Integration of Land Use, Transportation, and Energy Planning in Midsized Cities

MARY KIHL AND TIM FLATHERS

Broad-based concerns about long-term efficiency in using energy resources cannot be addressed primarily by the modification of the travel behavior of individuals. Alternatives that depend on redirecting travel patterns must be explored. The current study focuses on the use of such land use planning policies as the encouragement of infill and the development of neighborhood service centers as means of affecting modifications of travel patterns. After an analysis of the experiences of a national sample of 10 midsized cities, it was concluded that 10 years after the 1974 Arab oil crisis the potential for redirecting development patterns in midsized cities has only begun to be recognized. Whether such changes can significantly affect transportation patterns remains to be seen.

Almost a decade has elapsed since the Arab oil embargo awakened sensitivities to the finite quality of energy resources. In the last 10 years numerous strategies have been employed by federal, state, and local governments in an effort to facilitate energy conservation. However, many of these strategies appear to have been directed toward short-term solutions. Broad-based concerns about the long-term efficiency in using energy resources appear remote and somewhat unreal to those concerned about personal efficiency and convenience in tripmaking.

Consequently energy conservation measures cannot rely primarily on voluntary individual modifications of travel behavior. Other alternatives must be explored, alternatives that depend on modification of travel patterns rather than travel behavior. The current study focuses on land use planning techniques as a means of affecting change in travel patterns.

The potential for land use changes in redirecting travel patterns has long been acknowledged (1). The advent of regional shopping centers and suburban industrial parks sparked by the completion of limited-access highways in the 1960s diverted travel from the central business district (CBD), whereas strip development stimulated traffic congestion along the highways leading into most American cities. Within individual cities land use regulations have helped define the urban forms that have in turn defined travel patterns. Presumably local and municipal governments armed with a variety of land use regulations and with the cooperation of private investors can also become catalysts in redirecting urban growth and consequently travel patterns. Whereas federally assisted highway projects helped to scatter urban residents into automobile-dependent suburbs, revised land use plans initiated by local government and carried out with the cooperation of investors might potentially help restore more energy-efficient environments (2, pp. 521-525; 3). The current study considered the extent to which city planning efforts have formally or informally accepted that challenge in the decade since 1973.

The procedure involved, first, a comparison of available land use planning maps and planning documents for the years before 1974 and after 1974 and future projections for each city in the sample. Second the planning strategies used in the sample cities were assessed and finally a typology was developed indicating levels of coordination in energy conservation, transportation, and land use planning. Given the small sample of cities and the need for qualitative assessment, an in-depth statistical analysis was not possible.

The focus for the study was a sample of 10 midsized cities with standard metropolitan statistical areas (SMSAs) ranging from 100,000 to 200,000. This population class was selected for two primary reasons. First previous studies that have attempted to link urban form and energy use have generally focused on larger cities such as Atlanta, Baltimore, Buffalo, Denver, and Fort Worth (4,5). The experience of midsized cities has yet to be documented. Second recent census reports note considerable changes in the population bases of medium-sized cities. Presumably they would also have experienced considerable land use changes over the last 10 years. An initial sample of 54 cities was selected from among the 93 SMSAs in this population class. This sample included clusters representing established and expanding cities, Eastern and Western cities, and geographically confined and unconfined cities. Requests for plans, maps, and other specific types of data were sent to the planning offices in each of these cities. Twenty-four cities responded, but even with a follow-up, reasonably comparable data were only available from 10. Fortunately, as shown in Table 1, the final sample of 10 cities represented the variation in location, growth rate, and terrain specified initially.

STUDY SAMPLE OVERVIEW

If cities' planning efforts are to be reviewed in terms of progress toward creating a more energy-efficient environment, it is first necessary to develop a definition of that environment. The absence of any clear consensus on what constitutes such an environment is evident in the contradictory reviews given specific land use alternatives.

Arguments focus on whether infill and cluster development are workable approaches to conserving energy. Some maintain that infill reduces trip length and consequently conserves energy, whereas others argue that infill implies increased density and congestion and thereby saves little in terms of energy (6-8). The well-known study Cost of Sprawl, prepared by the Real Estate Corporation in 1974, included transportation costs to far-flung suburbs as support for its argument in favor of cluster development. Critics continue to attack that work's encouragement of increased density (9,10). However,

Table 1. Sample cities categorized.

City	Location	Terrain	Growth Rate
Amarillo, Tex.	West	No constraint	Stable
Asheville, N.C.	East	Severe constraint	Stable
Danbury, Conn.	East	Mild constraint	Expanding
Elkhart, Ind.	East	No constraint	Stable
Fort Collins, Colo.	West	Mild constraint	Expanding
Grand Forks, N. Dak.	West	No constraint	Moderate expansion
Lawton, Okla.	West	No constraint	Moderate expansion
Lubbock, Tex.	West	No constraint	Stable
Provo City, Utah	West	Mild constraint	Moderate expansion
Wilmington, N.C.	East	Severe constraint	Stable

if infill could proceed at the density of surrounding neighborhoods, it would find greater support (11, pp. 88, 102-103; 12).

Similarly, arguments regarding the energy conservation potential of multipurpose activity centers focus on the relative savings generated by reduction of trip length versus expense because of increased traffic volume on smaller arterials. Greene (4) discusses studies referring to a 30 to 50 percent savings in energy because of polynucleated development. A larger consensus could be formed regarding the benefits in terms of energy conservation of neighborhood service centers that divert shopping and professional trips to locations closer to residences and thereby reduce the frequency of longer trips to regional shopping centers (1, pp. vi, 2-3; 13). Because such neighborhood centers serve a geographically defined population base, congestion is not increased substantially.

For purposes of this paper the definition of a more energy-efficient urban environment will be built on planning concepts with broad bases of support: residential infill accompanied by neighborhood service centers. Although these concepts focus primarily on energy conservation derived from reoriented shopping and service trips, infill also provides the opportunity for shortening those work trips, particularly those oriented toward the CBD. [The clustering of worksites in decentralized activity centers, a concept parallel to that of neighborhood service centers, would prove to be less workable in smaller cities with limited numbers of basic employers (14).] What follows is a descriptive analysis of the land use planning efforts of the study sample with special reference to the degree to which concerns for an energy-efficient environment visibly affected planning practice.

The planning experience of each city is unique because of variation in socioeconomic, political, and geographic characteristics. These differences dictate the specific nature of responses to broad-based challenges such as those provided by energy shortages. Nevertheless, one would expect that well-publicized national concerns would invite some type of response, either through formal documented planning efforts or through more informal directional planning (15).

The cities in the study sample represent a range of planning responses as well as a wide variety of demographic and geographic characteristics. The 1975 estimated population for most of the cities in the sample was about 55,000, although Lubbock and Amarillo had populations of 163,525 and 138,743, respectively, in 1975 (16,17). Population density also varied. The median was 2,400 per square mile although the range extended from a low of 1,242 for Danbury to a high of 3,880 for Grand Forks. The population of most of the cities increased moderately during the period but that of Asheville decreased by 3 percent in the period 1970 to 1975 whereas that of Fort Collins increased 73 percent from 1960 to 1970 and 29 percent from 1970 to 1975. Although Amarillo declined 8 percent in the period 1960 to 1970, it recovered with a 9 percent increase from 1970 to 1975.

The basic housing stock of most of these cities was predominantly single family, although Grand Forks had only 31 percent single-family units in 1970. Amarillo, on the other hand, had 83 percent single-family dwellings. An indicator of potential for land use changes is the percentage of change in housing stock over a 10-year period. Variation in this figure was considerable; it ranged from a low of 6 percent in Asheville to a high of 114 percent in Danbury. Economic indicators included the variation in median family income, which ranged from a low of $6,986 in 1970 in Wilmington to a high of $11,439 in Elkhart. The percentage below the poverty level ranged from 5.5 percent in Elkhart to 14.9 percent in Asheville and Lawton in 1970 (16,17).

Statistics on vacant land were not available for all cities, but among those reporting, the amount of vacant land within city limits decreased substantially after 1973. (Figures on land use categories and other observations on land use were developed from the appropriate land use plans and maps supplied by city planning offices.) The 3,415 acres of vacant land in Grand Forks in the 1960s declined to 1,462 in the latter part of the 1970s, whereas the 25,199 acres in Asheville declined to 21,582 acres. For the same period the acres of land in streets and rail in Asheville increased only 2 percent, whereas the developed land increased 8 percent. In Danbury the proportion of developed land increased from 38 to 56 percent, whereas the proportion of roads and utilities increased only 2 percent, from 7 to 9 percent. Such figures suggest infill, either directed or natural. This observation is supported by a comparison of the land use maps of the cities in the study sample. Among the cities supplying sets of land use maps, which included a map from around 1970, a current map, and a future-projection map, all showed considerable infill.

All the cities are well served by railroad and highways. Each of the cities is served by the main line of at least one major railroad and five cities are served by more than one. Interstate highways or limited-access toll roads are also available for all but two cities and those have four-lane major highways. With these excellent transportation facilities it is not surprising that the cities have established light and heavy industry. Industrial parks have been established in at least six cities.

Each of the cities has a multipurpose CBD and most have written plans underscoring the need to strengthen the CBD. Nevertheless, all have regional shopping centers, and strip development is apparent in the maps supplied by all the cities in the sample. Future land use maps of all but one of the eight cities supplying them indicate the continuation of linear development patterns. For seven of the cities neighborhood service centers existed well before 1973. More recent maps indicate continuation of this configuration in four of the cities and some semblance of this pattern in four additional cities.

Nevertheless, despite these apparent similarities in land use maps, the planning orientation of these cities varies considerably. For example, only three of the cities have plans that formally link energy conservation and land use. For only four of the cities do the plans explicitly indicate an effort to direct growth on the periphery. The need to respond to population growth signaled a directed planning response in only three of the cities. Two of these were opposed to further growth, whereas one was encouraging it. The other four cities currently experiencing considerable growth had developed no unified planning response.

For purposes of this study it is important to note that the formal plans of only four of the cities (Asheville, Grand Forks, Lawton, and Amarillo) expressly linked land use and transportation planning, whereas the plans of the three others (Fort Collins, Lubbock, and Provo City) implied such a relationship. The remaining three cities gave no indication of this linkage in their planning documents. Among the four cities clearly linking transportation and land use planning only three (Asheville, Grand Forks, and Lawton) noted the additional link between transportation planning and energy conservation.

PLANNING STRATEGIES ASSESSED

A closer look at the strategies associated with transportation and land use planning is warranted. The available planning documents for each of the 10 cities were thoroughly reviewed. (Questions used in the data collection may be obtained from the authors.) Responses gleaned from the documents were recorded and verified through a series of follow-up telephone interviews with officials of the planning departments of each city. The resulting data were then tabulated and cross-tabulated in an effort to uncover possible associations between planning objectives and planning strategies. Although the small sample of 10 inhibits any statistical analysis, the results provide indications that can form the basis for further inquiry.

The procedure revealed elements of what would constitute a more energy-efficient environment in each of the 10 cities in the sample. However, few of the cities had unified planning strategies seeking to relate those elements in an environment that would reduce the need for lengthy tripmaking.

As indicated previously, all the cities have experienced infill within the last 10 years. However, in only five of the cities was contiguous development an expressed planning objective. Only three of those cities have sought to reinforce this objective by directing growth at the periphery. Although the plans of all but one of the cities in the sample decry the continuation of linear development, the specific steps needed to redirect that development are less well defined. Fort Collins, Danbury, and Amarillo indicate plans for more clustering of commercial development, whereas Grand Forks and Lubbock plan to encourage more general compacting of residential and commercial development. Wilmington, a city with a stable population base, has begun plans to redirect commercial activity from strip development along highways to vacant land and buildings closer to the CBD. On the other hand, Lawton and Asheville indicate no plans to vary the current pattern of linear development. Plans for Provo City include a new shopping center near the periphery. The benefits to be derived from infill and contiguous development were primarily expressed in terms of potential savings in city services and utilities. Nevertheless, two-thirds of those communities that were attempting to plan for contiguous development were also developing planning strategies that would link transportation and land use planning. This association generated a chi-square value significant at the 0.02 level. The association with the planning strategies for energy conservation was far less apparent. The need for energy conservation was mentioned in the planning documents of only three of the cities emphasizing contiguous development.

As indicated earlier, 7 of the 10 cities in the sample provided early evidence of small retail establishments located in largely residential neighborhoods. However, only three of the cities specifically presented neighborhood service centers as part of a planning strategy. Four additional cities had land use maps that implied plans for some form of neighborhood service centers.

The appropriate service area for neighborhood centers varied from walking distance (0.25 mile) in Fort Collins to about 4 miles in Danbury. The average was about 1 mile. As with infill, association between the concept of neighborhood service centers and transportation planning was considerable. Seventy-one percent of those cities that either explicitly or implicitly suggested adherence to the service-center concept also discussed the linkage between transportation and land use planning. Within the majority of cities linking service centers and transportation planning, neighborhood service centers were perceived as serving a radius of 1 mile or less.

Among the cities in the sample, transportation was equated primarily with automobile trips. Several cities had no mass transit systems, and of those with bus lines, few found them well used. For most of these smaller cities the population density and configuration made mass transit an unrealistic alternative. Bicycles appeared to provide a more workable alternative to the automobile and their use might well reinforce the need for neighborhood service centers. In Fort Collins, for example, the need to accommodate bicycles for shopping and work-related trips was explicitly presented.

An aggregate review of the characteristics of those cities pursuing either service-center development or infill indicated no clear pattern. There was little association between service-center development and an indicator of new development (the number of new houses built in 1975) and no association between directed growth on the periphery and development of service centers. Service centers were apparently inserted into existing neighborhoods. As such they would have potential for redirecting trips.

Efforts to relate the tendency toward infill or service-center development or both with socioeconomic characteristics or geographic characteristics of the cities in the sample indicated no significant correlations. For example, there was no significant association between population growth rates within the cities and planning strategies involving infill.

Economic indicators such as percentage below the poverty level or median family income similarly proved to be unrelated to a propensity to pursue directed growth. The degree of limitation to expansion imposed by the terrain, although providing an impetus for infill or directed growth in some cities, was not necessarily a determining factor. For example, 50 percent of those cities with severe geographic limitations were pursuing infill, whereas 60 percent of those with mild limitations and 100 percent of those with no limitations were encouraging infill. Where growth is not naturally diverted by the terrain, more formal planning strategies may well be deemed necessary.

STRATEGIES AS RELATED TO PLANNING PRACTICE

A closer look at the cities in the sample is needed to further understand the inclination to employ elements of a planning strategy in moving toward a more energy-efficient environment. The cities in the sample fell into three groups with respect to their efforts to redirect land use and thereby travel patterns. One group was assertively promoting such changes; a second group was responding when the need for such changes became obvious locally; and the third group was pursuing a laissez-faire, nondirective planning approach. The specific characteristics of the cities varied considerably. However, it is possible to develop a rough typology indicating the forms of land use planning practice most likely to redirect travel patterns and thereby increase energy efficiency.

Cities Assertively Changing

The most assertive group of cities in the sample included the growing cities of Fort Collins and Grand Forks and the relatively stable city of Wilmington. Lubbock was the most assertive with regard to one element of the energy-efficient environment although less effective with regard to the other. It was nevertheless included with the assertive group.

Fort Collins has formally recognized the association between land use, transportation, and energy use. The city plan states (18, p. 32): "When higher density development is combined with energy efficient locational criteria, the result is the reduction in the length of roads and utility systems which decreases costs of development, drain on city resources and usage of fuel." Both infill and service centers are encouraged (19, pp. 20,21). According to a telephone interview with the Fort Collins Planning Department in May 1982, two small service centers with grocery stores were complete and a third was under construction. The development of such centers is specifically associated with efforts to improve traffic circulation. A land guidance system fosters contiguous development through cooperation with private developers. The system passes the costs of increasing sewage and water lines along to the developer, an approach that has acted as an effective deterrent to linear or strip development (19, pp. 1, 5-8). Within the last 5 years an increasing amount of residential development has been in multifamily units, a trend responding to public demand.

A contrasting but nevertheless directive approach has been attempted in Wilmington. Although Fort Collins continues to absorb increased population, Wilmington is an older, more stable settlement. Nevertheless, it shares with Fort Collins the dissatisfaction with strip development and efforts to encourage infill. Vacant lands were identified in a survey that is now to be extended to identifying vacant floors of buildings. Rather than advocating the development of new service centers, Wilmington is attempting to create multiuse centers in existing commercial areas. Higher-density development near those centers will be encouraged so as to make them available to larger numbers of people. Energy conservation is clearly indicated as a primary concern in developing this strategy. Implementation will be encouraged by limiting extension of utilities outside the existing service area. According to a telephone interview with the Wilmington Planning Department in May 1982, this informal approach was selected because it would have been difficult politically to change the well-established zoning pattern.

A more comprehensive form of coordinating land use and transportation planning is evident in Grand Forks. Grand Forks went through a period of rapid growth from 1975 to 1979 and is now attempting to direct that growth into a more energy-efficient environment. Energy conservation is indicated as a community goal (20, p. 131); the policies to be used to achieve this goal include allocating land uses to reduce trip lengths and to increase the usefulness of mass transit. Plans call for development of activity centers linking both employers and shopping centers. The location of a shopping mall south of the city in 1979 is now perceived as a mistake in the sense that it violated the general directive toward contiguous development, but a telephone interview with the Grand Forks Planning Department in May 1982 indicated that infill is now being encouraged in the vacant land between the mall and the rest of the city. The primary planning tool encouraging both infill and neighborhood service centers is the planned urban development (PUD), which in Grand Forks includes grocery stores as well as mixed residential uses. PUDs are also specifically indicated to support making mass transit more useful by increasing population densities (20, pp. 95, 102). Strip development is being attacked by restricting direct access from major highways.

Lubbock has employed modern technology to redirect land use planning. A coordinate-based computer program is used to identify current land use and simulate alternative future uses. The results of the simulation form the basis for zoning and effective comprehensive planning. The concept of the neighborhood service center has been actively pursued as an alternative to strip development, and commercial enterprises are now clustered in nodes 1 mile^2 apart.

Infill, on the other hand, has enjoyed little political support. As the land use plan indicates (21, p. 54): "Before infill will take place public opinion, leading attitudes, and market preferences will have to be changed." A liberal annexation policy has generated a considerable amount of vacant land within the city and the city lacks effective tools to encourage infill without private initiation. The resulting scattered development has reinforced the dominance of the automobile, although the transportation plan indicates that the development of alternative modes is essential. Without redirected residential land use the transit improvement program has been reduced to rather ineffective efforts to lure riders out of their cars. A denser population base would have made mass transit a more usable travel alternative (22, p. 83).

Cities Responding to Outside Stimuli

The second group of cities--those responding to outside stimuli in relating land use and transportation planning--includes Amarillo, Provo City, and Elkhart. All three have experienced a leveling off of their population growth rates and consequently no longer have obvious pressure for directed growth. Only Provo City is constrained by its terrain and is consequently trying to encourage higher-density development.

None of these cities is currently advocating neighborhood service centers. A telephone interview with the Provo City Planning Department in May 1982 revealed that Provo City had instituted some service centers but that they had not been successful financially because of lack of cooperation from developers; no new centers are planned. According to a similar interview in Elkhart, "Ma and Pa" groceries are reemerging. Energy conservation is not a stated goal in any of these cities. Contiguous development, on the other hand, is proceeding in all three cities. Elkhart, with little undeveloped land, is using utilities to direct growth and is encouraging cluster development through PUDs. Flexible development standards are encouraging infill in Amarillo. Provo City is attempting to widen its strip development into more intensive commercial development through PUDs.

In advocating these changes the cities note the association between transportation and land use. The plan for Amarillo notes, for example, that there are no functioning elements of a city that are more interdependent than the transportation system and land use (23, Sec. 4, pp. 3-18). Transportation benefits to be derived from orderly contiguous development are, however, presented in terms of reduced traffic congestion, and the accompanying benefits in energy conservation are not indicated. Linkage between these strategies and an increasingly useful mass transit system is also overlooked.

Cities Using Laissez-Faire Approach

The third group of cities--those adopting a primary laissez-faire approach to land use transportation planning--includes the rapidly changing cities of Danbury and Lawton and the relatively stable city of Asheville. All three of these cities have considerable commercial strip development, and both commercial and residential development is continuing to

expand outward rather than moving toward infill. Some neighborhood shoping opportunities exist, but none of the cities has a defined policy to encourage their development. Linear growth dominates. In Ashville linear development is encouraged in part by the steep terrain, but in all three cities the lack of effective planning tools has inhibited efforts to redirect growth. Sprawl is encouraged in Asheville by a state law prohibiting this city from charging higher utility rates to customers outside the city limits (24; telephone interview, May 1982). In Lawton sprawl continues because of consistently low property tax rates (telephone interview, May 1982), and in Danbury it is encouraged by the lack of any specific plan either for redirecting growth or for encouraging contiguous development (telephone interview, May 1982). For all three cities traffic congestion is presented to be a problem, but none of them has attempted to reduce that through revised land use planning. Political opposition has discouraged instituting new concepts such as cluster development or PUDs. For none of these three cities is energy conservation a stated or implied goal, especially not for Lawton where local supplies of oil are abundant and energy use is, in fact, encouraged.

CONCLUSION

In general the experience of these 10 cities indicates a rather limited response to the challenge provided by energy shortages. Only two cities have developed comprehensive planning approaches incorporating land use strategies to redirect transportation patterns. Nevertheless, some of the cities have begun to take steps that will potentially change travel patterns.

Although the origin-destination data necessary to support claims in changes in travel patterns were not available from the cities in the sample, it was possible to use available land use maps as a rough surrogate to note changes in distance between residential areas and shopping facilities. The approximate distance between the center of each major residential area and the closest commercial center was calculated on pre-1970 maps, current maps, and maps of projected future land use. This process naturally cannot document whether individual residents indeed travel to the closest commercial region, but it does indicate the potential for such trip-length reduction. The process revealed considerable variation among the six cities supplying the necessary land use maps.

As expected, Grand Forks registered a considerable decrease in distance to shopping facilities. Elkhart and Amarillo, cities in the second group described earlier, also provided evidence of reduced potential shopping-trip distance (30 and 10 percent, respectively). The maps for both Lawton and Danbury, cities in the third group, indicated potential increases in future shopping-trip distances (20 and 8 percent, respectively). The case of Lubbock, the city actively pursuing service centers but not encouraging infill, reinforces the need for an integrated approach to redirection of land use. Maps for Lubbock indicate a 4 percent potential increase in shopping-trip distance by 1990 given current trends. Unfortunately, information regarding work-trip distance could not be derived from the land use maps.

Those cities that have begun to redirect land use development demonstrate the variety of planning tools used in this attempt and by extension in redirection of transportation patterns. The comprehensive land guidance system employed in Fort Collins supports the enthusiastic endorsement given that approach by planning scholars (25, pp. 193-309). It provides a framework by which to steer land use policy through a generalized set of regulations developed and supported by private developers as well as by the general public. The flexibility associated with this system permits changes in short-term planning needed to address long-term objectives. Flexibility in land use planning is also equated with the PUD. The PUD and the mixed residential cluster development employed in Elkhart similarly provide flexibility in land use planning (26, p. 78). Mixed residential cluster development as in Elkhart and Grand Forks is credited with saving energy through reduced trip distance and increased density and with enhancing the usefulness of mass transit (27, pp. 55-58). None of the cities in the sample has experimented with such concepts as transfer of development rights, which have been used in larger cities to redirect development (28).

Although the flexibility of some current planning techniques facilitates the redirection of land use, midsized cities have also been fairly successful in using more traditional approaches such as variable utility rates and limited sewage line expansion. Even zoning changes can be effective (29, pp. 70-72; 30, pp. 228-237). Cities with planning objectives indicating a need to redirect development patterns have generally been able to effect at least some changes in land use with whatever approaches were supported politically (31, pp. 88-99). Outside regulations or public lack of concern inhibited others from pursuing similar strategies.

In summary, the potential for redirecting development and changing the configuration of midsized cities from expansion and sprawl to more compact contiguous development has been recognized. However, the key elements forging the links between land use, transportation, and energy are not city size, terrain, location, or the use of specialized planning techniques but rather public determination, a positive political climate, and clearly defined planning objectives. Whether the reorientation of land use can significantly affect transportation patterns and thereby conserve energy remains to be seen. Ten years after the Arab oil crisis, efforts to encourage energy conservation through integrating transportation and land use planning are still in their infancy.

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Transportation Evaluation in Community Design: An Extension with Equilibrium Route Assignment

RICHARD PEISER

An integrated model of transportation and land use is developed for the purpose of evaluating alternative community master plans. Equilibrium route assignment is combined with the conventional four-stage transportation model to calculate the overall economic benefits of alternative urban planning decisions. Problems of measuring benefits associated with elastic trip demand and demand shifts are also examined. The model is used to evaluate planning alternatives for a 7,500-acre suburban community. It is especially adapted to the problem of evaluating a subcommunity within the context of a larger metropolitan area. Equilibrium route assignment provides an efficient low-cost method of determining route flows and the cost implications of various road networks and land use decisions.

Land use planning and transportation planning should go hand in hand. However, with few exceptions transportation analysis is performed only after land uses and densities have been set. The analyses are often performed in order to determine which road should be improved or whether a new road should be added, but they are rarely performed before the land use decisions are made that overburden existing transportation facilities.

The purpose of this paper is to demonstrate the application of transportation modeling to land use decision making with particular reference to master plans in communities of about 2,000 to 20,000 acres. Although other factors such as environment, soils, drainage, and public service are also an integral part of land use decision making, the current model focuses on the interrelationship between land use and transportation. An integrated model of transportation and land use is developed for the purpose of choosing among a series of land development and road network alternatives in a suburban community.

One of the major problems in transportation modeling is route assignment--the determination of which routes, among several alternatives, trip takers will choose to reach their destinations. Route assignment is particularly important in land use planning because it can be used to determine which transportation facilities will be burdened by a given land use change and when roads and other facilities will become congested.

Equilibrium route assignment as developed by