theory. In each of the SICs, the South and West regions are gaining employment at the expense of the Northeast and Midwest. Only in transportation services where comparative advantage may hinge on established institutional networks and on computer and communications systems is employment growth in the Northeast and Midwest comparable with the South. The services component of the transportation industry may be little affected by the natural north-south grain.

However, the outstanding growth states are not in the Old South as axial shift theory would suggest. Rather, they are in the West South Central and Mountain. This suggests a diagonal shift to the new South and near-lower West, especially to such states as Arizona, Colorado, Lousiana, Oklahoma, Texas, and Utah.

CONCLUSION

The shift-share approach is an instructive tool for displaying relationships between transportation and economy. By tracking shares in transportation employment across various transportation SICs, it is possible to segment various attributing factors (national growth, industry mix, and competitive share), and to identify regions or states of competitive gain or loss. Therefore, it adds to a body of meso-level approaches that are currently in demand for strategic analysis by state, regional, and local economic development specialists.

The shift-share approach also confirms some megatrends affecting the U.S. spatial economy, and thus, transportation network futures as well. Regional demographic and employment shifts in the United States appear to be affecting the regional distribution of transportation employment. Between 1969 and 1982, the Northeast and Midwest states lost competitive share to the South and West states. This occurred noticeably in all transportation employment categories except transportation services. The traditional Midwest trucking states for example, although still larger in absolute employment, are losing trucking and warehousing employment to the South.

These regional trends are congruent with an axial shift theory which asserts that the natural north-south grain of the United States may become more important relative to the historical east-west axis. Because the implications for transportation investments, both nationally and regionally, might be significant, this axial shift theory needs more thorough exploration.

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