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Transportation Research Record 1237

Contents

Foreword

The papers in this Record deal with issues relating to transportation planning, land use controls, and methods to alleviate traffic congestion in urban areas.

The first paper, by Gattis and Stover, recognizes that engineering values and concerns relating to transportation may not be shared by the public or by political decision makers. Using a Texas frontage road study, which used citizen survey techniques, they illustrate how to minimize public opposition.

Rossmy and Brown describe the use of focus groups in New York City to solicit the attitudes of automobile users. The focus groups were conducted to identify reasons why commuters use automobiles rather than transit for travel to the central business district.

Khisty et al. suggest that biometrical modeling may be superior to conventional modeling as an analytic tool for understanding growth and development in cities and the effects that the various infrastructure components have on the overall morphological system of the city.

The paper by Mullins et al. attempts to evaluate the land use impacts of transitways using Houston as an example. The results of the study indicate that the land use impacts of high-occupancy-vehicle lanes in the Houston area have been relatively insignificant.

A number of cities have attempted to control traffic congestion by adopting traffic level-of-service standards that statutorily restrict new development to the available street capacity. Dowling, in his paper, suggests that such standards may be too restrictive and proposes a more flexible approach.

Prevedouros and Schofer's paper investigates the use of cluster analysis to explore differences in demographics, household structure, and commuting patterns among the central business district area and the suburbs. The analysis suggests that the suburbs tend to be quite different from other areas in life-styles and transportation behavior. There must be a fundamental understanding of the underlying life-styles in order to develop transportation solutions for suburban residents.

Oppenheim presents an equilibrium model for urban activity and travel that considers costs and pricing of goods sold. The model reproduces spatial patterns of activity on the basis of the interaction of economic variables.

The paper by Miller et al. looks at the role and function of transit in growth management in Florida. The paper explores how transit influences growth in Florida and ways to improve the role of transit planning in the growth management process.

The last paper, by Deakin, reviews and critiques the ability of land use and transportation planning to respond to traffic congestion problems. It assesses the planning and policy issues raised by various strategies being used to address urban traffic congestion. The author suggests (a) additional research on methods to coordinate transportation and land use, (b) more rigorous requirements and incentives for local transportation and land use coordination, (c) cross-training of planners and engineers, and (d) greater training in project evaluation, negotiation, and the political process.

Planning Decisions and Public Attitudes About Roadway Operation

J. L. GATTIS AND VERGIL G. STOVER

Information about public needs and perceptions can help the engineer to anticipate and deal with public and political reactions to roadway planning and operational decisions. A Texas frontage road study conducted in 1986 and 1987 offered such insight. The specific concern was conversion of two-way frontage roads to one-way operation and the public opposition generated by such changes. Interviews to determine the attitudes held by certain segments of the public about frontage road management were conducted with 121 individuals in 15 small- and medium-size cities that have freeway frontage roads. The attitude survey indicated that various segments of the public have differing outlooks on the management of the frontage road network. Safety considerations were appreciated more readily by more of the groups than were operational factors such as delay. Coordinated planning could have prevented problems from arising. In a broader setting the survey indicated that engineering values and concerns may not be shared by others who are affected by the decisions the engineer makes. Comments made during the survey will inform the engineer of concerns expressed by others. By anticipating these concerns, the engineer and planner can plan so that problems do not arise in the first place, design in ways to minimize public opposition, and deal with existing situations in ways that placate opposition. Although Texas freeway frontage road patterns may not be common in other parts of the country, the observations and conclusions from the interviews have a broad range of applications.

Many engineers and planners working with streets and highways can muse about situations in which they acted according to "engineering and planning principles" only to be blindsided by sectors of the public taking quite different approaches to the situation. A few of these experiences can make one wary of dealing with the public, for as any government worker knows, no one ever calls to say things are all right; calls are made to protest what has been done. Although dealing with the public can be full of surprises, perhaps more so for engineers than for planners, an understanding of the attitudes and perspectives of key public groups can help one anticipate public concerns. By anticipating these public concerns, the engineer and planner can plan so that the problems do not arise in the first place, design in a way to minimize public opposition, and deal with existing situations in ways that placate opposition as much as possible.

A study conducted in 1986 and 1987 investigated certain aspects of frontage road operation in Texas. One part of this study (*1*) consisted of conducting interviews to determine the attitudes held by certain segments of the public about frontage road operation. The information gained through this study can help the engineer to anticipate and deal with public and political reactions to roadway planning and operational decisions.

Texas freeway frontage road operational patterns may not be similar to those in other parts of the country. However, the observations and conclusions from these interviews should be considered when planning and operating all roadway networks, not just frontage roads.

BACKGROUND

Texas freeways often are designed with entry and exit ramps connecting with frontage roads. Frontage roads in the major metropolitan core areas usually are one-way; most other frontage roads are two-way, even when entry and exit ramps connect the main lanes with the frontage road. The access and mobility provided by the freeway frontage road system often will stimulate adjacent commercial, industrial, and residential development. Such development is found both near large urban areas and in medium-size "stand-alone" towns. Traffic volumes on frontage roads in undeveloped areas usually are low, but subsequent land development creates higher traffic volumes.

The traffic situations created by higher volumes on two-way frontage roads include such problems as congestion at frontage road intersections with crossing streets. There is also the potential for accidents where the freeway ramps intersect the two-way frontage road. (In Texas the ramp traffic has the right-of-way at intersections with the frontage road.)

The engineering solution to these operational and safety problems often is conversion to one-way frontage roads. However, proposals to change the frontage roads to one-way operation can draw protests from local individuals who feel that the proposed change will have detrimental effects on them.

A review of literature showed that a number of reports have examined the economic aspects of freeway, frontage road, and access characteristics. A report by Woods (*2*) examined certain operational and safety problems of the ramp-frontage road intersections. However, none of these studies combined the impacts on traffic with impacts on local business to formulate an overall strategy for addressing short-range or long-range needs, both administratively and operationally.

SCOPE OF RESEARCH

In an attempt to better define the problems associated with frontage road conversion from two-way to one-way operations and, ultimately to propose effective solutions, the Texas State

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Department of Highways and Public Transportation (SDHPT) asked the Texas Transportation Institute (TTI) to conduct Study 402, "Warrants for One-Way Frontage Roads." One of the main foci of the study was the identification of opinions and attitudes about governmental operation of the frontage roads—specifically, the conversion of two-way frontage roads to one-way operation.

SURVEY METHODOLOGY

A project advisory panel composed of SDHPT staff was formed to help the TTI research team identify issues and concerns of SDHPT relative to directional conversion of freeway frontage roads. Since the emphasis of this research project was on the conversion of frontage roads from two-way to one-way operations, the panel suggested that the attitude surveys should be conducted in the locations where conversion to one-way frontage road operations is likely to occur or has recently occurred in Texas: municipalities in the urbanizing fringe of large metropolitan areas and small- and medium-size stand-alone urban areas. To better define the nature of the perceptions and attitudes relative to freeway frontage roads, informal interviews were conducted with city staff, council members, and developers in selected communities.

A draft survey questionnaire was then developed. Many of the questions/statements utilized a five-point semantic scale (strongly agree, agree, no opinion/no preference, disagree, and strongly disagree), so the participants responded by expressing levels of agreement or disagreement to a specific statement. The categorical responses produced by semantic scaling permitted a statistical analysis of the attitudes of the different interest groups. Open-ended questions were also employed in the survey to follow up on certain topics and to provide the respondents with the opportunity to express any opinion or observation relative to the subject of two-way and one-way freeway frontage roads.

The questionnaire was revised after being pretested in the field. Finally, the questionnaire was administered, primarily through personal interviews, although a few were completed by telephone or by mail. Overall, people from 15 Texas cities participated in the survey questionnaire. These cities were either in the developing fringe of a large metropolitan area or were mid-size stand-alone cities. The frontage roads found in these cities were categorized by one of the following:

1. The city had either all or a substantial number of two-way frontage roads.
2. The city had converted the frontage roads in its central portion to one-way.
3. The city had always had one-way frontage roads on almost all segments.

Opinion interviews were conducted in the summer and fall of 1986 and the winter of 1987.

In addition to people from various Texas cities, the interview was also administered to 12 members of the advisory panel during a meeting held in October of 1986. The responses of the panel were compared with those of the individuals interviewed around the state. This comparison offers insight into how the attitudes of highway professionals may agree with or differ from the attitudes of the public with whom the highway professionals may interact.

SURVEY POPULATION

Interviewees were identified through contact with the city staff. City staff were asked to name those individuals who represented the leadership within their area of interest and the community. For example, a city staff member was asked to identify city council members who exhibited a substantial interest in traffic and circulation issues and to whom other council members generally defer on such matters. Similarly, the city staff member was asked to name those individuals in business and real estate who were most visible in their area and whose lead typically was followed by others. In some cases city council members also had business or real estate interests or were developers. In these cases their attitudes as council members were solicited.

Owners and managers of businesses abutting the freeway frontage road were interviewed by TTI staff. These businesses included service stations, restaurants, motels, and automobile dealerships. The interviews were made with actual owners or managers with authority, such as the local manager of a national motel chain.

The following groups of citizens were surveyed:

- City staff, 19;
- City council members, 34;
- Real estate appraisers, 11;
- Real estate and development interests, 24; and
- Owners and managers of abutting businesses, 33.

A total of 121 people were interviewed.

As interviews were conducted, the results were compared periodically. This comparison indicated that the results did not change with additional interviews. Whereas a larger sample size would provide somewhat greater precision in confidence limits on the proportions of responses, the increase was not considered to be worth the considerable expense that would have been involved to obtain an even larger sample.

SURVEY RESPONSE ANALYSIS

A summary analysis of selected survey questions follows. Each question is presented as it appeared on the interview form.

Table 1 presents a statistical summary of the issues addressed and the attitudes evaluated. Respondents are categorized by type of frontage roads found in their city. The percent agreeing or strongly agreeing with the statement and the confidence limits are listed.

Table 2 is a similar summary by type of survey participant. The percent agreeing or strongly agreeing is listed. Those disagreeing, strongly disagreeing, or with no opinion compose the rest of the sample.

Preference for One-Way/Two-Way Frontage Roads

1. How do you classify your preference for one-way compared to two-way traffic on freeway frontage roads in urban areas?

Strongly favor one-way	Somewhat favor one-way	No preference	Somewhat favor two-way	Strongly favor two-way

Why? ______________________________

TABLE 1 SUMMARY COMPARISON OF ATTITUDES

	Proportion Agreeing With Statement						
	All respondents		Two-way(1)		One-way(2)		Advisory Panel
Statement	%	limits(3)	%	limits(3)	%	limits(3)	%
1. Favor one-way	52	45-59	50	40-60	55	43-66	92
2a. One-way hurts businesses at A and D	90	85-95	89	82-95	92	86-98	58
2b. One-way hurts businesses at B and C	39	32-46	31	22-40	50	38-62	8
3. Two-way safer	3	0-5	3	0-6	3	0-5	17
4. One-way higher capacity	55	47-62	54	44-64	55	43-66	83
6. Opposition increases with time	93	89-97	93	88-97	92	86-98	92
7. Build w/o frontage roads	14	9-19	13	6-19	16	7-24	17
8. Failure to develop back-up system	56	49-64	57	47-67	55	43-66	75

(1) Respondents where some or all freeway frontage roads are two-way

(2) Respondents where freeway frontage roads have been converted to one-way or have always been one-way

(3) Lower and upper 90% binomial confidence limits

A slight but not statistically significant majority of all respondents (52 percent) indicated a preference for one-way frontage roads. The percentage preferring one-way frontage roads was not significantly different for locations with two-way frontage roads versus locations with one-way frontage roads. The percentage (92 percent) of the advisory panel who favored one-way was much higher than the overall percentage.

Analysis of the responses by category of respondents indicated that there was a significant difference between the attitudes of the different groups of individuals. As Table 2 indicates, the majority of city staff (90 percent) and council members (68 percent) favored one-way freeway frontage roads. The proportions of staff and council favoring one-way frontage roads were significantly larger than 50 percent.

Appraisers indicated a preference for one-way freeway frontage roads. However, business people, real estate people, and developers generally preferred two-way operation.

Effect of Conversion on Business

2. In reference to Figure 1:

2a. Conversion of a two-way frontage road to one-way will have a detrimental effect on "highway-oriented" businesses (service stations, motels, and restaurants) at Locations A and D.

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

2b. Conversion of a two-way frontage road to one-way will have

TABLE 2 COMPARISON OF ADVISORY PANEL RESPONSES AND THOSE OF INTERVIEWEES

Statement	Advisory Panel %	Interviewees: Total %	City Staff %	City Council %	All Others %
1. Favor one-way frontage roads	92	52	90	68	34
2a. Agree, businesses upstream/downstream of ramp will be hurt	58	89	68	88	96
2b. Agree, businesses between off-ramp and on-ramp will be hurt	8	39	21	38	44
3. Agree, two-way safer	17	3	0	0	4
4. Agree, one-way has higher capacity	83	55	84	62	43
6. Agree, the longer two-way is maintained, more opposition to change to one-way	92	92	100	82	96
7. Agree, build freeways w/o frontage roads	17	14	31	15	9
8. Agree, two-way frontage roads lead to failure to develop alternate routes	75	56	68	59	52

a detrimental effect on highway-oriented businesses (service stations, motels, and restaurants) at locations B and C.

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

The vast majority (90 percent) of all respondents believed that conversion to one-way operation would be detrimental to businesses located downstream of an on-ramp or upstream of an off-ramp. There was little if any difference between the groups of respondents. Further, those residing in areas where the frontage roads were two-way had views that were similar to those where the frontage roads were one-way. During the interviews, 21 interviewees offered the unsolicited comment that the site upstream of the freeway exit ramp would be hurt more than the site downstream of the entrance ramp. It is possible that others of the 108 that agreed or strongly agreed with the given statement shared that opinion but did not make the comment.

Only 39 percent believed that the conversion from two-way to one-way frontage roads would have a detrimental effect on businesses located downstream of an off-ramp or upstream of an on-ramp. There were significant differences among the opinions of the various groups. Owners and managers differed from the other groups in their opinion that conversion to one-way traffic would be detrimental to businesses in these locations. Where the frontage roads always were one-way or were converted to one-way, a slightly higher proportion (50 percent) believed that one-way traffic is detrimental to businesses located between off- and on-ramps. However, the difference

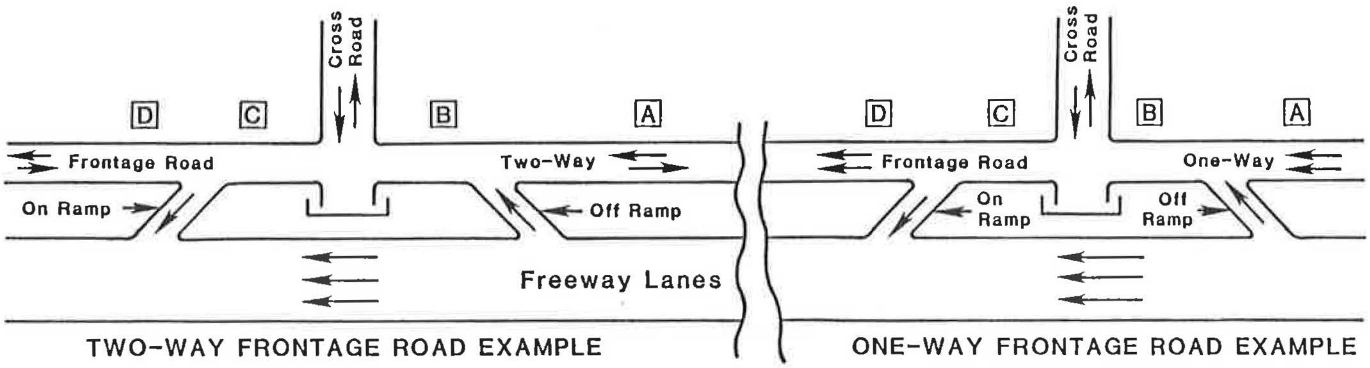

FIGURE 1 Sketch accompanying Question 2.

between respondents at one-way and two-way locations was not significantly different at the 90 percent confidence level.

The percentage of the advisory panel who felt that one-way operation would be detrimental to businesses was much smaller than that of the public. This was especially true regarding businesses located between an off-ramp and an on-ramp.

Two-Way Frontage Roads Are Safer

3. Two-way frontage roads are safer than one-way frontage roads.

Strongly agree	Agree	No opinion/ Don't know	Disagree	Strongly disagree

An overwhelming and statistically significant majority of respondents (85 percent) recognized that safety-wise, two-way freeway frontage roads were inferior to one-way. The chi-square analysis indicated that there were no significant differences among the different groups of respondents. The wording of this statement could be construed to conclude that two-way was considered to be as safe as one-way. However, the comments made during the interviews indicated that most persons, including those who preferred two-way frontage roads, recognized that one-way was safer.

One-Way Frontage Roads Have Higher Capacity at Intersections

4. The intersection of a frontage road and a cross street can carry more traffic after the frontage road is changed from two-way to one-way traffic.

Strongly agree	Agree	No opinion/ Don't know	Disagree	Strongly disagree

A slight majority (55 percent) agreed that the intersection of a frontage road and a cross street could carry more traffic when the frontage roads were one-way. The capacity advantage of one-way frontage roads was much less appreciated than the safety advantage.

The chi-square test indicated that there were significant differences among the different groups of respondents. City staff and, to a lesser extent, city council members tended to recognize the capacity issue. The other groups appeared to have no general recognition of the increase in capacity with one-way operation compared to two-way.

The percentage of the advisory panel holding the opinion that capacity is higher with one-way frontage roads (83 percent) was significantly higher than that of the survey participants (55 percent).

Effects of Conversion on Land Values

5. What effect does the conversion from two-way to one-way traffic have on the value of properties along the frontage road?

Responses can be categorized as follows:

	City		*Land*		*Total*
	No.	*%*	*No.*	*%*	*No.*
Conversion will be detrimental	11	21	27	40	38
Conversion will cause a short-term decline	11	21	6	9	17
Conversion will hurt some but not others	9	17	13	19	22
Conversion will hurt some and benefit others	9	17	9	13	18
Conversion will have little or no effect	7	13	8	12	15
Conversion will be beneficial	2	4	1	1	3
Don't know	3	6	4	6	7
No response	1	2	0	0	1
Total	53		68		121

The "land" interests (abutting owners, real estate and development interests, and real estate appraisers) were much more likely to predict a detrimental effect on real estate values due to conversion than were the "city" interests (staff and council). Among owners, 16 of 33 (48 percent) believed conversion would be detrimental; among realtors and appraisers, 11 of 35 (31 percent) felt this way.

Opposition to Change Increases with Time

6. The longer that two-way traffic is maintained on a freeway frontage road, the more opposition there is to a change to one-way.

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

Nearly 93 percent of the total survey responded that the longer that two-way traffic is maintained, the more opposition there is to a change to one-way flow. There were no significant differences among the different groups of respondents or between locations where frontage roads were one-way or two-way.

Freeways Should Be Built with Frontage Roads

7. Freeways should be built with entry and exit ramps but without frontage roads.

Strongly agree	Agree	No opinion/ Don't know	Disagree	Strongly disagree

A sizable proportion (78 percent) of the respondents indicated that freeways should originally be built with frontage roads. There was no significant difference between the groups of respondents, although some staff, council members, and business people expressed a preference for diamond interchanges without frontage roads. Although the difference was not statistically significant at the 10 percent significance level, freeways without frontage roads were more acceptable in areas where frontage roads are two-way than where they are one-way.

Failure to Develop Backup Street System

8. The presence of two-way frontage roads will lead to a failure to develop a supporting street system of alternative routes to the frontage road.

Strongly agree	Agree	No opinion/ Don't know	Disagree	Strongly disagree

Explain ______________________________

A slight but not statistically significant majority (56 percent) indicated that the presence of two-way frontage roads will lead to a failure to develop a supporting street system of alternative routes to the frontage road. However, a sizable majority of the real estate people/developers (71 percent) and city staff (68 percent) were of the opinion that two-way frontage roads did indeed retard the development of a supporting street system. City council members (59 percent) also expressed this view.

SELECTED SURVEY COMMENTS

The survey included open-ended questions to follow up on some of the semantically scaled questions and to obtain individual opinions and comments. The following comments were selected to provide additional insight into the public's view of freeway frontage road management.

Influence in Making the Decision to Change

The decision to convert a two-way frontage road to one-way is not only an engineering decision but also a political one. Various interests affected by the conversion will form opinions about the proposed conversion and then express those opinions to their political leaders. A council member may then arrive at a position based on pressure from various interest groups.

The following comments express a range of attitudes that affect political realities.

- "Two-way would be nice, but I hope I'm not so mercenary over the dollar." Comment from an abutting owner favoring one-way.
- "I get more pressure from people who pay taxes [abutting property owners] than from people that drive." Comment by a council member favoring two-way.
- "If you didn't have property owners along the frontage road, then the state would not have worries about conversion." Comment from a realtor favoring two-way.

The State's Role

Some interviewees made comments about the role of the state in operating frontage roads. The following selection of comments reflects a wide range of philosophical perspectives.

- "SDHPT should establish some standards as to when one-way or two-way frontage roads are to be used." Comment by a businessman.
- "If the frontage road is going one-way, then [SDHPT] should have done it from the beginning." Comment by a council member (a professor).
- "Eliminate uncertainty; set up frontage road, then don't change it." Comment by a developer.

Negative Attitudes

Comments made by business owners and others in opposition to conversion to one-way show that one-way operation is perceived to be, and in fact may be, detrimental to some businesses in given situations.

- "If I had known that this frontage road was going to be converted to one-way [in the future], I would not have opened up here." Comment by an abutting owner favoring two-way.
- "I developed this business under two-way frontage road conditions and want it to stay two-way." Comment by an abutting owner favoring two-way.
- "People have complained about getting to my business [which is on a one-way frontage road]." Comment by an abutting owner favoring two-way.
- "I know of a location rejected by a motel because the frontage road was one-way." Comment from a real estate agent favoring two-way.
- "I have seen conversion to one-way cause a child care business to fail." Comment from an appraiser favoring two-way.

One owner of a local restaurant located along a frontage road that had been converted to one-way did not want to be interviewed but did complain about the conversion. He believed that a sizable portion of his patrons had previously reached the restaurant by driving in the contraflow direction on the two-way frontage road and now no longer came because of the extra distance down to the next crossover and back under one-way operation.

Positive Attitudes

The comments of some who had experienced conversion to one-way frontage road operation show that the perception of problems in advance of conversion may be much worse than the reality after conversion.

- "We thought that the change to one-way would hurt (business) but it didn't." Comment by an auto dealer on a frontage road that was changed from two-way to one-way traffic.
- "Conversion to one-way does not hurt (detrimental to business/property value) as much as people think." Comment by a real estate appraiser.
- "Our business does not suffer due to one-way frontage roads because we are a specialty business." Comment by an abutting owner on a one-way section who favors two-way.
- "Previous conversion to one-way didn't affect the price of the site bought just after conversion." Comment by an abutting owner who favors two-way.

Backup Street System

Comments about the absence and presence of backup street systems to the frontage roads (i.e., alternative routes) reveal a variety of perceptions. Some of the interviewees do believe that the presence of frontage roads inhibits development of the street circulation system whereas others do not.

- "If the bypass frontage roads were one-way instead of two-way, the street [a proposed parallel, minor arterial] would have been built." Similar statements were made by two city council members and by the developer of one of the abutting subdivisions.
- "The problem with converting from two-way is that the paralleling supporting roadways were not planned for." Comment from a council member favoring one-way.
- "It is hard to get people to vote money [for a backup road] when the frontage road exists." Comment from a developer favoring one-way.

Freeway Effects on Circulation

In addition to comments about the backup street system, a number of survey participants offered unsolicited comments about the state of ramp configurations, frequency of streets crossing the freeway, and the effects of the freeway upon vehicular circulation.

- "Freeways create an urban barrier, interrupting the circulation patterns." Comment by a staff person favoring two-way.
- "I'm concerned with the excessive distance between crossing streets, especially in urban areas." Comment by a council member favoring one-way.
- "In urban areas with plenty of crossovers, one-way would not have a real impact." Statement by a mayor.

A number of interviewees expressed concern with the availability of roads crossing the freeway. A higher frequency of crossovers makes one-way frontage roads more acceptable.

Comfort and Safety

Motorists may feel vaguely uncomfortable or outright unsafe when driving on two-way frontage roads with connecting entry and exit ramps. Motorists from out of state or large metropolitan areas may be used to one-way frontage roads only; they can be surprised by a two-way frontage road.

- "Two-way is more convenient but more dangerous." Comment by a council member favoring one-way.
- "A number of bad experiences with two-way can cause people to change their minds and favor one-way." Comment from an appraiser favoring one-way.

In one city an unfortunate fatal accident related to two-way operation seemed to be a major factor in convincing local leaders to choose conversion to one-way operation.

CASE STUDIES

In a few instances the local people being interviewed related case histories of two-way frontage road conversion to one-way to the interviewers. These case histories show what can go wrong.

Reviewing the city files revealed that those who oppose conversion are more likely to attend city council meetings; the proponents may only write or call their council member. Recorded instances of a business person putting public interests ahead of personal business interests were rare.

The lack of alternative or backup routes caused some interesting situations. The leaders in one town recognized that there was exclusive reliance on the two-way frontage road. However, the new alternate street was long delayed because competing development interests could not agree on a route for a street parallel to the frontage road.

In one city residents have successfully opposed the completion of the backup street, not wanting through traffic in their area. Thus, the subdivision relies entirely on the frontage road for access. Since a backup street is not in place, millions of dollars are being spent on overpasses to reduce the circuity of travel that will result from conversion to one-way frontage roads.

Residents of one west Texas city solved the problem of roundabout routes after conversion to one-way frontage roads. They simply drove through a vacant lot to reach their destination. Rainwater-filled tire ruts are clearly visible in photographs of the route. In the same city an alley used to overcome roundabout routes had a peak-hour count of over 250 vehicles.

A few comments indicated that some motorists deliberately drove the wrong way on a one-way frontage road to avoid the indirect routes present in the one-way system. In the two cities where this comment was made, backup or alternative circulation routes were sorely lacking.

CONCLUSIONS

This survey was successful in reporting attitudes of various segments of the public toward frontage road management. The attitudes of various key groups were sometimes in conflict. The process of identifying public attitudes about frontage road management also revealed attitudes concerning the management of the roadway system in general. Engineers, planners, and other public officials can be more effective if they understand both the issues and the various players in roadway decision processes: the elected officials, developers, and affected property owners or tenants.

Different Groups May Have Incompatible Perspectives

Different interest groups that the engineer in government must serve can have perspectives that are different and sometimes incompatible with the engineering perspective. The engineer may be concerned with an orderly or logical roadway pattern, whereas the business person may be concerned with the welfare of his or her business concern. A particular situation may be one small part of an engineer's job but may affect the entire livelihood of a business person.

Engineers and planners may have perspectives that differ from those of others owing to education, tendencies to absorb peer group values, different psychological compositions of individuals who tend to enter different occupations, or other factors. Whatever the cause, tension and conflict can be exacerbated if the engineer is not aware of fundamental differences in values and perspectives among different individuals and groups.

Engineers need to prepare for the political side of engineering. The nature of governmental engineering employment may limit exposure to other interest groups and thus deny the engineer the opportunity to consider different perspectives and different ways of thinking. In particular, most business people and developers place a high value on perceived access to their site. They can be expected to take a vested-interest view; many will not be satisfied by an overall analysis showing benefits to the public in general.

The outlook of the advisory panel engineers differed from that of the business persons and developers on a number of issues. On the other hand, the engineering advisory panel shared some perspectives with city staff, such as on preference for one-way frontage roads, effect on businesses, safety, capacity, and two-way frontage roads leading to a failure to develop a backup street system. City council members generally were more attuned to the advisory panel perspective, although less so than city staff interviewees, most of whom were engineers and planners.

When state engineers see a need within a city, advance contact and identifying shared views with potential allies—city staff, city council, and citywide groups—can help withstand the often intense opposition a few intense individuals can generate. If the public officials can identify those who share their views and encourage them to be as active as the opposition, the political environment may be more conducive to implementing needed improvements.

Some Concerns Are Shared, Some Are Not

From time to time the engineer will take controversial actions. When a need for action is explained to the council or the public, some issues will be better understood than others. For instance, traffic safety is a substantial concern that most people recognize. Also, accident information is readily understood by most individuals. Location-specific data such as conflict analysis, erratic maneuvers, and "near misses" may be convincing evidence in addition to accident data.

On the other hand, capacity and operational advantages of certain roadway options do not appear to be generally understood. This means that such data should be presented in as simple and nontechnical a manner as possible or perhaps should be avoided altogether.

One important desire of the business person, a desire perhaps not shared by the engineer or planner, is for a clear, unchanging set of government regulations. The business person wants to know what to expect. One developer said, in effect, "I don't care what you do, just make everybody play by the same rules and don't change them."

Fair Hearing for All Sides

It is also desirable, if not essential, to make those individuals who believe that a change will adversely affect them believe that they have received a fair hearing and that their individual concerns have been addressed. Based on experiences involving public works projects, it appears that the following are essential in dealing effectively with the portion of the public that has a vested interest in a change from two-way to one-way frontage road operations.

1. Provide the opportunity for individuals to freely express their concerns and develop a belief on their part that their concerns are appreciated. Experience indicates that this is best accomplished in an open, informal meeting where it is made clear that the purpose is to obtain information and for individuals to express their concerns and that no decision has yet been made.
2. Address the concerns of each individual in a factual, easy-to-understand manner.
3. Proceed to a formal public hearing only after a thorough study has been made of the problems and advantages of one-way versus two-way frontage road operations.

Such a procedure has been effective in ameliorating opposition where the decision is controversial among a few individuals but the general public has not become involved. The engineer may need assistance or training to adequately address situations where public participation is called for.

Roadway Impacts

Traffic engineers recognize the ways that development can affect the street system, and many cities require a traffic impact analysis for new development. But by the same token, roadway changes can affect nearby businesses and landowners.

The survey results indicate that the potential for the greatest negative impact resulting from conversion to one-way operation is to those tracts of land located upstream of an exit ramp or downstream of an entry ramp (i.e., outside of the diamond interchange area). It appears that businesses that are unique or that have relatively little competition will not be affected greatly even if they are situated in the area outside of the diamond interchange. An automobile dealership situated upstream of an exit ramp would be expected to fare better than a local restaurant if the frontage road were converted to one-way. The business that relies on convenient access, such as a fast-food establishment, may be hurt by conversion to one-way operation.

To Delay or Not To Delay

There are cases in which the opposition to a roadway improvement may subside with time. But waiting also can allow the city structure to become more dependent upon the network as it is. This study indicates the clear perception by most that a change from two-way to one-way traffic should be undertaken as soon as possible because opposition may increase with time.

Coordinated Planning Could Prevent Problems from Arising

Land use planning must be coordinated with roadway facility planning. Many of the problems and adverse reactions to conversion to one-way frontage roads result from an apparent lack of such planning. The same can be said for a number of traffic operations problems.

More attention to land planning and land development along the freeway corridor could produce long-term benefits. Needed conversions to one-way operation would be more acceptable to various interest groups if the affected area were not totally reliant on the frontage road for access and circulation. Planning and regulation are necessary to ensure that these alternative routes are in place when needed. The process for governmental approval of land plats or building permits along a two-way frontage road should provide for written notification to the applicant that the frontage road may be converted to one-way in the future. This notification should be on record in the event of future questions. The state agency should coordinate roadway layout planning with local governments.

In structural design practice, redundant or backup members are provided so that all of the design "eggs" are not placed in one basket. In a somewhat similar way, the roadway/land use system designed without redundancy can fail when an unexpected traffic operational load is imposed. When the frontage road (or any road) is converted to one-way, a great deal of inconvenience to the traveler can result from increased circuity of travel when no backup or alternative road serves the area or there are infrequent cross streets. Unless a backup roadway network is already in place before the frontage roads are built, the mere provision of frontage roads can prevent other redundant roads from being built.

Preference for Frontage Roads

The interviewees preferred freeways having ramps connecting with frontage roads to freeways and ramps without frontage roads. As the survey progressed, the interviewer noted that the few who opposed frontage roads seemed to have accents from other parts of the country. The interviewer began to ask opposing respondents where they were from, and most were from other states. Although the study did not address this issue, it could be that the preference for the ramps connected with frontage roads simply reflects what most of the people were used to.

SUMMARY

These interviews showed that the engineer and planner can expect to have views and concerns that are significantly different from those who may be affected by engineering and planning decisions. The reported comments give the engineer insight into some concerns held by certain key groups—concerns the engineer may not have considered. Planning and regulation of development could lessen the chance of conflict between the engineer/planner managing the roadways and elements of the public.

The frontage road interview results offer the engineer and planner an understanding of the attitudes and perspectives of key public groups about both frontage roads and roadways in general. By understanding and anticipating public concerns, the engineer and planner can plan so that the problems do not arise in the first place, design in a way to minimize public opposition, and deal with existing situations in ways that placate opposition as much as possible.

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Congestion Management in New York City: Managing Why People Drive

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The solution to Manhattan's congestion management problem of increasing traffic congestion, increasing air pollution, and decreasing transit ridership requires comprehensive actions to modify regional travel behavior. To this end, a cooperative interagency research effort was conducted using focus groups to solicit the attitudes of automobile users. That effort and the process of which it was a part are presented here. To maximize efforts related to Manhattan's congestion management problem, the Manhattan Central Business District (CBD) Access Group—composed of transportation, environmental, and planning agencies serving the New York City region—was convened. In its behalf, *The Manhattan Auto Use Decision Study* was conducted to identify the reasons travelers use automobiles rather than transit for CBD travel and to solicit suggestions and reactions to proposals for shifting travelers from cars to transit. The insights into travel behavior and market attitudes provide information for developing strategies to reduce vehicular congestion, improve air quality, and increase transit ridership. The study found that automobile travelers have a dichotomy of views about automobile use; commuters are making logical choices; cost may be dominant, but subtle, in influencing mode choice; and a "carrot and stick" may be needed to divert automobile users to transit. Many of the project's findings have been accepted and acted upon, underscoring the validity of the study's results and the relevance of the focus group methodology.

The search for congestion management solutions has become a national phenomenon. Increasingly, suburban congestion, innovative transportation management ordinances, and gridlock alert days find their way into the local and national media. In early 1987 New York City embarked on a regional effort to address its own congestion problem. As part of that effort, focus groups were conducted to identify pertinent issues and to introduce transportation user perspectives to the early stages of the planning process. The following review of that process provides both insight to the problem and a case study on the use of focus groups.

NEW YORK CITY'S CONGESTION MANAGEMENT PROBLEM

The solution to the congestion management problem of increasing traffic congestion paralleled by increasing air pollution and decreasing transit ridership requires modifying regional travel behavior. Comprehensive responses are needed so that the results are socially acceptable.

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First, it is necessary to define the terms. The New York City congestion management problem has been defined primarily as relating to access to and movement within the Manhattan Central Business District (CBD)—that is, that portion of Manhattan south of 60th Street. The CBD is unique in that its 8.4 square miles contains the highest concentration of business and commercial enterprises in the United States, employing approximately 25 percent of the region's work force (*1*).

On a typical fall business day in 1985, about 3,350,000 persons entered the CBD using a wide variety of mass transit and arterial facilities during a 24-hour period. The utilization of modes by CBD travelers was as follows:

	Persons entering Manhattan	
Mode	*Number*	*Percent*
Automobile, taxi, or truck	1,149,947	34.4
Public transportation		
Rapid transit	1,640,732	49.1
Suburban rail	218,692	6.5
Ferry or tramway	37,947	1.1
Express bus	201,220	6.0
Local bus	96,127	2.9
Total, public transportation	2,194,718	65.6
Total, all modes	3,344,665	100.0

Nearly two-thirds (65.6 percent) of all daily entrants arrived in the CBD by mass transportation, despite a decline in subway ridership during the first part of this decade. The automobile congestion problem was generated by the remaining 1,149,947 persons, who entered the CBD by automobile, taxi, or truck (*1*). Metropolitan Transportation Authority (MTA) analysis indicated that not quite two out of every three automobile travelers (63.9 percent or 735,970 persons) entered the CBD from other parts of New York City, with the remainder coming from New Jersey, Long Island, and the northern suburbs.

A COMMON NEED TO UNDERSTAND THE AUTOMOBILE USER'S PERSPECTIVE

In order to contribute to the resolution of the congestion management problem, a cooperative market research effort was conducted to identify the underlying reasons why automobile travelers drive instead of using public transit and to solicit their suggestions and reactions to proposals for shifting travelers from their cars to public transit. The study, entitled *The Manhattan Auto Use Decision Study*, was brought about by a convergence of views among 11 agencies represented in the CBD Access Group. Organized to focus on the New York City congestion management problem, the CBD Access Group provided the forum in which the differing views of the major players—that is, New York City, the MTA, and the Port Authority of New York and New Jersey (PANYNJ)—coalesced. However, it was the effects of congestion on air quality that brought the issue to a head.

The environmental dimension originally was raised by the Clean Air Act of 1970. The act set uniform national ambient air quality standards, established an attainment deadline for meeting those air quality standards, required federal approval of state implementation plans (SIPs), established motor vehicle emission standards, and outlined broad citizen participation requirements (*2*). Although it has been amended, the act's basic standards require New York City and other cities to implement strategies to reduce ozone, carbon monoxide, and other air pollutants that darken their skies and threaten human health. Although industrial emissions account for some pollutants, the Environmental Protection Agency (EPA) notes that in New York, motor vehicles are by far the primary source of carbon monoxide and lead and a significant source of nitrogen oxides, ozone-forming hydrocarbons, and particulates (*3*).

Subsequently delayed, the applicable deadline for compliance was December 31, 1987. Penalties arising from noncompliance jeopardized receipt of $800 million in federal funds for highway and antipollution projects in the New York City metropolitan area. Accordingly, the act was a major motivator for attempts to resolve the automobile congestion, air pollution, and transit ridership problem.

Partially in response to the act's pending pollution control deadline, the New York City Department of Transportation (NYCDOT) Commissioner Ross Sandler issued a report to the mayor entitled "An Approach to Reducing Vehicle Congestion in New York City." This report (of September 1986) stated that unless new programs were initiated, vehicular congestion in New York City would deteriorate. Accordingly, the report discussed the problem of arterial congestion in New York City, the need to reduce it in the short term, a menu of possible measures for attaining such a reduction, and the need to take action before the federally mandated Clean Air Act compliance date.

The report attributed the automobile congestion problem to an increase in the percentage of persons entering the Manhattan CBD by automobile. The market share of CBD entries captured by automobile, taxi, and truck increased from 18 percent in 1948 to 34 percent in 1984. This represents an 83 percent increase in vehicular passengers, from 657,000 persons to 1,112,000 persons, despite an 11 percent decline in total daily CBD entries from 3,691,000 persons to 3,274,000 during the same period. The number of vehicles entering the CBD nearly doubled, from approximately 388,000 to 734,000 vehicles, between 1948 and 1984. In contrast, total transit ridership into the Manhattan CBD declined by 24 percent during the same period, according to the New York Metropolitan Transportation Council (NYMTC) (*1*). Interestingly, had the 1948 modal split remained constant until today, 349,000 fewer vehicles would be entering the CBD, and the subway would have 504,000 more riders daily. The report went on to project that the unprecedented levels of automobile travel experienced during the 1980 transit strike could become a daily occurrence by 1990 (*4*).

The report assumed that strategies to reverse the traffic situation should be based on continued enforcement of traffic parking regulations and implementation of the MTA's capital program, as "improved, attractive, reliable public transportation will better compete with the auto" (*4*).

The report was a call to action, not endorsing a specific "menu" of measures but endorsing the process of continued analysis, public hearings, and responsive decision making (*4*). The recommended approach was to reduce vehicles in motion in Manhattan, downtown Brooklyn, and Long Island City. Actions suggested for consideration included banning cars (during a part of the day in a section of the CBD), instituting congestion pricing, restricting single-occupant cars, restricting entries by license plate, placing tolls on free East River crossings, establishing more transitways to speed buses and taxis, restricting vehicles that stay in motion, and reducing the automobile commuter tax-free fringe benefit. Other measures discussed included enforcing laws more strictly, constructing peripheral park-and-ride sites, and requiring alternate fuels for taxis, buses, and other fleet vehicles. Not only did NYCDOT want solutions to the automobile congestion problem but also assistance in getting them. Accordingly, the significance of the report went beyond what was said to include the development of the planning process that continues.

In response to the city report, a coalition of leading businesses, business organizations, labor unions, and civic and community groups was formed (*5*). Entitled the Coalition for Improved Transportation and Air Quality, this group contributed to the dialogue between the business community and the city on this issue.

As another follow-up to the NYCDOT report, a group of 11 agencies, including MTA and the Port Authority, was convened in October 1986. The host was NYMTC, the federally designated Metropolitan Planning Organization (MPO). Entitled the CBD Access Group, the group's objective was to better define the specific problem and proposed solutions relating to New York City congestion. The CBD Access Group provided the forum in which the interests of New York City, MTA, and the Port Authority coalesced to form a cooperative planning effort. A work program was devised to develop information quickly by using existing research and resources to the extent possible. Regular meetings were held to divide responsibilities among members, report on work progress, and coordinate efforts.

This paper examines one element of that work program—*The Manhattan Auto Use Decision Study*—its findings, the events that brought about the overall cooperative effort that spawned it, and discusses how the project's findings have reinforced and influenced subsequent efforts. Sponsored by the MTA, developed with the Port Authority, and funded by the UMTA, the project was executed with the assistance of the Decision Research Corporation, a market research firm.

First a few words about the MTA. Every weekday morning, public transportation gets 83 percent of the members of the work force to their jobs in the Manhattan CBD (*6*). The MTA, which has jurisdiction over the New York City Transit Authority, Long Island Rail Road, and Metro-North Commuter Railroad, carries most of those people. As it entered the 1980s, the mass transit network chronically received less than 30 percent of the capital needed to keep it running. By 1980 the system was in a state of desperate disrepair (*6*). However, in 1981 the New York State Legislature declared a "transportation emergency" and approved the MTA's first 5-year capital program, funded at $8.5 billion, to rebuild mass transportation for the metropolitan economy (*6*).

In September 1985, to establish its case for the continued availability of capital funds, the MTA conceived its 3-year Strategic Planning Initiative (SPI) (*7*). One of the first SPI efforts was an analysis of the performance of the subway system and the potential impact of the Capital Program (*8*). In 1986, based on this analysis, the MTA established goals to increase ridership by 1992—15 percent on the subway system and 10 percent on the regional transportation system as a whole. By restoring the system to a state of good repair, ridership became the principal parameter of system performance.

In that regard, MTA was interested in helping the city address its congestion management problem. By assisting New York City in getting people out of cars and onto transit, an important contribution to realizing MTA's ridership goals would be made.

MTA was not the only agency concerned about its role in helping the region meet its future travel needs. In 1984 PANYNJ linked surging trans-Hudson travel demand, marked by longer delays at vehicular crossings and overcrowding on some Port Authority Trans-Hudson (PATH) routes, to an increasingly integrated regional economy. PANYNJ noted that these regional economic growth trends could continue if expansion of transportation services could outpace worsening rush-hour congestion and crowding. Improving mass transportation was the only workable strategy for meeting the projected growth in the trans-Hudson commuter market (*9*). Accordingly, the Port Authority offered a plan for coordinated improvements in trans-Hudson mass transportation on a bistate basis. It proposed and identified new projects and expanded services with the potential to handle an additional 50,000 peak-period commuters via transit, costing in excess of $900 million in new investments (*9*). Several improvements in trans-Hudson capacity were initiated—expanding PATH stations for longer trains, instituting new ferry service between Hoboken and the World Financial Center, planning New Jersey Transit projects that would bring more commuter rail passengers directly into Penn Station, and developing a second high-occupancy vehicle lane at its Lincoln Tunnel to help accommodate the 5,000 daily buses. From this work the Port Authority knew firsthand the importance of maintaining a balanced transportation system and its role in supporting the economic vitality of the region.

To maximize the effectiveness of New York City, MTA, and Port Authority efforts, a common understanding of the automobile user's perspective should be reflected in strategies to reduce automobile congestion, improve air quality, and increase transit ridership. To that end, *The Manhattan Auto Use Decision Study* was undertaken.

FOCUS GROUP METHODOLOGY

The CBD Access Group designed a qualitative market research methodology based on the use of focus groups. This methodology enabled the concerned agencies to get a better understanding of the reasons underlying automobile traveler behavior without formal and time-consuming traditional citizen participation mechanisms. One hundred and seventy-one commuters and daytime travelers who use automobiles to get to or about Manhattan spoke about their automobile use decisions in a series of 18 roundtable discussions. The study included two groups of Manhattan CBD commuters from each of seven geographic market areas east of the Hudson River—northern counties, the Bronx, Manhattan, Queens, Brooklyn, Long Island, and Staten Island—and four groups of midday Manhattan CBD travelers. Counties west of the Hudson were not included since they had been considered in previous research by the Port Authority. The majority of participants were selected from respondents to NYCDOT's East River Crossings Survey. The survey listing was supplemented by the consultant's appropriate directories. Prospective participants were screened using a brief telephone survey. Having met the criteria, interviewees were offered a $50 stipend to participate in a 2-hour group discussion on transportation issues.

Led by the focus group moderator, participants discussed their travel options, as well as how and why they chose to travel by automobile. Also, they discussed their views on the personal and societal impacts of their modal choice and the equity, efficacy, and potential effects of suggested incentives and disincentives for motivating them and their fellow automobile travelers to switch to public transit.

In interpreting the responses of participants, it is important to keep in mind that the results of focus groups cannot be projected and thus do not produce quantitative information to predict responses of the market at large. However, focus groups do allow transportation planners to become "smart" quickly about the types of issues and reactions that may arise as a result of implementing given proposals. Most important, focus groups uncover the public's real-world perception of existing conditions, potential changes, and their probable impacts. The groups allow for an analysis of the decision process leading to participants' behavior. Focus groups are valuable for identifying and describing market segments in terms of their attitudinal and behavioral characteristics. These market segment profiles provide the basic framework for developing the subsequent quantitative research needed to measure the relative size and distribution of the market segments.

FINDINGS AND IMPLICATIONS

The Automobile Problem

The problems associated with Manhattan automobile congestion and poor air quality were presented to participants for their consideration. Participants discussed their perceptions of these problems, offered solutions, and speculated on the probable regional and personal impacts of these and moderator-provided solutions.

Participants were consistent in their view that automobile congestion and air pollution have eased during recent years and in their belief that they are not the primary cause of either problem. For example, the Manhattan taxi commuter blamed the non-Manhattan driver, the suburban driver blamed the city driver, and the automobile traveler from the non-Manhattan boroughs blamed the taxis and buses. In addition, automobile commuters did not see themselves as part of the midtown congestion problem. They argued that city streets are relatively clear in the morning when commuters drive from the highway directly to their parking lot. They described midtown congestion as a midday problem caused by taxis and trucks or by noncommuters who double-park and circle the block looking for their destination or a parking space.

Further, participants often expressed a belief that automobiles are not the primary cause of urban air pollution. They pointed to the puffs of smoke emitted from trucks and buses as evidence. They argued that because their cars meet State-imposed emission standards, their cars were environmentally sound. Interestingly, some automobile commuters said that they were enhancing the attractiveness of public transit by not adding to already-crowded conditions on the subway.

Travelers' Perspective

Automobile users were consistent in expressing their travel perspective as "I need to get to and from work as quickly, dependably, safely, and comfortably as possible." In describing how they decided to get to and from work and business appointments, participants presented a wide assortment of travel needs, concerns, and route choices indicative of the complex nature of travel patterns and travel resources in and around the Manhattan CBD. However, in describing their reasons for choosing to travel by automobile, participants generally fell into one of two categories.

Two Groups

Members of the first group claimed to travel exclusively by automobile because of what they perceived to be special personal or work-related needs. "I need my car for work" or "transit is too far from my home" were among the reasons these travelers mentioned. Interestingly, these travelers often viewed themselves as "different" from or "more sensitive" than travelers who used public transit. In fact, they were also somewhat price insensitive. Accordingly, it may cost them more out-of-pocket money or cause an increase in employer-provided payments or a change in work or residential location, but these people will not use public transit. When measures to restrict automobile access or reduce automobile subsidies were suggested, many of these automobile users balked loudly and argued that it was their *right* to travel as they chose. Some even threatened to change jobs if they could not drive in and around Manhattan. They saw it as government's responsibility to provide the necessary vehicular capacity.

Members of the second group were more receptive to improved transit and willing to use it, but decided that the automobile was the superior travel option given their current personal, work, economic, and transportation conditions. They carefully weighed such critical factors as travel costs, time, reliability, predictability, and safety in reaching their travel mode decision. This group, as well as the other group, placed increasing importance on quality of service factors, such as comfort, convenience, and human or interpersonal factors. This second group was more price sensitive and aware of transit. In some cases these travelers were attracted to their cars because of economic incentives, such as employer parking/automobile subsidies, free on-street parking, or family carpools. In other cases these travelers were retreating from public transit in order to attain the control they felt they needed in order to get to their destination reliably and safely.

Commuter Perspective

Commuters generally had a consistent perspective in terms of their awareness of the total travel experience, basic transportation factors, emerging service-quality issues, and cost. Although mentioned last, cost appears to play a dominant role in influencing those travelers who use the car and may be the most intractable issue to resolve equitably.

Door-to-Door Perspective

Travelers explained that they view their trip in its entirety rather than as a series of short trips and transfers. Importantly, the overall attractiveness of a trip is constrained by the quality of its least desirable segment. For instance, commuting by public transit may not be desirable if the commuter railroad is excellent but the subway is problematic. On the other hand, traveling north-south in the CBD by private automobile may be undesirable if it is subject to traffic delay or parking is unavailable. Similarly, midday travel within Manhattan using a superior subway service is viewed as unacceptable if connecting to the crosstown bus results in delay due to traffic. This door-to-door perspective of participants highlights the need for coordination among all of the region's transportation agencies as well as the value of corridor-based planning. Planning and marketing efforts should take this door-to-door perspective into account if public transit is to increase its share of the travel market.

Transportation Basics

Transportation planning axioms indicate that travelers behave logically in making their travel decisions. Automobile users consider such factors as travel time, reliability, predictability, safety, and the availability of information. When transportation does not meet these basic criteria, travelers look for other means that do so (i.e., they look for the means that will enable them to be in control of their travel). Losing this control was a frequent and strongly emotional concern raised without solicitation in all of the roundtable discussions. This reaction suggests that loss of control is a key factor in attracting people to use the automobile and in driving people out of public transit, and returning a sense of control can contribute to convincing them to return. Automobile commuters point out that if they are caught in traffic as a bus passenger, they must wait out the delay while they are trapped in the bus; however, if they are caught in traffic while driving their car, they can take an alternate route, listen to their radio, regulate their air conditioner, or stop to call their office and have a cup of coffee. To return a sense of control to transit users, transit reliability, transit predictability, travel time, system connectivity, and the information necessary to make logical choices are critical factors.

It should be noted that the transportation requirements of some automobile travelers may make it impossible for them to respond to any changed circumstances, and they will continue to use the car.

Importance of Service Quality

Quality of service surfaced as a major issue through the focus group sessions. Some participants explained that they are willing to pay a premium to use the automobile because they are worthy of the superior ride and the freedom it provides. This is particularly noteworthy since these costs are often not borne by the automobile user. As pointed out in Decision Research Corporation's analysis, service quality has become a critical issue to service industries nationally (*10*). As a service provider, therefore, public transit must offer a high-quality, user-friendly product that is priced competitively. In that regard, automobile travelers believe that they deserve to be treated as human beings and in a manner that protects their dignity and personal well being. Other service-related concerns included crowding, communication, and information availability. These need to be incorporated with the transportation basics to reinforce the transit user's sense of control.

Cost Considerations

Automobile travelers consistently reported the availability of free employer-provided or on-street parking. Out-of-pocket costs were also reduced through employer-provided reimbursement of parking, tolls, and other travel expenses. Further, reductions in automobile expenses result from tax regulations that provide for the deductibility of automobile travel expenses incurred during business-related travel. Midday travelers were treated similarly with regard to the use of taxis and car services. This results in a cost advantage for automobile use, as the true costs often are not borne by the user. Accordingly, transit is at a competitive cost disadvantage.

Many participants indicated a willingness to use transit if employer and tax treatments of automobile and transit travel costs were the same.

Recognition of Public Transit Improvements

Travelers recognized recent improvements in the region's transit system from personal experience or from conversations with others. However, their knowledge of improvements often was limited or dated. Reduced graffiti, new subway cars, and commuter railroad improvements were appreciated by participants as a sign that transit is getting better. However, according to participants, these improvements by themselves were not sufficient to cause them to switch to transit. Some travelers required additional transit-based incentives, while other travelers required an automobile-based disincentive to motivate them to switch to transit.

Automobile Reduction Measures

Proposals to reduce automobile use through restrictions or user fees were regarded negatively by participants. They argued that a program based solely on disincentives is a clear message that government is shirking its responsibility and is looking for the easy way out. Participants regarded it as government's responsibility to provide sufficient capacity for travelers to use their mode of preference. Participants said that it was not reasonable for them to be forced from their cars without providing them with a viable transit alternative. Participants suggested a "carrot and stick" approach to reducing automobile use. A clear implication of such a carrot and stick approach is the need for agency coordination.

Participants reacted positively to a reduction of CBD parking when coupled with the development of non-CBD parking facilities at intermodal connections (i.e., park-and-ride). However, participants stressed the need for improved transit services at these facilities.

Similarly, Manhattan and midday travelers reacted favorably to the development of taxi stations for group riding and reducing taxi cruising. Automobile occupancy requirements were received more favorably when coupled with carpooling incentives, such as high-occupancy vehicle lanes and reduced tolls.

Alternatives

Auto commuters who live within the five boroughs of New York City often mentioned express bus service, water ferries, and private vans as preferable to local buses and the subway. However, it may not be the type of mode in itself that determines a commuter's preference but rather the perceived degree to which a particular mode meets his or her travel requirements. If a new ferry service were to operate infrequently and during limited hours, for example, it would follow that commuters would not use the service. Similarly, if an individual subway line were regarded as being relatively uncrowded, safe, reliable, clean, and comfortable, it would follow that some automobile commuters who live and work in proximity to that service would switch to public transit. An example of this situation can be seen on the 7th Avenue/Jerome Avenue Interboro Rapid Transit subway line, where the introduction of new cars and improved communication by the operator coincided with increases in ridership. Increases are presumed to include switches from the automobile as well as from other less desirable subway lines.

In this context, participants suggested that vans and jitneys could be made available where transit is inappropriate.

Gaining Travelers' Confidence

Travelers need to believe that their interests are important to the transit operator and that the operators are making a genuine effort to meet rider needs. In particular, unpleasant smells, dirt, and unreliable information reinforce the automobile user's perception that transit is the less efficient and pleasant mode of travel. As service-quality considerations are of increasing importance to the automobile user, he or she is less tolerant of unresponsive transportation. Given the financial and logistical ability to commute by automobile, automobile commuters are making a rational choice.

Gaining the loyalty of automobile commuters will require time and a concerted effort to improve the "look and feel" of the system both physically and psychologically in response to travelers' needs. This may include treating riders as valued customers as well as disseminating correct information about current and future system conditions. In that regard, government must be certain that it can deliver promised improvements in a timely manner.

Marketing Strategies

In any effort to reduce CBD automobile congestion, automobile use disincentives, marketing programs, and transit improvements should be targeted to meet the needs of individual market segments.

The results of the study indicate that projects to discourage travel by automobile should be developed with the involvement of the public, should not be heavy-handed in their implementation, and should be presented as part of a comprehensive program to improve mobility in the region.

The study defined a broad market segment of potential automobile-to-transit switchers and identified some of the attitudinal and behavioral characteristics that can be used to fine tune this market into subgroups. However, in order to determine the size and distribution of these target markets a follow-up quantitative research study is necessary. The study would measure the incidence of these subgroup characteristics across quantifiable sociodemographic and geographic factors.

The study's use of focus groups allowed the agencies to gain an appreciation for the differences in the emotional level of responses and for the defining of subjective measurements that may not have surfaced through quantitative research. In addition, the focus groups were able to uncover and explore in detail the importance of two critical influences on the modal decision.

The *first influence* is the availability of financial incentives to use an automobile. Incentives include free parking, employer-provided automobile-commuting subsidies, "around-town" travel reimbursements, and tax deductibility. For some, simply removing these incentives will cause them to switch to public transit. For others, removal of these incentives in concert with improvements to transit will persuade them to switch.

The *second influence* is travelers' underlying need to be treated in a manner that respects their dignity and acknowledges their basic concerns. This is distinct from having transportation perform reliably. Fulfillment of this attitudinal requirement for service quality not only promises to make travelers more receptive to marketing and capital programs but likely will make travelers more tolerant of transit's shortcomings while improvements are under way. It encompasses many changes, such as improved communications with riders, realistic advisories on transit improvements and delays, and a friendly and respectful attitude among operating and field employees. These two key influences should be addressed actively as part of any effort aimed at changing the modal decision of automobile users.

IMPACTS OF THE STUDY

The study's final report of March 1988 called for comprehensive measures. However, an immediate payoff of the study has been to establish a common basis of understanding among the participating agencies. The focus groups provided an opportunity to probe the public about the agencies' parochial issues in a multiagency setting. Accordingly, the study and its focus groups provided the opportunity for the participating agencies to observe and learn together.

The process of coordinated planning and implementation has been adopted in numerous transportation projects consistent with the findings of *The Manhattan Auto Use Decision Study*. The city's 2-month emergency closure of the Williamsburg Bridge and the Port Authority's roadway access improvements at LaGuardia Airport both depended on cooperative interagency efforts. Studies on the development of improvement strategies in corridors throughout the city were undertaken at the Department of City Planning and the MTA. While the studies and analyses called for by the CBD Access Group are under way at NYCDOT, more coordination needs to be implemented if the region is not to slip back to its business-as-usual status.

New York City has advanced its congestion management efforts. Specifically, the city

- Has increased the fines for illegal midtown parking,
- Is promoting commuter ferry terminals with parking availability, and
- Has developed a marketing campaign for park-and-ride sites at Shea Stadium and Kennedy International Airport as a bellwether for future efforts.

In the fall of 1987, NYCDOT initiated its "NY Get Smart" campaign. This effort was intended to promulgate Strategies for Mobility, Access, and Reduction of Traffic (SMART). As a part of this effort, corporations and businesses located in Manhattan were solicited to contribute to a reduction in CBD congestion. The effort called for companies to help in such ways as the following [as described by the NYCDOT (*11*)]:

1. Designate a mobility coordinator to assess employee commuting patterns;
2. Support mass transit by promoting transit subsidies such as the TransitCheck, discouraging automobile subsidies, and rewarding carpoolers and transit users;
3. Reevaluate company transportation policies and consider midday transit alternatives and shifting delivery schedules to early morning and late evening hours; and
4. Contribute ideas, skills, and energy to make things happen.

With regard to the status of the city's research and planning effort, work started in March 1989 on a NYCDOT study to quantify the empirical relationship between motor vehicle volumes/speeds and carbon monoxide. This study will result in the development of a model that will test the impact of different policies on vehicle trips and resultant carbon monoxide levels. Accordingly, specific mechanisms to reduce carbon monoxide and automobile congestion can be developed.

As part of the study, the various mechanisms to reduce congestion and carbon monoxide will be evaluated for their physical, logistical, legal, economic, and fiscal impact. Various combinations of mechanisms will be developed and evaluated. However, the implications of *The Manhattan Auto Use Decision Study* need to be considered if a successful effort is to be implemented.

An important part of any follow-up work to *The Manhattan Auto Use Decision Study* is the quantification of automobile and transit users' origins and destinations, as well as automobile users' attitudes on diversion to transit use. In that regard, the previous regionwide multimodal Origin-Destination (O-D) survey was conducted in 1963. In 1979 the New York City Transit Authority (NYCTA) conducted an O-D survey of subway users. Both sets of data are now out of date. In response to this widely perceived data void, the MTA has initiated a Total Travel Project that will aggregate Manhattan-bound travel within the MTA district by mode and origins-destinations. This will include automobile travel. A component of the project will be a regional telephone survey that will identify potential market areas and solicit views held by travelers, including automobile users. This information should enable the quantification of automobile users and the development of programs tailored to attract them to transit.

With regard to the availability of transit, transit information, and the marketing of transit services, a midday marketing campaign on the CBD's two north-south corridors was initiated by MTA. *The Manhattan Auto Use Decision Study* contributed to the development of MTA's midday marketing campaign. This campaign was tailored directly to the automobile user and those who do not use the subway as part of their midday travel. This was an essential effort to alter people's perceptions of transit improvements and their travel behavior.

Early in 1988, the MTA Board adopted a station parking policy, which for the first time provides for the development of parking programs at MTA operating agencies and funding assistance by the MTA Capital Program. This significant policy change should assist the MTA in responding to the study's call for development of parking facilities at intermodal connections outside the CBD.

The study found that cost is a significant factor influencing modal use. In that regard, public and private transit operators of the region continue to support TransitCenter, an alliance with the city of New York and the business community, for the promotion of transit. The TransitCenter administers the $15 public transit fringe benefit, known as TransitCheck, authorized by the Deficit Reduction Act of 1984. This enables employers to subsidize employee transit costs up to a maximum of $15 per month as a nontaxable fringe benefit. Nearly 900 companies have participated in generating over $3.5 million in revenue for the TransitCheck program. The allowable fringe benefit should be increased if the tax treatment of travel costs is to be borne equitably by transit users and automobile users.

Another possible means to reduce transit travel costs is Automatic Fare Collection (AFC). AFC may enable a reduction in intermodal travel costs to encourage use. The NYCTA is working toward AFC implementation by 1996.

The problem of congestion management has entered the national consciousness. For example, a *New York Times Magazine* article entitled "National Gridlock" attested to the fact that arterial congestion is a national phenomenon (*12*). This and numerous other articles suggest that a pervasive national problem requires national remedies. In its cover story of September 12, 1988, entitled "Gridlock," *Time* magazine stated that on a national scale, "breaking gridlock will take all the ingenuity the U.S. can muster, especially in a time when the nation cannot afford to buy millions of yards of concrete to pave over the problem" (*13*). The federal response, however, has not been encouraging.

In its television series "Currents," WNET Channel 13 produced a show during the summer of 1988 entitled "Car Wars." In it Alfred A. Dellibovi, President Reagan's UMTA administrator, was asked why transit subsidies were cut at a time of increasing automobile congestion when transit appears to be the only viable alternative for reducing congestion in many urban areas. In response, Mr. Dellibovi stated the need for increased reliance on privatization.

If effective solutions using the findings of this and other market research are not reflected in the region's strategies to alter travel behavior (i.e., to achieve marked shifts from travel by automobile to travel by transit), what can we expect?

- Congestion may itself become the ultimate constraint in travel behavior as a new equilibrium in mode split is reached.
- Urban congestion will continue and suburban congestion will spread, as indicated by UMTA's recent suburban mobility initiative.
- Air quality will be degraded locally, further contributing to the greenhouse effect around the world.
- Transit's share of the CBD travel market will continue to decline, stabilize, or increase only slowly, as individual travelers continue to respond to what they consider to be their logical choices.

By the year 2000 the projected work force in the MTA region will increase by 2.3 million people. Their anticipated travel needs must be taken into account to allow growth in the region's economy. The challenge facing policy makers is to develop and implement solutions that respond to and modify the public's attitudes and travel behavior. Half-hearted measures will not achieve the desired result.

SOME ADDITIONAL THOUGHTS ON CITIZEN INVOLVEMENT THROUGH FOCUS GROUPS

The Manhattan Auto Use Decision Study and the planning process of which it was part illustrate an effective use of the focus group technique. The focus groups provided a means by which a broad array of regional agencies were able to sit together to gain a common understanding of the automobile-using public's perspective regarding the congestion management problem and potential traffic mitigation strategies.

Focus groups allowed the agencies far more control over the scope and depth of issues discussed than would have traditional citizen involvement methods. For example, the groups were arranged to include all relevant market segments as well as to facilitate group interaction. Although screening of participants allowed the inclusion of a cross section of citizens and views, the research remains qualitative in nature, and thus its findings cannot be projected to quantify the attitudes of the public at large. Client agencies observed the discussions from behind a one-way mirror so that they were able to get firsthand knowledge of the groups' reactions without being confronted directly by participants. Whereas a discussion guide provided prompts for the moderator in covering those topics deemed most important by the agencies, the ability of the focus group moderator to react to a dynamic situation was critical in directing the discussion and controlling group interactions so as to bring out participants' true feelings and the basic motivation behind their behavior and attitudes. Likewise, the focus group moderator's perceptive interpretation of the group discussion was a key ingredient in producing meaningful and actionable research results.

Focus groups cannot always replace traditional citizen involvement techniques. Most importantly, focus groups are not open forums. Thus, they do not provide an opportunity for all citizens to be heard. Unlike public hearings, focus groups do not allow citizens to directly confront officials, nor do they provide an opportunity for open debate.

Focus groups are an appropriate method for obtaining citizen input during a project's evolution. Unlike traditional public forums, focus groups provide an informal, nonthreatening environment for the public to voice its views and for clients to listen. With a better understanding of citizens' reality, officials should be in a better position to communicate effectively with the community during the planning and implementation stages of a given project. The information obtained in focus groups can be especially valuable in leading to project designs that are sensitive to the public's perspective.

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Morphological Modeling of the City and Its Transportation System: A Preliminary Investigation

C. J. Khisty, M. Y. Rahi, and C. S. Hsu

The morphological study of a growing entity, such as a city, deals with its structure and form. In biological sciences morphological analysis is essential for understanding the functions of the component parts of a growing system. Likewise, for city planners there is a need to really understand how a city grows, develops, and evolves. Urban growth components have been identified as objects of a system, where the system is defined as a set of objects together with relationships among these objects. A morphological model of a city therefore attempts to relate urban growth or decay to the urban infrastructure, such as its transportation and other life-supporting systems. This paper serves as an introduction to the morphological modeling of the city in general and the transportation system in particular. Since professionals of many disciplines are involved in city planning and design, it is expected that the morphological modeling of city systems also will involve knowledge distilled from several disciplines. Research findings in the areas of automaton, control, and stochastic theories could be integrated advantageously for use in such modeling through interdisciplinary research involving biologists, control systems engineers, city planners, system analysts, and transportation engineers. In this paper an explanation is presented of the morphology of city systems in terms of their growth and decay patterns and the basics of control theory, and, finally, a brief introduction is given to the biometrical modeling of the city. Several real-world applications of simple morphological and allometric methods applied to transportation systems planning are described. The need for a coordinated transfer of knowledge initially developed in systems control to urban system design is discussed. It is expected that such research will greatly benefit professionals involved in urban systems design and management, since morphological modeling of city systems will put the design components of the city in a new perspective. Several important and valid reasons are given that illustrate the superiority of morphological modeling over conventional analytical modeling as currently practiced.

One of the delights of science is the discovery and rediscovery of patterns of order in nature. These patterns are awesome not just for their beauty but because they suggest an order underlying their growth (and decay). This basic pattern-forming process indicates that certain proportions and limits occur over and over again in all forms of nature. Can the harmony that is apparent in natural forms be transplanted to man-made forms, such as the metropolis? With advancements in land use and communication theories coupled with even more spectacular strides made in biometrics and control theory, an interdisciplinary inquiry deserves critical investigation.

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The purpose of this paper is to serve as an introduction to the morphological modeling of the city in general and the transportation system in particular. Morphology is defined as the science of structure and form of a growing entity. A morphological modeling of the city, therefore, attempts to relate urban growth to the urban infrastructure, such as water distribution systems, sewage and waste water disposal systems, land use activity systems, power transmission systems, electronic communication systems, emergency management systems, surface (road and rail) transportation systems, and so on.

Over the years city planners have felt a need to really understand how a city grows, develops, and evolves (*1*). Because it is known that the development of one growth component is related in some way to that of the other components, the need to establish these relationships is logical. For instance, the land use pattern of a city does not develop independently of its transport facilities; on the contrary, it forms a closed-loop system (*1, 2*). Indeed, urban growth components have long since been identified as "objects" of a system where the "system" is "a set of objects together with relationships between the objects" (*2, 3*).

In biology morphological analysis deals with functions of component parts of a growing system. Biometrical modeling deals with the optimality of the performance of component parts under various conditions. For urban systems, however, no such modeling exists to date, although some analogies between the characteristics of urban components and those of biological components have been roughly drawn. Most urban systems models in use today are of the analytical type. It has been pointed out that the parameters of growth relationships of urban components must be interpreted differently from abstract biology, because unlike the typical biological systems where the growth information is fixed and embedded in the genes, the corresponding growth information in urban systems is determined by numerous decisions made by the policy makers over time (*4*).

Although a few researchers have demonstrated the use and application of morphological analysis in system planning and design (*5, 6, 7*), there is still a great need to study the metabolism of urban growth and the metabolic performance of the morphological components of the city. It is also necessary to identify the potential impacts of urban components on each other and on the total growth of the city. Therefore, it can be concluded that without such knowledge and understanding, the exact diagnosis and prognosis of urban problems and their treatment are well nigh impossible. Analogous to medical science, it is the knowledge and understanding that the medical profession has acquired about biological systems that allow its members to scientifically diagnose and cure the diseases of their patients. It can therefore be hypothesized that a critical examination of the growth and decay components of the city will reveal valuable insights in diagnosing urban problems. A morphological modeling of the city hopefully will permit one to understand urban problems through new ideas in automaton, control, and stochastic theories.

A word should be said about the form of this paper. The problem is one of presenting a subject where virtually everything is related to everything else. The crucial ideas center around several topics, and, therefore, questions such as what to present and when and which juxtapositions and continuities to hold and which to break are all problematic. However, the many detours and digressions hopefully will interest both the serious travelers and the casual spectators. The sum and substance of this paper may be read as proposing a problem or question, not as supplying a final answer; all it does is to lay the groundwork for further investigation and dialogue.

DEFINITIONS

Some of the basic concepts used in this paper are borrowed from the biological sciences and are defined briefly here.

Feedback Systems

Control systems that utilize feedback are called feedback systems. They are composite systems with at least two components: (a) a controlled system that is desired to execute a specific activity through the manipulation of the inputs by an amount depending on the deviation of the system at each time t from its desired position at that time and (b) a controlling system that computes the deviation of the controlled system from its desired behavior and then provides appropriate inputs to the controlled system by receiving a signal input from the environment and from the controlled system as a feedback.

Adaptive Systems

Systems that exhibit adaptive behavior are called adaptive systems. These systems can modify their activity, if necessary, to bring such activity to a preferred (or optimal) state with respect to particular environmental situations. Input-output error-actuated devices are good examples of these systems. Biological organisms demonstrate many different kinds of adaptive behavior. Understanding the adaptive behavior of natural systems is very important to biologists and psychologists. Likewise, the concepts are highly useful to the applied scientists and engineers who would like to incorporate biological adaptive systems as prototypes for man-made systems.

Biological Systems

A biological system has an inside and an outside. It possesses physically obvious compartments or organs and tissues that are composed of microscopic cells and relatively homogeneous entities called organelles. As opposed to a closed system, a biological system, like all other physical systems, is truly an open system. An open system is affected by its environment, whereas a closed system is isolated from its environment. A biological system also is a dynamic system since it shows a delayed response (i.e., its response to an output variable is not instantaneous but delayed because of the time taken for the input's effects to be transmitted to the system output). Feedback is one of the most important phenomena occurring in dynamic biological systems. The feedback mechanism may be illustrated by an example of thermoregulation. When the temperature information is fed back from the skin via the nervous system, the thermoregulatory center initiates action to regulate temperature at its desired level. If the information fed back indicates that the skin temperature is too low, signals are transmitted by the thermoregulatory system to the muscles to increase oxidation and, hence, augment the heat supply to the body. The reverse happens if the skin temperature is too high (*8*).

Morphology

As pointed out earlier, morphology is the science used to study the form and structure of a system and the functions of the components. In other words, a system can be defined uniquely by its morphology. A morphological study or analysis is, therefore, essential in understanding the behavior and vital characteristics of any system. Biologists are constantly using morphology in studying biological systems. Although the term rarely is used in general systems theory, systems analysts can in many ways be regarded as morphologists. Zwicky (*9, 10*) defined the exploratory techniques of systems planning and design as morphological methods. The method consists of describing the parameters and the fundamental aspects of a system process that is already known. The constituent elements of the process can be seen as a set of elements where each element may have several alternatives—that is, there are alternative morphologies (each made up of different elements) for the process as a whole. These alternative morphologies are described fully by the lattice of combinations of all alternatives for each element of the set with all other alternative elements in the set (*6*). The word "analysis" is not entirely descriptive of the technique's usefulness, for it can be employed both in forecasting future changes in forms or structures and as a normative device for pointing to possible future innovations in such forms (*9, 11*).

Allometry

Allometry defines the relationships between the form functionals of a system. Allometric relations (or at least correlations) between various pairs of different kinds of measurements yield insights into the underlying rationale of the objects under study and ultimately reveal how and why the objects behave the way they do. Rosen (*12*) points out that most of the important examples on allometry are drawn from growing systems. In growing systems the values assumed by a specific form functional (x) become an explicit function of real time t. This is so because the form F of the system is itself changing in real time: $F = F(t)$, and so $x(F) = x[F(t)] = x(t)$. Given two form functionals $x(t)$, $y(t)$ defined on growing systems, it is possible to eliminate time between them and to obtain a relation involving x, y alone. The most familiar growth law satisfied by a biological form functional $x(t)$ is that its increase is proportional to its magnitude at any instant. Therefore,

$$x(t) = kx$$

where k is a constant. This equation, characteristic of many biological systems, leads to

$$x(t) = x_0e^{kt}$$

where x_0 is the value of the form functional x at some initial time t_0. Systems obeying this equation are said to be growing exponentially. Now, for two form functionals x, y of a system with exponential growth, we have

$$x = x_0e^{k_1t}$$

$$y = y_0e^{k_2t}$$

which leads to

$$y = y_0e^{k_2t} = \frac{y_0}{x_0^{k_2/k_1}}(x_0e^{k_1t})^{k_2/k_1} = \alpha x^{\beta}$$

In other words, at least for growing systems, whenever any two form functionals of the system are growing exponentially, they are necessarily related by an allometric law. However, it should be noted that exponential growth rates are not the only ones yielding allometric laws (*12*). The allometric constants α, β (known as "structural constants" of the system) are, respectively, a ratio of initial values and the ratio of a pair of rate constants. Since the ratio of any pair of rate constants is always independent of time, the allometric formulation of the rate of growth equations can substitute for t a particular form functional as a kind of "physiological time" (i.e., the rate of growth of a form functional is no longer to be measured with regard to absolute time t but rather with respect to another form functional).

CITY SYSTEMS AND THE SYSTEM APPROACH IN PLANNING

The idea of systems stemmed originally from the biological sciences, and the early development of systems thinking was associated with the biologist Ludwig von Bertalanffy (*13*). In his *General System Theory* Bertalanffy viewed systems science as the unity of the conception of the world whose general principles are seen everywhere in inanimate things, organisms, and mental and social processes. The mathematical definitions of a general system are best given as follows (*14*):

- A set of implicitly defined formal objects,
- A set of elementary transformations T,
- A set of rules P for forming sequences T, and
- A set of statements indicating initial forms of the formal objects for use in generating new forms of the objects.

It will be useful at this point to examine the various kinds of systems as defined by systems philosophers:

- Natural or concrete systems—a nonrandom accumulation of matter-energy, in a region of physical space-time, that is nonrandomly organized into coacting interrelated subsystems or components (*15*). Laszlo (*16*) states that the naturalsystems (e.g., atoms, molecules, crystals, cells, viruses, organisms, ecologies, societies) are characterized by the measurable nonrandom regularity of the coactions of their components, generating conceptual invariances (i.e., different equations stating functional relationships between variables).
- Cognitive systems—a system constituted by mind-events, including perceptions, sensations, feelings, volitions, dispositions, thoughts, memories, and imagination—that is, anything present in the mind (*16*).

Chadwick (*6*) shows how a system can be characterized along with several subsystems as an input-output process through which there is a flow—information, energy, or matter. He points out that the human body is a commonly observable system; the relationship of man to his setting is an ecosystem—a community and its habitat, a group of organisms, and the soil, water, climate, and other physical features of the environment. According to Dice (*17*), such ecosystems can be of any size, from a drop of pond water to the whole earth and all its plants, animals, and human inhabitants, but both are systems in process, exchanging matter and energy continually between community and habitat.

The evolution of systems thinking has encouraged researchers to apply this approach to the modeling of human decision making in a sociophysical environment. Sociologists have applied these models to study problems in sociology and other social sciences that have been dealt with traditionally by philosophers. They have stressed that both the conception of the structure and the dynamic process of complex sociocultural systems require a better understanding of the microprocesses underlying the macrolevel. Ashby (*18*) warns that a normal analysis of a system will not be adequate to understand the system because a normal analysis process gives us only a vast number of separate parts or items of information, the results of whose interactions no one can predict.

The systems approach still is used widely in urban studies and urban planning. Chadwick (*6*) views planning itself as a conceptual system that starts with two directions of enquiry: the recognition and description of the system and the formulation of criteria for its testing, which advantageously proceed side by side. He notes that planning deals with very large systems that are, in cybernetic terms, very complex, have large variety, and can at best be specified only incompletely. According to him, planning should be seen as dealing with stochastic processes to specify the system statistically. The real world, he continues, is a complex system of both natural and man-made things that can be discerned to have a morphology with a characteristic and complex endogenous behavior undergoing irreversible change through the passing of time. Mesarovic (*19*) considers the city a complex system capable of counterintuitive responses, and it can be properly understood and controlled only if the interactions between four basic urban factors—the individual, the groups of people living or working together, the natural environment, and the man-made or technological environment—are accounted for properly. Alfeld and Meadows (*20*) point out that almost all of the urban programs initiated in the 1970s for raising the quality of urban life in American cities were failures because planners were looking at city problems on an individual component basis. These authors emphasize the need for a new theory to deal effectively with urban behavior; this theory must embrace a conceptual understanding of the city as a whole through various interrelated activities or functions. Doxiadis (*21*) views the crisis in cities through a systematic study of city growth. He explains this as follows:

- The city is a system of people living together, pooling their energies, and developing a community with a common economy that is growing out of balance in certain areas. People and the energy produced by them grew in the past at the same rate with the resultant economic growth, thus indicating a balance in the city system among people, energy, economy, and physical formation. The system components, however, have developed an imbalance during the last hundred years because of the differing rates of growth of population, energy, and economy. The commercial form of energy that helped people go far out of the cities has resulted in a system that cannot be supported properly in economic terms. This situation has, in effect, afflicted the citizens for the most part and, to a greater extent, the weakest economic groups of society.
- The city, like any other growing system, develops an increasing degree of complexity that is always served in nature or in society by corresponding physical and institutional structures. These structures do not correspond to the complexity of today's city systems as effectively as they did in the past.

Chadwick (*6*) gives a general classification of systems problems and concludes that the problems exhibited in the field of town and regional planning fall into three broad classes that can be stated in the form of the following questions:

- The analysis problem—the system exists in fact and its structure is or can be known; how will the system behave on the basis of a knowledge of its structure?
- The black box situation—the system exists but nothing is known about it, and its structure cannot be determined by direct means; how can one ascertain the behavior of the system and, if possible, its structure?

All of the above discussions on systems approach lead to one conclusion: the city systems, apparently perfect for the application of systems theory, should be adequately and completely defined and advantageously modeled so that the existing developments in systems concepts can be utilized effectively.

CITY FORM

That the city is characterized by form is an established fact; the form is one of impressive variety and social expression. From a physical standpoint, urban form exhibits huge variation—from concentric cities to linear cities. However, urban form is not merely a matter of descriptive geometry.

The idea of form essentially has two aspects: morphological and conceptual. Morphologically, the idea of form refers to its visible aspects, in terms of the arrangements of parts and delimited entities. On the other hand, conceptually, the idea of form refers to its componential and inferential aspects, in terms of appearance, of imputation, and of differentiation of parts. The significance of these two aspects is illustrated in Table 1.

Form follows function and is fitted to function; function also is fitted to form. Variation of form may (as in urban form) be seen as an adjustment to the level of function. For example, in an urban area one might make adjustments of first-order functions, such as defense and security, and these might induce adjustments in second-order functions, such as transportation, business, and industry, which, in turn, might then force adjustments in third-order functions, such as the economy, and these may cause adjustments to be made in fourth-order functions, such as individual life-styles, access to the social structure, and mobility. And so the list goes on.

Urban form can be regarded as an agency of input-output process, as an instrument or system of commerce and industry, as a complex pattern of paths and locations, or as social space. In all these examples of the idea of form, there is an unmistakable linkage between form as product and form as process—in other words, between form and form giving (*22*).

MORPHOLOGICAL ANALOGY OF THE CITY

Biologists and paleontologists consistently have investigated the growth pattern of entities in terms of the relationships among system components and between the components and the whole. They have been successful in establishing the state of equifinality (i.e., a growth status in which the components of entities with growth characteristics grow in time at an established rate). Systems having growth phenomena, such as biological organisms, have been studied morphologically for a long time. The relationships between the components have been reported to approximate allometric relations of the form

$$m = aM^b \quad (a, b > 0)$$

where

m = measurement of the system component,
M = measurement of the whole system, and
a and b = constant characteristics of the system's components.

The urban system has been considered as a system of growth phenomena consisting of several components which themselves behave as growing systems. Bertalanffy and Naroll (*23*) demonstrate that the relative growth of urban and rural populations in nations and regions can be usefully compared by fitting power function equations to the observed growth of these components. Stewert (*24*) discovered a regular allometric relationship between the urban fraction of the population of the United States and its total population over 15 decades of growth. The allometric relations are based on the principle that during the growth of a system, some basic measurements of system components remain proportional to constant powers of measurements of the whole system. Thus, an allometric formula can be used in the measurement of relative growth in which a given dimension of a part of a system is compared to the corresponding dimension of another part of the same system or of the whole. This makes allometric analysis very useful for designating the differences in proportions correlated with changes over time in absolute magnitude of the total system or of the specific components under consid-

TABLE 1 IDEA OF FORM AND URBAN FORM GIVING (*22*)

Urban Form	Urban Form Giving
Morphological	
Arrangement of parts	Market determination of land use patterns and building types;
	Topographical/geographic determination of land use patterns and building types;
	Ecological distribution patterns and processes;
Boundaried entity	System determination of urban functions, location, articulation, pattern;
	System models in planning and management development of cities;
Realization of essence	Urban physical/social structures as developmental functions of interests, needs, goals of human community;
	Utopian, ideal, designed cities as realization of human values inherent in the human community;
Conceptual	
Appearance	Physical structures of city = f (urban social structures);
	Social structures of city = f (urban physical structures);
Imputation	The symbolic shrine/palace city of archaic/classical urbanisms;
	Urban forms as social/perceptual spaces;
	Urban social form as social constructions;
Differentiation	Types of cities in terms of dominant functions;
	Types of cities in terms of dominant culture/economy/polity;
	Types and functions of urban social structures.

eration. In studying growth phenomena, the constant a of the allometric equation is termed the initial growth index, while b is termed the equilibrium constant or, in absolute size comparisons, the limiting equilibrium constant.

Based on the concepts discussed above, we formulate some morphological analogies of city systems:

- Natural systems such as living organisms grow on the basis of their fixed morphology. The processes of nature are carried out in the best possible manner, described by allometric equations. Similarly, the components of the city also must grow in certain proportion to the whole system. The design for the city's form and structure should be planned so that its growth is optimal. In other words, the infrastructure systems of the city should be designed such that the total energy expenditure (e.g., movement from one place to another) is the minimum.
- The growth decisions for a living organism are made by its genes according to some fixed optimality criteria. For a city, planners and decision makers correspond to genes in a living system. They ought to follow certain rules to be developed from a morphological modeling of the city for the purpose of normative planning.

Therefore, it can be pointed out that a clear understanding of a biological growth process in terms of the genes and morphological components will be useful in developing the criteria for the appropriate growth of a city.

BIOMETRICAL MODELING OF THE CITY

In this section we try to describe the city systems in terms of the governing theories of biometry. It is important to investigate how mathematical modeling is accomplished for the biological system through the use of concepts and theories developed originally by engineers and applied scientists. The following is a brief account of the theories that we believe will be useful for modeling the city.

Theory of Abstract Dynamical Systems

The theory of abstract dynamical systems is obtained by turning around the theory of classical mechanics. By using the set of rules of classical mechanics that tell how each observable of a system may be expressed in terms of the state of the system at each instant of time as postulates, it is possible to specify a new class of state of the system that satisfies the postulates. According to the theory of input-output systems, any external force impressed on the system, in general, is called an input to the system, and any observable of the system that can be expressed as a continuous function of the coordinates is called an output of the system. Rosen (*12*) formulated the central problem in the theory of abstract dynamical system as follows: by manipulating the inputs to a dynamical system, can one force the system to produce a preassigned output? In other words, can an appropriate choice of input be made that will cause a system to assume a preassigned state?

Theory of Optimal Control

The inputs to a dynamical system generally are called controls. The application of external forces, or controls, to a mechanical system may greatly alter the set of states the system may assume. Rosen (*12*) states the central problem of control by using the following example: if a ballistic missile or space vehicle assumes a trajectory that differs from the one desired, is it possible by means of appropriate controls to force the vehicle back to the desired trajectory? Consequently, the question that derives from the theory of optimal control is this: how can the inputs to a system be chosen in such a manner that the transition to the preassigned state is made in the "best possible" way? For optimal control of a linear dynamic system, two things must be defined: (a) an admissible set of systems that will exhibit the behavior desired and (b) some kind of index of the activity, or cost functional in terms of the set of possible controls, which is to be minimized. Most of the applications of the theory of optimal control are concerned with bringing a dynamical system from some initial state to some desired final state at some terminal time.

Theory of Adaptive Systems

According to this theory, the state of a system at any instant is given by the values assumed at that instant by an appropriate set of "state variables," which in the case of dynamical systems are linear combinations of the outputs of the system. For an adaptive system there exists for each possible input a set of one or more preferred states or outputs. If the system is not initially in a preferred state, the system will act so as to alter its state until one of the preferred states is achieved. Rosen (*12*) indicates the problem in the theory of adaptive systems as follows: given a system, together with an input $f(t)$, an output $g(t)$, and a preferred response of the system with input $f(t)$ as $h(t) \neq g(t)$, how can the actual response be altered to achieve the preferred response? The ways in which this can be done are two: (a) the desired response $h(t)$ can be achieved by modifying the input $f(t)$ until it becomes identical with an input $k(t)$ known to produce $h(t)$ and then presenting this modified input to the system, and (b) the desired response $h(t)$ can be achieved by causing an alteration to the transfer function so that it takes the form of a function known to belong to a system that produces $h(t)$ from input $f(t)$. Possibility (a) appears to be the characteristic of many applied feedback systems because of the simplicity in implementing it. Here, the input is modified by means of the feedback loop and converted to an error signal that tends the system toward the desired response. Possibility (b) is a rather more drastic one involving a change in transfer function of an input-output system. Adaptation in many biological systems and others of technological interest frequently is governed by possibility (b), which is also known as "feedback through parameters." This is the reason why biological processes often are nonlinear when considered from the viewpoint of systems theory. It is also interesting to note that naturally occurring adaptive systems often choose possibility (b) rather than possibility (a).

Theory of Finite Automata

The theory of finite automata is useful in modeling the simplest forms of behavior (*25*). An automaton is considered to be an object capable of receiving a finite number of signals, $s \in (s_1, s_2, \ldots, s_N)$, at every instant of time, $t = 1, 2, \ldots$, and changing its internal state in accordance with these signals. The automaton can carry out a finite number of actions, $f \in (f_1, f_2, \ldots, f_x)$. The choice of the action is determined by the internal states, $\phi \in (\phi_1, \phi_2, \ldots, \phi_m)$; the number m is called the memory capacity of the automaton. It is assumed that the automaton is situated in a certain environment and that the actions of the automaton cause responses s of the medium C. These responses are, in turn, the input signals of the automaton. It uses them to decide its further actions. Tsetlin (*25*) formulates the behavior of people in a town as a problem that can be well described in terms of the theory of finite automata. In this problem, given a town with a population of N people and n regions with room for $b_1, b_2, \ldots, b_n$ persons and m factories whose demand for labor is $a_1, a_2, \ldots, a_m$ persons, it is assumed that $N = a_1 + \ldots + a_m = b_1 + \ldots + b_n$. The population distribution is given in the form of a matrix (x_{ij}), $1 \leq i \leq m$, $1 \leq j \leq n$, where x_{ij} is the number of persons living in the jth section and working in the ith factory. Therefore, $\Sigma_j x_{ij} = a_i$, $\Sigma_i x_{ij} = b_j$. The distribution of factories and sections is such that a person with an index (i, j) needs time t_{ij} to get to work. Now, if the town residents exchange living quarters to shorten their commuting time, how can one describe the dynamics of the population redistribution in the town as a result of address changes and describe the distribution that is reached in the limit? A determination of such a stable population distribution is important in forecasting traffic flows in a city that is in the planning state.

SOME APPLICATIONS

Examples of the use of simple morphological and allometric methods applied to transportation systems planning are given below.

Morphological Method Applied to New Town Design

Chadwick (*6*) has applied the morphological method as an exploratory technique in examining possible options and combinations in designing a new town (see Figure 1). An alarming number of possibilities results in $2 \times 3 \times 5 \times 4 \times 4 \times 5 \times 4 \times 3 \times 3 \times 3 \times 2 \times 2 \times 3 = 3{,}110{,}400$. Of course, the best way of reducing this incredible number is to eliminate those options that have internal inconsistencies; for example, a linear town cannot possibly have a triangular street network. In addition, such factors as the topography of the town site would further eliminate some of the options. Figure 1 illus-

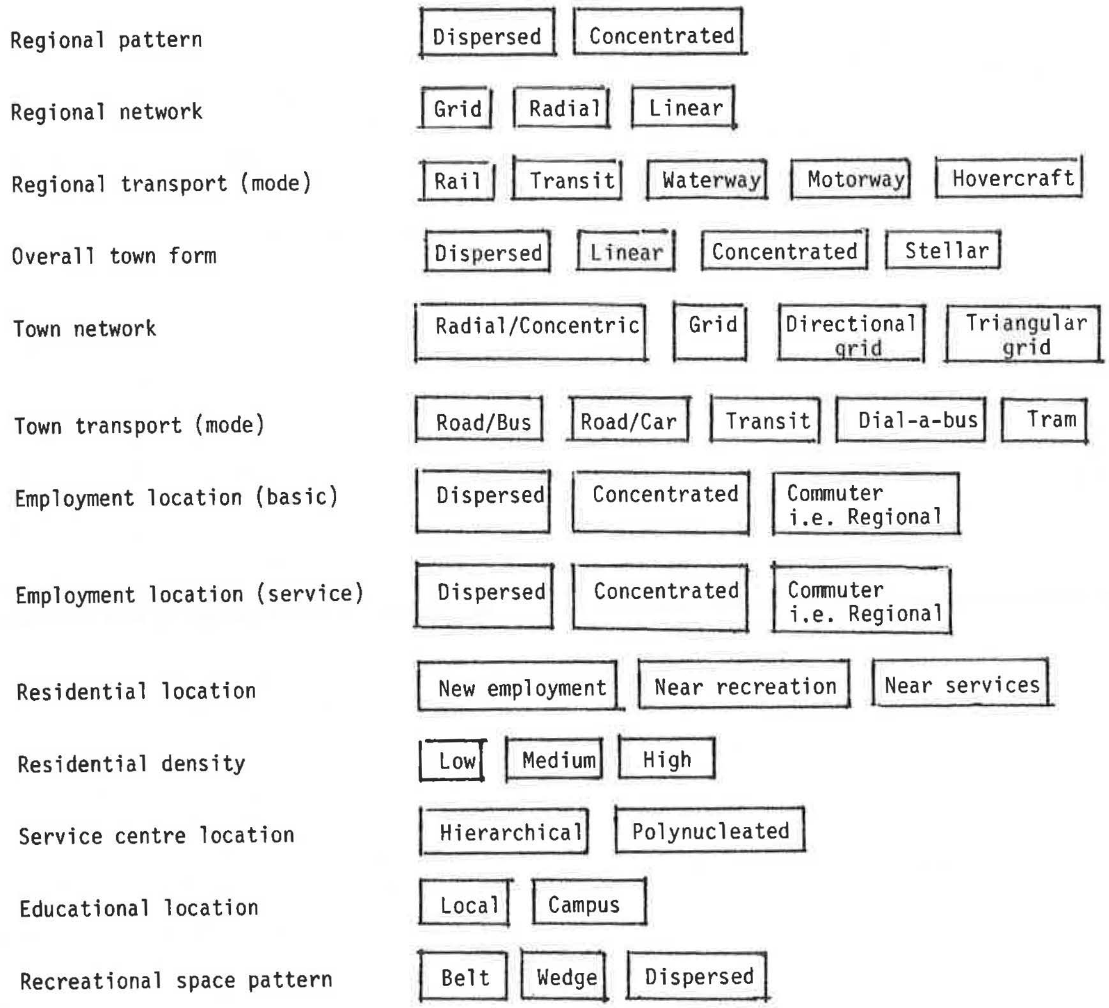

FIGURE 1 Morphological method applied to a new town design.

trates the various factors and the choices available under each of these factors.

The concept of morphological analysis was perceived and applied by Zwicky as early as 1942. He advocated its use in the fields of discovery, invention, and research. In his own words (*9*):

> Morphological analysis and morphological planning and execution of large-scale projects have been conceived for the express purpose of properly appraising *all* of the facts (or scientifically speaking, the boundary conditions) needed for the biased deduction of the possible solutions to any given problem. Only after all of these solutions have been thoroughly evaluated do we select the one among them that best satisfies our requirements.

The merit of this approach lies in its extraordinary suggestive power that results from its systematic exploratory behavior. Because of this power, the whole class of discoveries and inventions in a given field are made possible not only systematically but also simultaneously.

Efficiency of Alternative Network Designs

Different geometric patterns of road network are associated with different relative accessibilities. Smeed and his associates were able to calculate the average distance traveled on the streets of a city by the shortest route and their calculations revealed that $d = 0.87A^{1/2}$, where d is the distance traveled in miles and A is the area covered by the city in square miles. Smeed also established allometric relationships between d and A on a variety of street patterns as shown in Figure 2, indicating the advantage or otherwise of adopting a particular configuration of streets (*26*).

Alternative Routing Systems

Holroyd studied a variety of differing routing systems for circular cities. Some use internal or external ring roads, whereas others rely on radial and grid pattern lattices. The efficiency of the networks is evaluated in Table 2 for internal trips. Figure 3 shows the networks and average distances traveled between random pairs of prints. This procedure allows one to determine the type of street configuration most suitable for adoption in a city. Table 2 shows the average length of trips and the street length for each configuration. Note that trip length ranges from 0.905 miles to 2.237 miles. The most efficient alternatives are the radial, internal ring, and rectangular, as shown in Figure 4 (*26*).

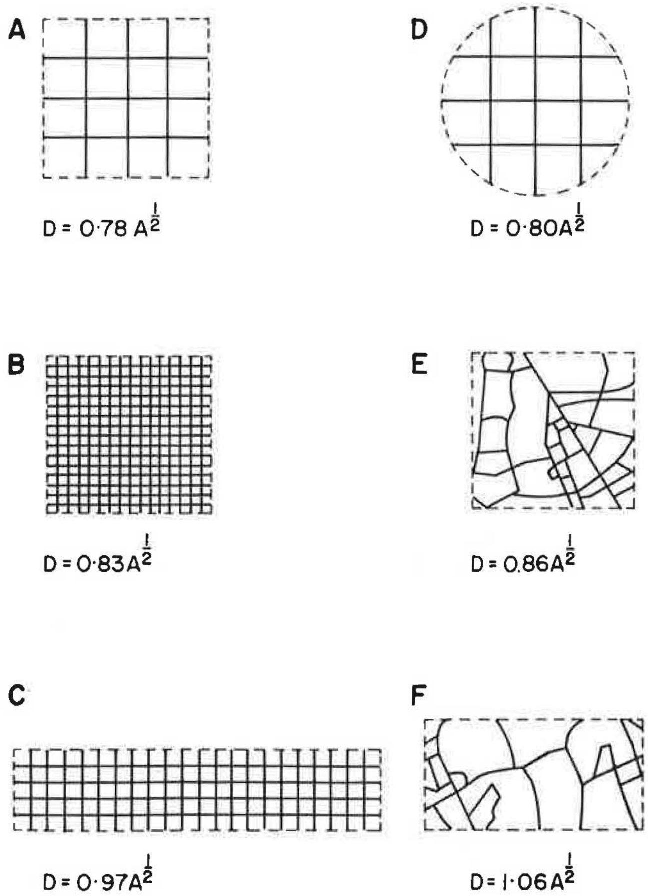

FIGURE 2 **Efficiency of alternative city networks.**

TABLE 2 AVERAGE LENGTH OF TRIPS IN A CIRCULAR CITY

CONFIGURATION	TRIP LENGTH (MILES)	STREET LENGTH (MILES)
1. DIRECT	0.905	∞
2. RADIAL	1.333	24
3. EXT. RING	2.237	30.28
4. INT. RING	1.445	27.14
5. RADIAL-ARC	1.104	42.84
6. RECTANGULAR	1.153	28
7. TRIANGULAR	0.998	43
8. HEXAGONAL	1.153	45

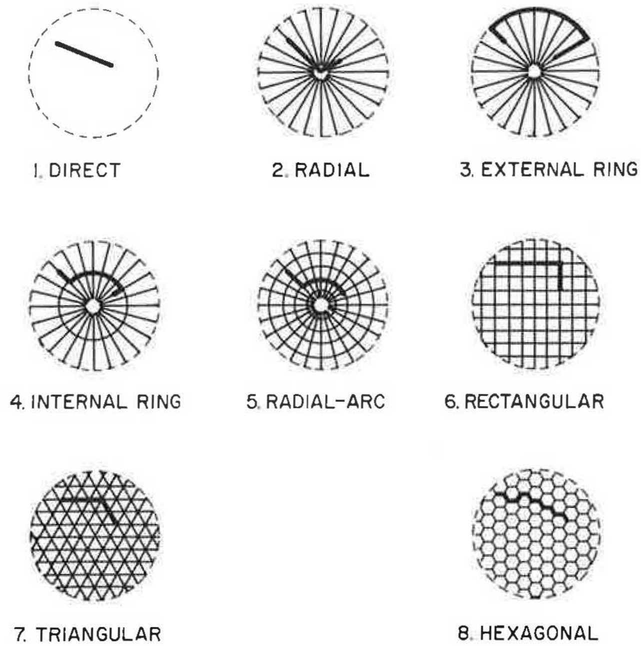

FIGURE 3 **Alternative routing systems.**

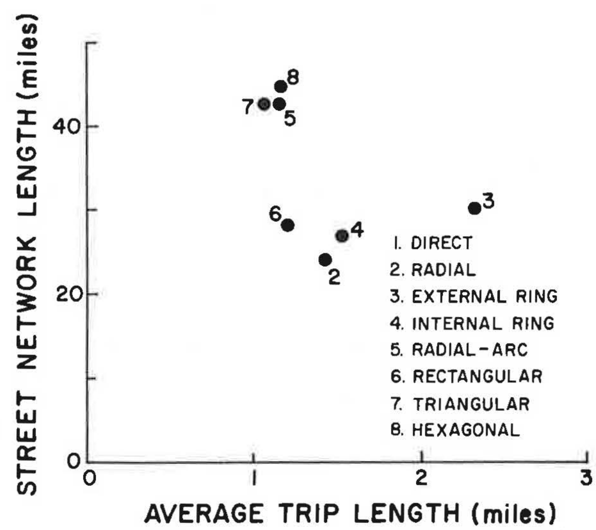

FIGURE 4 **Average trip length versus street length.**

Morphological Analysis of a Metropolitan Highway System

The benefits to be derived from morphological modeling of the city are versatile. Since professionals of many disciplines are involved in city planning and design, it is expected that the application of morphological modeling of city systems also will involve several disciplines. For the sake of illustration, let us consider the design of some components of an urban transportation system. City population can be considered as the most important measurement of the city as a whole entity (M); its component systems will have some measurements, m, that are to be determined for design purposes using the allometric relationship

$$m = aM^b \qquad (a, b > 0)$$

where a is the initial growth constant and b is the equilibrium constant of the growing systems under consideration. For example, the total number of trips made by the city population on an average day can be considered as the measurement, m, of the transportation component of the system. Using the statistical data with reference to M and m, an important relationship between these two variables can be derived where constants a and b can be calibrated. This relationship can be used for future design in estimating the expected number of total trips where the city population can be projected to a horizon year.

Now the total number of trips can be used as M for the transportation system (now a whole system itself), and components of the transportation system, say the length of roads in the city, can be considered for design. By denoting the total length of roads as m and using the morphological relationship between total number of trips per day and road lengths, one can continue to establish other system components, thus shooting for the proper balance in the system at any instant in time. This will enable the engineer to determine any deficiency or surplus in the provision of roads and to take actions accordingly. Since both deficiencies and surplus in a system are reasons for imbalance, the procedure will help to identify the sources of problems the city might face at some later time.

The results of these analyses will indicate patterns that may be considered as "norms" reflecting a collective societal logic in determining what is good for society. It is a proven fact, although not widely known, that there are many partial equilibria among an urban system's components, and each one of them is connected with an equilibrium norm. In the simple application given above, the following six questions are being raised:

1. What are the norms that are able to maintain the existing highway and mass transportation facilities within an urban area?
2. What structure (network) parameters can be identified that bring order (or disorder) to the existing highway and mass transportation system?
3. How do the equilibrium parameters and norms interact among and between themselves in providing a given level of service for transporting people?
4. What is the sensitivity of highway and mass transportation components to changes in the demand for transportation?
5. Can these sensitive components be sorted out and then used for attaining an optimum arrangement toward balancing the highway and mass transportation facilities?
6. Can land use arrangements coupled with sensitive components of transportation be incrementally or radically altered for optimizing traffic flow vis-à-vis harmonious land use patterns?

Balkus and Olsen (*4*) have applied a morphological analysis approach to a metropolitan highway system to establish an allometric relationship between M, the demand measured by miles driven per day per square mile of land area; L, the availability of facilities for meeting this travel demand measured by road miles per square mile; F, miles of driving surface measured in foot miles per square mile; and d, the vehicular trip end densities.

$$M = 36.09d^{0.8122} \qquad R^2 = 0.86$$

$$F = 0.3458d^{0.6081} \qquad R^2 = 0.94$$

$$L = 0.0319M^{0.5522} \qquad R^2 = 0.80$$

One can perform a sensitivity analysis from the above size comparisons because the exponents are the corresponding elasticities. Structural parameters can be discovered through such morphological analysis. Also, these three relationships can help one to visualize the regularities of the highway system's arrangement, and they also can help to serve as criteria in laying out a highway system in a new community or, possibly, correcting a system already existing.

NEED FOR RESEARCH

The discussions in the previous sections encourage one to believe that for a proper growth of the city system, an intelligent growth control system, if available, will be useful to the decision makers of the city. An intelligent control system is defined as an adaptive control system where the range of uncertainty to handle the system is substantially wide. The objective of intelligent control systems is to ensure an acceptable performance of the controller over a wide range of uncertainty. Three approaches that have the potential for intelligent control are as follows (*27*):

- Expert systems as adaptive elements in a control system,
- "Fuzzy" calculations as decision-producing elements in a control system, and
- "Neural networks" as compensation elements in a control system.

The first two approaches have been used extensively but narrowly in several areas of urban planning in the last decade with some success. The third approach using neural network has attracted researchers in control theory quite recently. A neural network has been defined as a system of interconnected elements modeled after the human brain. A network of "neuronlike" units operates on data all at once rather than step by step. One of the interests of researchers of neural networks is the investigation of the operation and structure of biological neural networks. Algorithmic work in neural networks has concentrated on computationally intensive areas of signal processing, such as adaptive pattern recognition, real-time speech recognition, and image interpretation. In systems and control, real-time identification and control of large flexible structures in aerospace is one such example of a computationally intensive area. Concepts developed in these areas might be useful in controlling and planning urban areas.

It is obvious that an integration of concepts and theories developed over the last few years is essential to provide decision makers of city systems a useful tool based on biological system morphology. The model may be able to apprehend the complexity of problems associated with the growth of city systems, thus serving the purpose of making appropriate policy decisions by the city planners. Since this approach of understanding city systems is innovative and promising, the following objectives may be undertaken in such research:

- Studying the decision making mechanisms relating to the "growth of the city system" in various types of cities (growing, stable, or decaying) across the nation;
- Analyzing the problems involved in decision making processes that currently exist in cities;
- Examining critically the decision making mechanism used by biological systems to maintain their growth (findings of research on neural networks might help in this investigation);
- Identifying important morphological components of the city (similar to the morphological elements of a biological system) and analyzing their functions in structuring the city; and

• Utilizing the research findings in developing a decision making model for intelligent control of the city by policy makers (this model will serve as a useful tool for city engineers and planners in analyzing alternative plans and in providing sufficient information to policy makers in adopting the optimum course of action in a given situation).

More specifically, in the preliminary stages of research the following tasks may be accomplished to develop the model:

1. Identify system parameters.
2. Determine a "minimal" set of physical variables to be used as state variables of the system model.
3. Determine or hypothesize the component models (i.e., the relationship among state variables).
4. "Connect" component models or define compartments to generate an overall model.
5. Specify the desired system responses (external and internal, measurable and inaccessible).
6. Specify admissible inputs (e.g., available resources and current policies).
7. Determine the "cost functional" (performance index, system objective) of the system. The notion of carrying capacity could be emphasized.

After the model is developed, a case study could be undertaken. This could include the following:

• Analysis of the system,
• Synthesis (optimality),
• Simulation, and
• Refining of models via aggregation of variables, compartments, and so on.

Finally, research could be performed to operationalize the model. This would include the following:

• Physical interpretation of results obtained from case studies,
• Implementation issues (feasibility and reality), and
• Comparative studies (i.e., advantages over other methodologies).

CONCLUSION

In conclusion, one might well ask the following. Why is morphological modeling superior to conventional analytical modeling and why does it lead planners in more productive directions? Eleven important and valid reasons answer this question:

1. Morphological modeling inherently is compatible with the systems approach, well known to planners, and provides a sound basis for the diagnosis and prognosis of urban problems.
2. Morphological modeling reveals valuable insights regarding the growth and decay of various components of the city, as well as the entire well being of the city.
3. It can be employed both in forecasting future changes and as a normative device in pointing to possible future changes and need for control.
4. Cities are a complex system of both natural and man-made components that can be discerned to have a morphology undergoing irreversible change through time. The myriad interactions between individuals, groups of individuals, and the natural and man-made environment can best be captured through morphological models.
5. Analytical models currently used in solving urban problems in the 1970s and 1980s have proved to be partial failures because they have examined individual components of the city system.
6. Natural systems grow on the basis of their fixed morphologies and can be described precisely by allometric equations. Similarly, the components of the city must grow preferably in certain fixed morphologies to the whole system. Hence the need for morphological and allometric analysis.
7. Morphological modeling has extraordinary suggestive powers that result from its systematic exploratory behavior.
8. Application of morphological analysis on a broad and realistic basis for policy-directed urban analysis harmonizes with the need for overall improvement of the quality of life.
9. The steps in such analysis are highly interrelated, sequential, straightforward, and direct.
10. Recognizing the importance of morphology and allometry, Dutton states the following (*28*):

> Allometric concepts and the analysis of relative growth may help to fill our current vacuum of ignorance concerning relevant norms of societal growth and change. As humanity takes conscious control of the planet which shaped the species, the analysis of relative growth can indicate what changes are possible, which are most likely, and to some degree, which may be desirable. By attending to changes in shape of our social organism, we may become more competent in shaping change.

11. Zwicky, who was responsible for introducing morphological analysis to the scientific community, writes the following in connection with morphology (*9*):

> Morphological analysis and morphological planning and execution of large-scale projects have been conceived for the express purpose of properly appraising *all* of the facts (or scientifically speaking, the boundary conditions) needed for the unbiased deduction of the possible solutions to any given problem. Only after all of these solutions have been thoroughly evaluated do we select the one among them that best satisfies our requirements.

The concept of morphological modeling of city systems is a relatively new and innovative idea in urban planning, design, and control. The similarity that city systems have to biological systems in their growth and decay commands the immediate attention of researchers in the areas of city systems planning, transportation, control theory, and biometry. Therefore, a coordinated research is essential to transfer knowledge already developed in systems control and microbiology to urban systems design and control. It is expected that such research will greatly benefit professionals involved in urban systems design and management because morphological modeling of city systems will put all of the design components of the city into one perspective.

An explanation is presented of city systems, the morphological analogy of the city in terms of growth and decay patterns and control theory, and, lastly, of biometrical modeling of the city. Still, there are much larger questions that remain unanswered, and these hopefully will be addressed when further research is carried out.

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Land Use Impacts of the Houston Transitway System

JAMES A. MULLINS III, EARL J. WASHINGTON, AND ROBERT W. STOKES

This research effort was directed toward assisting the Texas State Department of Highways and Public Transportation in the planning and impact evaluation of high-occupancy vehicle (HOV) lanes or transitways. The primary objective of this research effort was to measure, analyze, and evaluate the land use impacts of the construction of permanent transitways and park-and-ride facilities on freeway corridors in Houston, Texas. Given the relative newness of transitways in the nation, very little data have been collected or experience gained with the land use impacts of this type of transportation improvement. A review of the literature failed to identify any direct literature on this subject. A survey of operational transitways identified some locations where transitway facility land use impacts possibly had occurred. The prevailing opinion among transitway operators is, and evidence suggests, that land use impacts of transitways are likely to be highly localized and that transitways may induce some shifts in development and settlement patterns rather than generate entirely new development. This paper presents the results of before-after analyses of land use changes in the vicinity of a typical park-and-ride lot in Houston's North Freeway (I-45N) corridor. The results indicate that the land use impacts of the HOV treatments have been relatively insignificant. The study site showed only three possible instances of land use impacts. However, study areas in the corridors surveyed have substantial amounts of undeveloped land, and it may prove necessary to wait until the transitways and associated support facilities become fully operational before a more definitive assessment of land use impacts is possible.

Houston is in the process of implementing high-occupancy vehicle (HOV) projects on five radial freeways in the area. This network is one of the most extensive HOV priority treatment networks in the nation. Over 25 miles of transitways now are operational, 18 miles currently are under construction, and another 23 miles are in the final planning and design stages. The ultimate commitment to transitways may result in over 100 miles of these facilities in operation with a total capital cost in excess of $1 billion (*1*). Figure 1 shows the location and status of the transitway facilities. As can be seen in this figure, these facilities, referred to locally as Authorized Vehicle Lanes (AVLs) and more commonly as transitways or busways, are or will be located in the Katy (I-10W), North (I-45N), Gulf (I-45S), Northwest (US-290), and Southwest (US-59S) freeway corridors.

The priority facilities have similar designs, with a cross section of approximately 20 feet. They are single, reversible lanes (traffic travels inbound toward downtown in the morning and outbound in the afternoon). These lanes typically are constructed within the existing median of the freeways and are protected from other freeway lanes by concrete barriers. Adequate space is provided for emergencies and breakdowns within the transitway cross section. Access points are limited and controlled. However, each facility differs slightly from the others in its particular design, construction, and operational features.

The primary objective of this limited research effort was to measure, analyze, and evaluate the land use impacts resulting from the construction of permanent transitways and park-and-ride facilities in the Houston area. During the initial phase of this small-scale study, the following specific objectives were identified:

1. To conduct, based upon available data, case studies of transitway facilities in cities other than Houston for comparison of design and operational characteristics;
2. To examine land use impacts of the contraflow lane in Houston's North (I-45N) Freeway corridor;
3. To develop a "before" or prebusway land use data base in Houston's North (I-45N), Gulf (I-45S), and Katy (I-10W) freeway corridors; and
4. To project anticipated land use impacts, in the three Houston freeway corridors, that are likely to occur from implementing permanent busways and park-and-ride facilities.

This paper summarizes the land use impacts at one of seven study sites, the North Shepherd park-and-ride lot, which serves the North Freeway (I-45N) Transitway. The results from this site are typical of those found at the other study sites. More detailed discussions of the overall study results are presented elsewhere (*2–7*).

PREVIOUS RESEARCH

The impacts of public transportation on land use and land values were reviewed in four categories: environmental, economic, social, and political or policy. Given the relative newness of transitways in the nation, very little data have been collected or experience gained with land use impacts resulting from these types of transportation improvements. Most previous research and evaluations have concentrated on rail development impacts.

In addition to a review of the previous research on land use impacts, a review of operational transitways in the United States and Canada was performed. This review focused on identifying the transportation and land use impacts the transitway facilities have had or were expected to have on the urban areas in which they are located.

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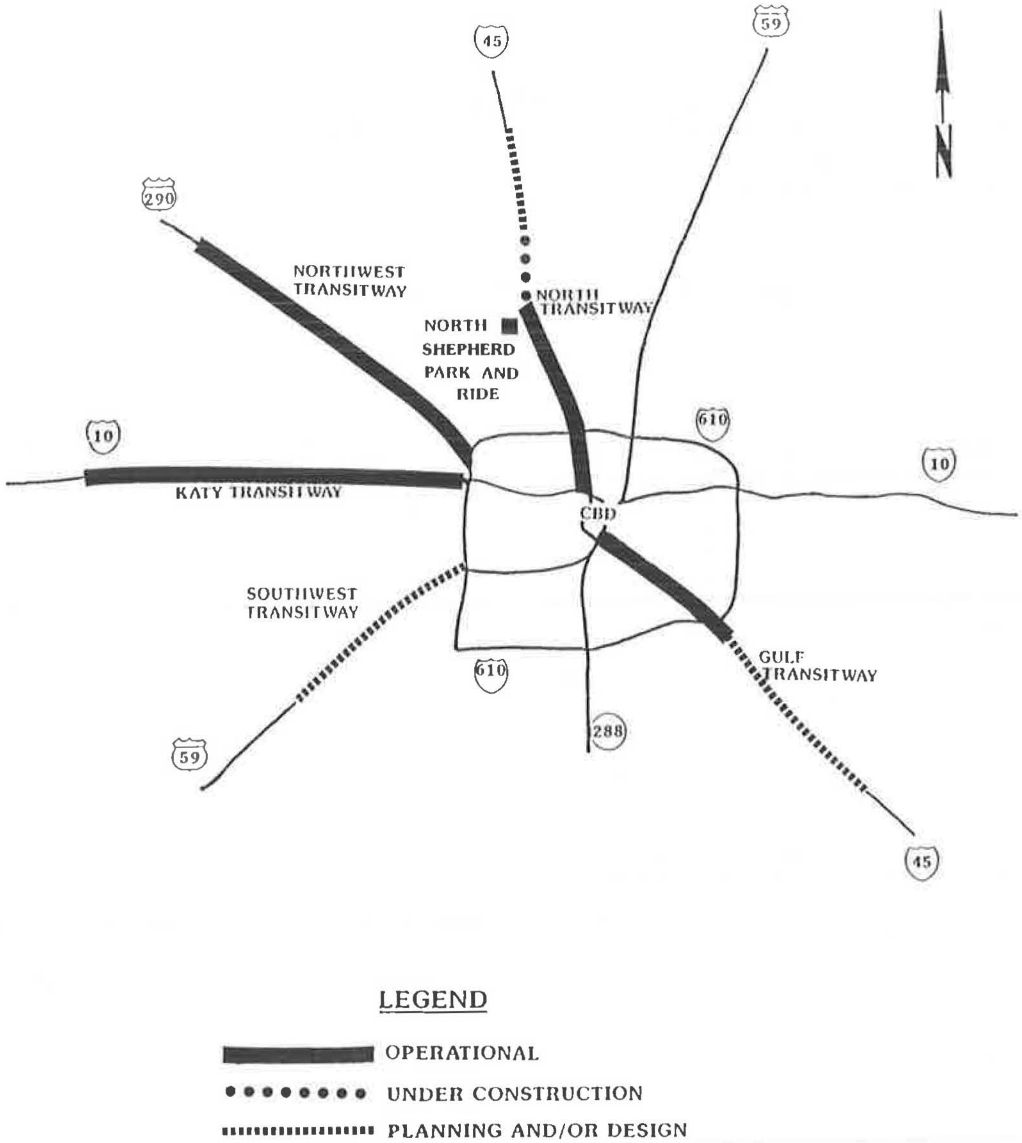

FIGURE 1 Status of the Houston transitways–June 1988.

According to studies by Graff and Knight (*8*), the Bay Area Rapid Transit (BART) system has not had much impact on its environment. The FHWA (*9*) reported in its study on the influence of central city radial freeways on manufacturing decisions that no major negative environmental impacts were identified beyond those normally associated with urban development or beyond the scope of contemporary performance standards.

In many instances, economic and development impacts are included as positive objectives of major transportation investments. This contention is supported by Rollins et al. (*10*). The authors state that "the effect of improving existing urban roadways on surrounding land use is an important consideration in highway agency decisions regarding roadway improvements. Such decisions should consider the economic impact of proposed improvements." Also, Berechman and Paaswell (*11*) report that anticipated increases in service employment, retail activity, and land development, mainly in the declining central business district (CBD) area, were viewed as the major benefits of Buffalo, New York's, light rapid rail transit system.

Another frequently cited impact of transportation improvements is increasing land values. This is evident in the Washington Metropolitan Area Transit Authority (WMATA) system of Washington, D.C., where a sample of land value increases generated by the opening of METRO led to the finding that a minimum of $2 billion in land values has already been added to the existing land value base (*12*).

The social implications associated with transportation improvements and land use indicate that the effects have been small, relative to expectations. When assessing the BART system, however, it is becoming a highly ranked factor in the location decisions of households and employers. Also, characteristics of the transportation system such as freeway configuration and proximity and access to other modes affect cluster and corridor development.

Recent actions aimed at the promotion and coordination of land use and transportation planning concentrate on pooling arrangements and joint development activities. These measures usually are administered under Transportation System Management (TSM) programs and emphasize more efficient use of existing facilities. Although many people fail to take advantage of or even resist these opportunities when offered, the future remains bright for the coordination of land use management and transportation planning.

In summary, the review of the literature did not identify any direct literature assessing the land use impacts of transitways. Therefore, this small-scale study effort is new to the research community and to the literature.

The second phase of the survey effort consisted of mail and telephone surveys of project operators to update information from the literature review and to solicit additional data on transitway projects. Six operational transitways in three states and one Canadian province were identified and reviewed. Table 1 presents a summary of the results of the survey.

The prevailing opinion among transitway operators is that given the exclusive line-haul nature of transitways, their land use impacts are likely to be highly localized, occurring around station areas and major access points.

Preliminary evidence from Ottawa suggests that these localized developments may be substantial. The building industry has expressed interest in pursuing major developments at a number of existing and planned transitway stations. Table 2 summarizes these preliminary development proposals. However, transit use in Ottawa is the highest for all bus-only systems in North America, and experiences there may not be representative of the potential development impacts of transitways. Additionally, indications from the Ottawa experience are that the presence of a transitway may be but one factor in decisions regarding the timing and location of developments. Specifically, discussions with transitway officials in Ottawa indicate that the presence of the transitway system may merely have accelerated the timing of developments rather than influencing location decisions.

Because of the increased accessibility the Shirley Highway HOV lanes in Washington, D.C., offer to persons employed in downtown Washington and the Pentagon, Rosslyn, and Crystal City areas, substantial residential development has occurred along the corridor to the south. People have found that they can reside at locations farther away than many other suburban sites but still commute to work in less time. With housing costs decreasing with the distance from the D.C. core, the result has been major new housing developments at such locations as Dumfries, Triangle, Montclair, and Dale City.

Development impacts of the East M. L. King Busway in Pittsburgh at the time of the survey had been limited to small-scale redevelopments of a service-oriented nature at or near station areas.

Although neither the North (I-45N) Transitway or Katy (I-10W) Transitway in Houston had been in operation long enough at the time of the survey to assess their impacts on land uses in their respective corridors, data from the I-45N freeway contraflow lane, which preceded the transitway, suggest that the presence of HOV facilities may affect choices regarding

TABLE 1 CHARACTERISTICS OF TRANSITWAYS IN THE UNITED STATES AND CANADA (*4*)

Transitway/Location	Year Operational	Type of Facility	Length/Direction	Eligible Vehicles	Estimated Peak Hour Ridership (persons[a])	Transitway Land Use Impacts
Shirley Highway HOV Lanes	1969	1-lane reversible roadway	11.5 miles Fairfax Co. to Washington, D.C.	Buses, vanpools, 4+ carpools	22,000	Possible
I-66 HOV Facility Northern Virginia	1982	4-lane, 2-way exclusive facility -- peak hours and direction only; rest of the time open to regular traffic	9.6 miles I-495 Beltway to Roosevelt Bridge	Buses, vanpools, 3+ carpools	11,200	None
El Monte Busway Los Angeles, CA	1973	2-lane, 2-way exclusive HOV facility	11.2 miles El Monte Bus Station to Los Angeles CBD	Buses, vanpools, 3+ carpools	16,600 6,000	None
East King Busway Pittsburgh, PA	1983	2-way exclusive, partially grade separated.	6.8 miles Wilkinsburg to CBD	Public buses, certified private	6,000	Possible
South Patway Busway Pittsburgh, PA	1977	2-way exclusive, partially grade separated.	4.5 miles SW suburbs to CBD	Public buses, certified private	2,950	None
Katy Freeway Transitway Houston, TX	1984	1-lane reversible median busway	11.5 miles W. Harris County to Houston	Vanpools, buses, 2+ carpools	4,300[b]	None
North Freeway Transitway Houston, TX	1985	1-lane reversible median busway	9.6 miles N. Houston to CBD (20 miles when completed)	Authorized vanpools and buses	4,000[b]	Possible
Ottawa Transitway System, Canada	1984	2-lane, 2-way exclusive facility	7 miles of proposed 18 mile system currently in operation	Buses only	19,200[c]	Possible

[a]ITE 1985 Survey of Operating Transitway Projects, unless noted otherwise.
[b]Katy and North Transitway Operational Summary, TTI, June 1988.
[c]6900 from West Transitway, 12300 from Southeast and Southwest Transitways.

TABLE 2 DEVELOPMENT PROPOSALS IN VICINITY OF OTTAWA TRANSITWAY STATIONS (*4*)

Class of Development	Size of Development	Approximate Investment Value ($ Million)
Office	2 Million Square Feet	$180
Retail	232,000 Square Feet	$33
Residential	5000 Units	$180
Mixed Use (Residential/Office/Retail)	140 Acres	$200

where people live and work. Table 3 summarizes data from surveys of park-and-ride lots served by the I-45N contraflow lane and surveys of lots not served by the contraflow lane or other HOV lane. The table presents a breakdown of whether the presence of the park-and-ride and/or contraflow lane influenced people's decisions regarding job and residential locations (for those respondents who indicated they had changed their residential or job location since the park-and-ride or contraflow lane opened). These data indicate that the presence of both park-and-ride and priority treatment (in this case, contraflow) may influence location decisions. The trend is particularly strong for those who indicated a change of residential location.

The evidence from Houston suggests that the presence of a busway may affect choices regarding where people live and work. This would seem to indicate that the transitways may induce some shifts in development and settlement patterns instead of generating entirely new development.

No land use impacts or development impacts of transitways could be identified in the remaining survey locations in Houston.

METHODOLOGY

The methodology used in the research for this pilot study is referred to as the "before-after" study approach. Data from a time period before the transportation improvement are compared to similar data collected after the completion of the improvement in the affected area. Therefore, the effects of the transportation change are determined by comparing "before" period data with "after" period data, which are collected and updated on an annual basis. This approach was applied to seven sites of the Houston transitway system.

To satisfy the study objectives, land use data were obtained from (a) aerial photographs of study areas, (b) site visits, (c) *Cole's City Directory*, and (d) developer interviews.

TABLE 3 CHANGES IN JOB AND RESIDENTIAL LOCATIONS SINCE PARK-AND-RIDE LOT OPENED, WITH AND WITHOUT PRIORITY FREEWAY LANES (*13*)

Question	Contraflow Lane Lots	Non-Contraflow Lane Lots	Total Sample
Have you changed job locations since park-and-ride (or park-and-ride and contraflow lane) opened?	(n=1118)	(n=558)	(n=1676)
Yes	41%	27%	36%
No	59	73	64
If "yes", did the availability of Park-and-Ride (or park-and-ride and contraflow lane) influence decision?	(n=445)	(n=147)	(n=592)
Yes	51%	40%	48%
No	49	60	52
Have you changed residential locations since park-and-ride (or park-and-ride and contraflow lane) opened?	(n=1122)	(n=563)	(n=1685)
Yes	55%	54%	55%
No	45	46	45
If "yes", did the availability of park-and-ride and contraflow lane influence decision?	(n=603)	(n=303)	(n=906)
Yes	57%	50%	54%
No	43	50	46

n = Sample Size

Aerial photographs of the study areas were examined to identify land use changes in the vicinity of the study sites. The process of identifying land use changes consisted of taking the earliest available photos (between 1973 and 1975) and overlaying them with the next interval (time frame) photos. This procedure was repeated until the latest available (1986) photos were examined.

Site visits were made to the study areas to verify and supplement the results obtained from the aerial photograph analysis. The visits also were used to assess the types of development and their approximate age.

Because the aerial photography analysis can identify only "new developments," changes in the use of existing structures (prior to the "before" time frame) had to be identified through site visits and the city directory.

Cole's City Directory contains information on each occupied address in the Greater Houston area. Land use changes were identified by reviewing the addresses listed within the study area on an annual basis. The addresses listed for the first year of observation (1973) were compared to those for the following year (1974) and so on through the most current year of the study period available (1986). Also, any new addresses within the study area were listed and observed for the remainder of the study period.

As part of this limited research effort, it was decided that interviews with the developers of major office and commercial projects within the freeway corridors would be an expedient and direct method of assessing the interaction between the transitway and its support facilities and the developer's decision concerning where, when, what, why, and how much to develop. The information obtained from the interviews, combined with the other data, should then provide as complete a picture as possible of the impacts of the transitway and support facilities on the freeway corridors. The interviews were conducted with developers of various projects along the I-45N freeway corridor.

ZONE OF INFLUENCE

The zone of influence or "impact area" is commonly an area of a specified dimension inside which may occur land use impacts as a result of a transportation improvement. For this small-scale study a distance of one-quarter mile was chosen as the limit for the impact area of all study locations. This distance was chosen in order to maintain consistency with prior rail and rapid transit impact studies. The one-quarter-mile distance has become somewhat of a standard definition for the zone of influence of transit improvements and is consistent with the general approach used in numerous other impact studies (*10, 14, 15*).

Because of funding limitations, a more rigorous and desirable experimental design could not be applied. Future research in this area might include investigation of larger areas as well as a control site.

RESULTS

The North Transitway or AVL, is a one-lane reversible authorized bus and vanpool facility located in the median of I-45N, known locally as the North Freeway. Implementation of the project was divided into four phases, in conjunction with freeway improvements, as can be seen in Figure 2. Phases I and II extend 9.1 miles from the Houston CBD at Franklin Street to North Shepherd Drive. This portion of the construction replaced Houston's contraflow lane with a physically separated transitway. Phase I construction began in 1983 and, upon completion of Phase II, became operational in May 1985. Phase III will extend the transitway 5.0 miles from North Shepherd Drive to Beltway 8, known locally as the North Belt, with Phase IV continuing the lane an additional 5.6 miles from North Belt to FM 1960. Phase III construction currently is under way with an estimated completion date of early 1989. Construction of Phase IV currently is planned to begin in 1990 and should be completed by 1994.

The entire 20-mile transitway improvement is a joint project between the Texas State Department of Highways and Public Transportation (SDHPT) and the Metropolitan Transit Authority of Harris County (METRO). Financial assistance for the median facility and the interchange ramps is being provided by the FHWA and UMTA.

The I-45N corridor is one of Houston's more heavily traveled corridors and is bordered by significant residential and commercial activity. The facility serves the CBD, the Greenspoint Development at Beltway 8, the Houston Intercontinental Airport, and a number of residential areas and developments (e.g., the Woodlands, Spring, and Conroe areas).

For the sake of brevity, the results presented in this paper focus on one of the seven study sites—the North Shepherd park-and-ride lot. The North Shepherd site possesses similar characteristics to the other sites, and the results here are representative of the findings at the other study sites.

Tables 4 through 6 present parcel data for the North Shepherd park-and-ride lot impact area from the *Cole's City Directory*. The data cover the years 1973 through 1986, with years 1973 through 1980 comprising the before period and years 1981 through 1986 comprising the after period. Parcels along three roadways in the impact area—North Shepherd Drive, Veterans Memorial Drive, and the I-45N freeway—are presented. Figure 3 indicates the location of these streets in relation to the park-and-ride lot, as well as the general location of the parcels monitored for this study. Table 4, which presents land use information for parcels along I-45N, indicates that land uses along I-45N have been and remain exclusively of a commercial nature. This feature is quite natural and would be expected along most if not all interstate roadways in the Houston area. The data also indicate that there has been an increase in the number of commercial land uses throughout the study period until 1985, when a modest decline took place. This particular characteristic is most likely tied to the overall economic growth and mid-1980s economic decline during the study period. There is no evidence of any influence on these land use changes by the transitway or the park-and-ride lot.

Table 5 and 6 present land use information for parcels along North Shepherd Drive and Veterans Memorial Drive, respectively. Table 5 indicates that land uses have changed from being evenly distributed between residential and commercial uses in the early years of the study period to overwhelmingly commercial uses by 1986. As can be seen in Table 5, commercial uses that started at, roughly, a 50 percent level gradually grew to represent roughly 70 to 75 percent of the impact area land uses by the end of the before period. The after

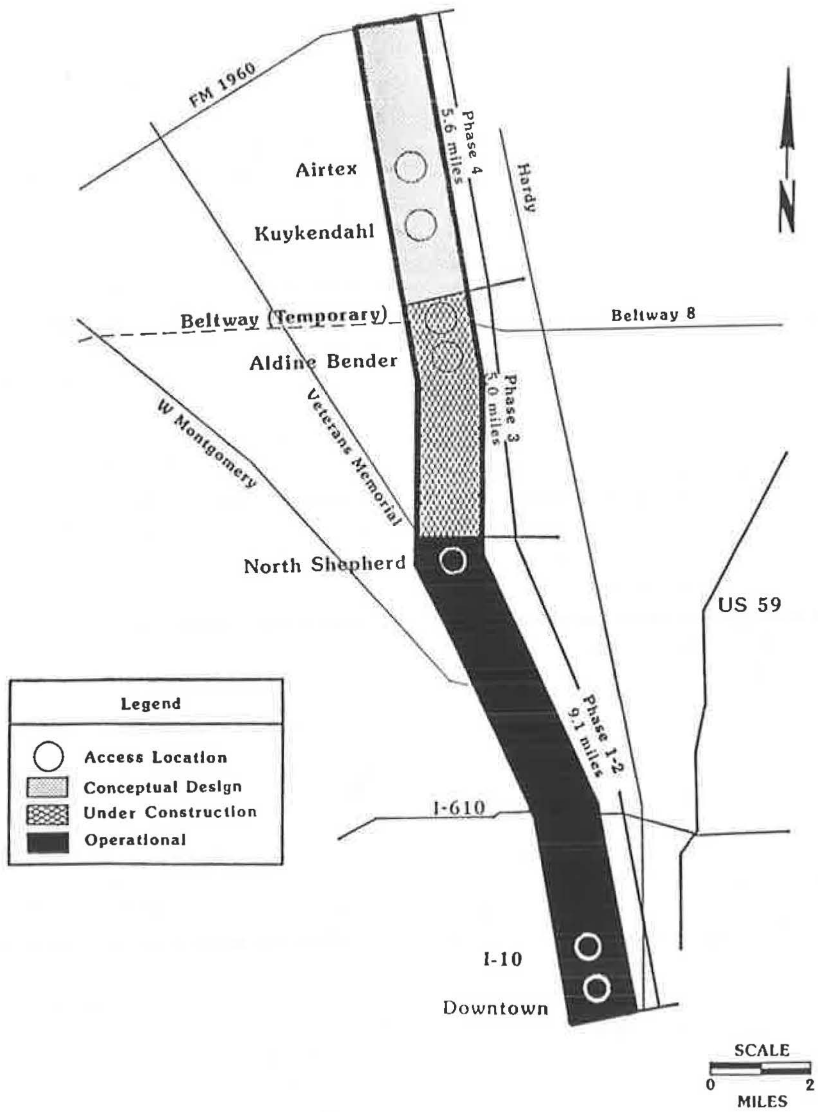

FIGURE 2 North (I-45N) Freeway Transitway (*16*).

period has seen commercial use grow from an 80 percent level to a 95 percent level by the latest available data. All of the residential uses that existed during the before period had become vacant or changed uses by the latest study year. Over 72 percent of the commercial uses that existed during the latest study year previously had been vacant sometime in the study period. These facts indicate that the change in the character of the area may have been controlled more by developmental influences than transportation influences.

The trend of gradual elimination of residential uses and incremental increases in commercial uses appears to be fairly typical of land use changes along arterial roadways in areas that grew increasingly urban in nature as Houston's economy grew. Like the situation along the North Freeway, the land use changes along North Shepherd Drive are more likely a result of the economic growth of the area and appear not to have been influenced by the location of the transitway or park-and-ride lot.

Table 6 details land use changes of parcels along Veterans Memorial Drive. The data indicate that there has been a gradual reversal of dominant land uses throughout the study period. The table shows only one parcel that changed land uses within the study period and involved residential uses changing to commercial uses, and it shows as well that both original residential uses that existed in the before period had become vacant by the latest year of study. Additionally, 80 percent (four of five) of the commercial uses that remained in existence during the latest year of the study originally were vacant parcels. One land use change, that of Parcel Number 47, might represent a partial impact of the park-and-ride lot. The impact may have resulted from the fact that this parcel is located immediately outside the park-and-ride lot, and the business on this parcel—auto repair—is of a nature that could benefit from being located adjacent to such a facility. However, the overall increase in commercial land uses from 1973 until 1985 as well as the decline from 1985 to 1986 more likely is influenced by the economic conditions of the Houston area during the study period.

In addition to the one possible site of potential park-and-ride lot land use influence along Veterans Memorial Drive identified through *Cole's City Directory*, two other Veterans Memorial sites, identified through site visits, show potential

TABLE 4 NORTH (I-45N) FREEWAY LAND USE DATA (1973–1986)

Parcel Number	Land Use and Year													
	73	74	75	76	77	78	79	80	81	82	83	84	85	86
26					CM	X	X	X	X	X				
27	CM	X			CM	X	X	X	X	X		CM		
28														CM
29													CM	X
30														CM
31	RS	X	X	X										
32	CM	X	X	X	X	X	X	X	X	X	X	X	X	X
33	CM	X	X	X	X	X	X	X	X	X	X	X	X	X
34	CM	X	X	X	X	X	X	X	X	X	X	X	X	X
35	CM	X	X	X	X	X	X	X	X	X	X			
36														CM
37												CM	X	X
38													CM	
39			CM	X	X	X	X	X	X	X	X	X	X	X
40								RS						
41					CM	X	X	X	X	X	X	X	X	X
42	CM						CM	X	X	X	X	X	X	X
% CM/RS	53/47	57/43	47/53	59/41	76/24	79/21	76/24	68/32	81/19	83/17	93/7	94/6	94/6	95/5

CM = Commercial Land Use
RS = Residential Land Use
X = Continuance of Previously Listed Use
Blank = No Occupant
Note: All parcels within zone of influence. See Figure 3.

TABLE 5 NORTH SHEPHERD LAND USE DATA (1973–1986)

Parcel Number	Land Use and Year													
	73	74	75	76	77	78	79	80	81	82	83	84	85	86
1	CM	X	X	X	X	X	X	X	X	X				
2				CM										
3	CM	X	X	X	X	X	X	X	X	X	X	X	X	X
4	CM		CM	X				CM	X	X	X	X	X	X
5								CM						
6								CM						
7	CM	X	X	X	X	X	X	X	X	X	X	X	X	X
8							CM	X	X	X	X			
9	CM	X	X	X	X									
10									CM	X	X	X	X	X
11										CM	X	X	X	X
11												CM	X	X
13					CM									
14			CM											
15							CM	X	X	X	X	X	X	X
16											CM	X	X	X
17												CM	X	X
18												CM	X	X
19					CM	X								
20							CM	X	X	X	X	X	X	X
21						CM	X	X	X	X	X	X	X	X
22	CM	X	X	X	X	X								
23						CM	X	X	X	X	X	X		CM
24									CM	X	X	X		CM
25	CM	X	X	X	X	X	X	X	X	X	X	X	X	X
% CM/RS	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0	100/0

CM = Commercial Land Use
RS = Residential Land Use
X = Continuance of Previously Listed Use
Blank = No Occupant
Note: All parcels within zone of influence. See Figure 3.

land use impacts of the park-and-ride lot. Because these sites are located on either side of the initially identified site (just outside the park-and-ride lot) and are engaged in a similar business (automobile service), it is felt that they may also represent possible land use impacts of the North Shepherd park-and-ride lot.

Tables 4, 5, and 6 show that the impact area of the North Shepherd park-and-ride lot has become dominated by commercial land uses. The data suggest that over the length of the study period, particularly after 1980, the character of the area began to change, resulting in large numbers of residential land uses becoming vacant and commercial uses appearing in areas that previously had been vacant. However, other than the three automobile repair establishments, there is little direct

TABLE 6 VETERANS MEMORIAL DRIVE LAND USE DATA (1973–1986)

Parcel Number	Land Use and Year													
	73	74	75	76	77	78	79	80	81	82	83	84	85	86
43	CM	X	X	X	X	X	X	X	X	X	X	X	X	
44							CM	X	X	X	X	X	X	
45							CM	X	X	X	X	X		CM
46					CM	X	X	X	X	X	X	X	X	
47														CM
48	CM	X				CM	X	X	X	X	X	X	X	
49												CM	X	
50					CM	X	X	X	X	X	X	X	X	X
51			CM	X	X	X	X	X	X	X	X	X	X	X
52	CM	X	X	X	X	CM	X	X	X	X	X	X		
53				RS	CM	X	X	X						
54											CM	X	X	
55	RS	X												
56				CM										
% CM/RS	38/62	30/70	27/73	36/64	46/54	50/50	67/33	62/38	69/31	64/36	75/25	73/27	77/23	71/29

CM = Commercial Land Use
RS = Residential Land Use
X = Continuance of Previously Listed Use
Blank = No Occupant
Note: All parcels within zone of influence. See Figure 3.

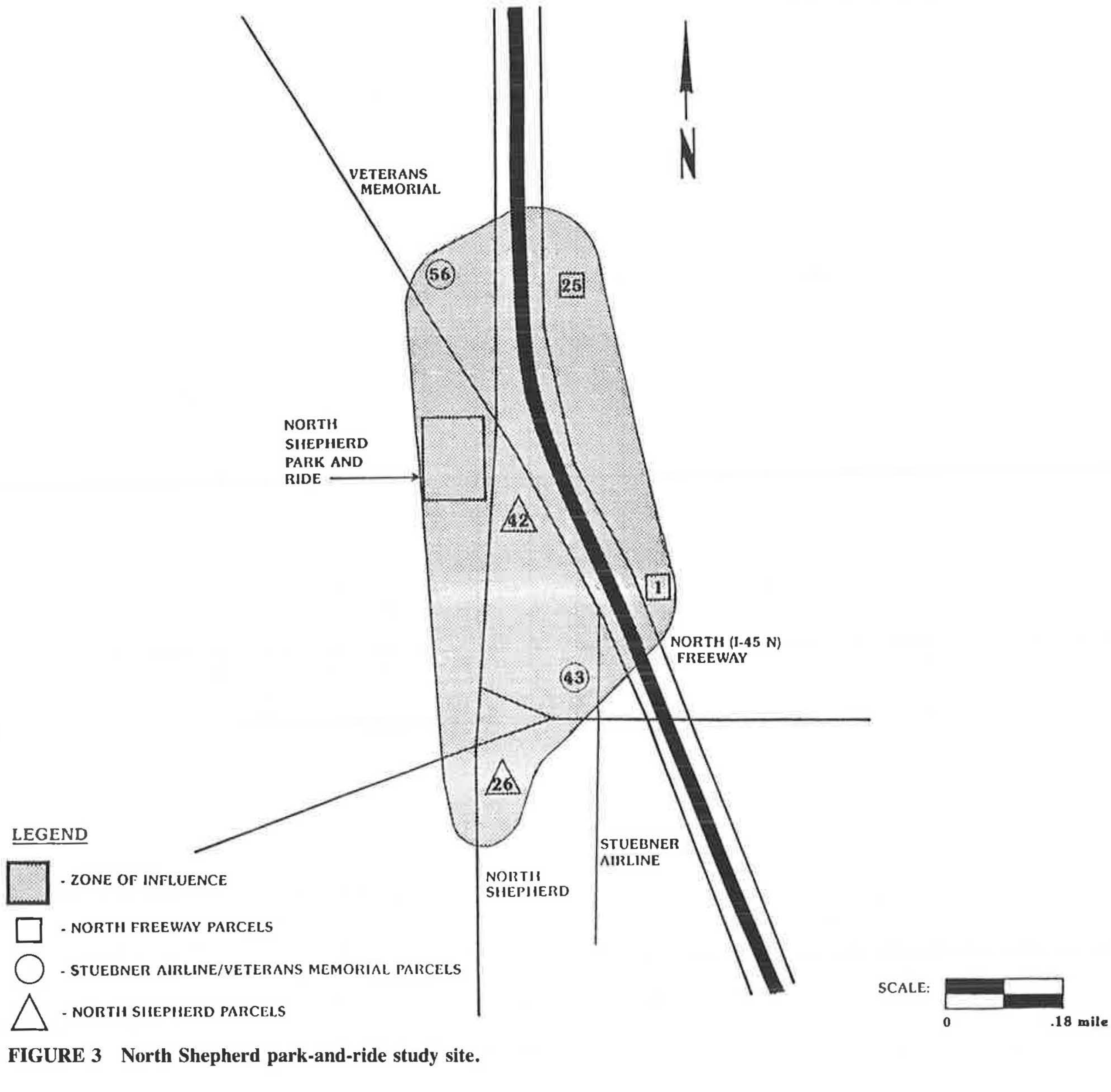

FIGURE 3 North Shepherd park-and-ride study site.

evidence of any land use impacts that can be attributed either to the North Shepherd park-and-ride lot or the North Freeway Transitway (i.e., the uses do not appear to be of a nature that would benefit from their proximity to the park-and-ride lot).

The interviews with I-45N freeway developers revealed that most of the developers generally were aware of the transitway and park-and-ride facilities in the area of their project. Most developers stated that the presence of the transitway and park-and-ride facilities was not a consideration in their decision making regarding the location, timing, and sizing of past development projects. Also, a majority of developers stated that the presence of the transitway did not affect their ability to market their development. Many developers felt that the transitway may benefit the area as a whole but did not affect, positively or negatively, their interests. Almost all of the developers interviewed stated that they did not anticipate that the transitway or park-and-ride facilities or the extension of the former would affect their decisions with regard to any future project.

CONCLUSIONS

A review of previous research and of the literature was conducted in order to determine the extent of work that has been performed previously in this area. A review of operational transitways in the United States and Canada focused on identifying the general design and operating characteristics of transitways and the transportation and land use impacts these facilities have had (or were expected to have) on the urban areas in which they are located. The transportation impacts of transitways are well documented elsewhere. Consequently, this review focused primarily on the land use and development impacts of transitways.

The results of the review indicated that virtually no research had been conducted on the land use impacts of transitways. Additionally, the majority of the transitway operators surveyed indicated that no such research was being considered in the near future. The prevailing opinion among transitway operators was that given the exclusive line-haul nature of transitways, their land use impacts are likely to be highly localized, occurring around station areas and major access points. Preliminary evidence from Ottawa suggests that these localized developments may be substantial. However, transit use in Ottawa is the highest for all bus-only systems in North America, and experiences there may not be representative of the potential development impacts of transitways.

In a more areawide context, preliminary evidence from Houston suggests that the presence of a transitway may affect choices regarding where people live and work. This would seem to indicate that transitways may induce some "shifts" in development and settlement patterns instead of generating entirely new development.

The conclusion drawn from the Houston developer interviews is that neither the North (I-45N) Freeway Transitway nor its support facilities have influenced land use or development decisions over the last 7 years. Interviews with CBD developers might prove more significant in that this type of facility may not influence land use in areas paralleling the facility, as one might initially expect. The influence may be more readily felt where the service is apparent—that is, at the delivery end of the "pipeline."

The results of this limited analysis, although preliminary in nature, indicate that while the HOV priority treatments implemented in the Houston freeway corridors may have produced substantial improvements in corridor capacity, the land use impacts of the HOV treatments have been relatively insignificant. The specific site detailed in this presentation certainly follows this pattern. Only three parcels within the North Shepherd park-and-ride lot impact area showed any change in land use that may have resulted from the HOV facilities. However, study areas in the corridors surveyed have substantial amounts of undeveloped land, and it may prove necessary to wait until the transitways and associated support facilities become fully operational before a more definitive assessment of land use impacts will be possible. Continued monitoring of land uses and completion of the developer interview portions of the research should provide a reasonable assessment of the potential land use impacts of the Houston transitway system.

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Controlling Growth with Level-of-Service Policies

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In the last few years many rapidly growing cities have adopted traffic level of service (LOS) standards that restrict new development to available street capacity. These standards go beyond the usual general plan goals for reducing traffic congestion in that they take away from elected decision makers the authority to approve any proposed land development that would cause traffic levels of service to exceed these standards. Most of the statutory LOS standards that have been adopted to date, however, tend to be so inflexible that they result in de facto growth moratoriums. They fail to recognize both the impacts of through traffic generated outside of their jurisdiction and the fact that other community goals occasionally may supersede the single-minded goal of eliminating traffic congestion. Some agencies subsequently have had to "stretch" the technical analysis to fit more development under a given level of service ceiling. They spread out the peak periods, they average the level of service over several intersections, or they simply use higher saturation flows in the capacity analysis. A better approach is to leave the technical calculations alone and to write into the LOS standards administrative provisions for dealing with "overriding considerations" and "special circumstances" beyond the city's control. These provisions, backed by the appropriate policies and procedures, provide a flexible and responsive traffic policy that does not have to be stretched in order to avoid a building moratorium. This paper presents the experiences of a selected group of California cities that have had statutory LOS standards in effect for several years. These standards are described, their weaknesses critiqued, and the results of two recent court tests briefly reviewed. A suggested model LOS policy then is presented that would provide improved administrative flexibility while still constraining the rate of land development to the rate of street construction.

Almost three-quarters of the cities in the United States have traffic policies that set the preferred minimum acceptable level of service (LOS) for their streets (*1*). New development projects are reviewed individually and mitigation measures developed to maintain the desired LOS. Each project is judged on its merits before the city council and may be approved or denied regardless of the LOS policy.

Rapid growth, however, has outpaced the ability of many cities to construct the needed street improvements. New development projects are approved on a day-to-day basis under the local general plan, but public agencies are unable to fund and construct the needed circulation improvements that keep pace with private developers' construction. The result has been strong pressure from local residents to slow down or stop growth until traffic congestion can be eliminated or at least improved.

Several rapidly growing cities in the last few years consequently have adopted (or have been compelled to adopt) a statutory traffic LOS standard that prevents their elected officials from approving new development projects until there is some assurance that adequate street capacity is or will be available to carry the added traffic.

LOS standards are simple in concept and thus very appealing to the general public. The city sets a peak hour LOS standard of, say, LOS D. No development project then can be approved by the city unless all intersections are forecasted to operate at or better than LOS D. After passage of such a statute, the general public often thinks it has now successfully "legislated away" all future traffic congestion.

These LOS statutes, however, do not usually deliver on their implied promise of no more congestion. Stopping growth alone does not solve preexisting traffic problems. Similarly, stopping growth in one jurisdiction does not prevent other jurisdictions from continuing to grow and generating increased through traffic.

The impacts of statutory LOS standards on the fabric of the city also are far from simple. Rigid LOS statutes rapidly become de facto building moratoriums in the face of increasing traffic from outside the jurisdiction. Beneficial projects, such as schools, recreation centers, and senior housing, then are caught in this moratorium, along with the commercial projects the city wishes to control.

This paper describes the evolution of statutory LOS standards in four rapidly growing cities in California. The experiences of the cities administering these standards then are critiqued to identify the strengths and weaknesses of LOS standards. Two ongoing court cases are highlighted that have challenged the legality of statutory LOS standards. Finally, a suggested model LOS standard statute is proposed that would provide the needed administrative flexibility while continuing to regulate the pace of growth in rapidly growing cities.

CURRENT EXPERIENCE

Although many rapidly growing cities recently have enacted statutory LOS standards, most of these standards are so new that there is relatively little working experience with them. A few California cities, however, have had these statutory standards in effect for as long as 10 years. The evolution of statutory LOS standards in four California cities—San Jose, Newport Beach, Walnut Creek, and Concord—illustrates the strengths and weaknesses of typical statutory LOS standards.

San Jose

The city of San Jose was one of the earliest cities in California to enact an LOS standard. San Jose has a population of about

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750,000 and experienced a 9 percent increase in population and a 20 percent increase in employment in 5 years (1980–1985) (*2*).

In 1978 the city adopted a citywide peak-hour LOS policy (*3*) that requires that any project causing a 1 percent change in the intersection critical volume and a consequent drop in the LOS to E to mitigate its impacts. The building permit can be issued no more than 1 year prior to the expected completion of the mitigation measures.

The city council can (and does) modify the policy at its own discretion. The central business district (CBD) specifically was excluded from the policy since it is the city's goal to redevelop the downtown. Certain other areas of the city also have had their own specific LOS policies adopted by the city council.

Development projects under a specific size are exempted from the policy. Retail projects under 5,000 ft^2 (465 m^2), office projects under 10,000 ft^2 (930 m^2), industrial projects under 30,000 ft^2 (2790 m^2), single-family detached projects under 15 units, and multifamily projects under 25 units are exempt from the LOS policy.

The city maintains a citywide list of previously approved developments for use in the traffic analysis. Developers are allowed to include as their mitigation city street improvements listed in the first year of the city's capital improvements program. The LOS calculation method is *Circular 212* (*4*), modified by San Jose, with capacities of 1,780 vehicles per hour of green per lane (vphgl) for through traffic and 1,675 vphgl for left turns (*5*).

This citywide LOS policy has worked fairly smoothly where the city controls virtually all the development likely to affect its streets. The policy has not worked as smoothly in the northern San Jose area (the Golden Triangle area between US-101 and Interstate 880), where traffic from development in neighboring cities significantly affects San Jose's streets. The city was in the position of pacing growth to its own detriment and to the benefit of the neighboring cities.

The city of San Jose consequently joined five neighboring cities in the Golden Triangle Study to evaluate various growth management options. San Jose subsequently adopted a specific LOS policy for the northern San Jose area based on some of the conclusions of that study (*6*).

The more liberal northern San Jose LOS policy (*7,8*) exempts all "regional" intersections from the policy. A regional intersection is defined as any intersection where one of the street legs is operated by another city, the county, or the state. These intersections presumably would be mitigated by a "regional impact fee" that has not yet been adopted by the city but that would be levied presumably on new development.

The northern San Jose policy also allows developers to take the average of all intersections affected by 1 percent or more, with mitigation required only if the average LOS at these intersections exceeds LOS D. The LOS calculation method for the Golden Triangle area is *Circular 212* with 1,900 vphgl for all movements.

Newport Beach

Newport Beach, a city of 70,000 people (*9*), first established an LOS policy in 1979. They passed their traffic phasing ordinance in 1986 (*10*). This ordinance prohibits the issuance of building or grading permits unless there is or will be adequate street capacity to allow all major street intersections to operate at LOS D *and* at less than or equal to 0.89 volume/capacity (V/C) ratio.

Building and grading permits are delayed for development projects that will be completed in less than 5 years, if the city's primary streets do not meet the LOS standard or will not meet the standard 1 year after the project is completed. The building and grading permits can be issued, however, if

- The project mitigates the problem intersections (where such improvements are feasible),
- The project mitigates the problem so that the affected intersections on the average meet the LOS standard, or
- A major street improvement already planned by the city and expected to be completed within 4 years will mitigate the congestion (the proposed development project must contribute a fee for its share of the major improvement).

If a large development project will take over 5 years to complete, it can be approved in stages based on a traffic study showing that each stage will meet the LOS standards, assuming street improvements are consistent with the city's general plan.

LOS is calculated for the peak morning and the peak evening peak 1-hour periods according to the latest *Highway Capacity Manual* method (*11*), and the V/C ratio is calculated according to the intersection capacity utilization (ICU) method (*12*). Newport Beach uses a saturation flow of 1,600 vphgl, with no reduction for yellow loss time (*13*).

A small development project is excepted from the LOS standard based on a hearing in front of the Planning Commission if it meets the following conditions:

1. The project is a commercial/industrial project smaller than 10,000 ft^2 (930 m^2) floor area or is a residential project less than 10 dwelling units, and
2. The project generates 130 or fewer daily trips.

The Planning Commission also can except larger development projects from the LOS standards if

- The project was approved by the city prior to enactment of the ordinance,
- The project-generated traffic would affect any leg of a critical intersection by less than 1 percent during the peak 2½-hour morning and evening peak periods, or
- The project's beneficial effects outweigh its traffic impacts (requires a four-fifths planning commission vote and a confirming four-fifths city council vote).

A group of Newport Beach residents recently objected to the "flexibility" of the LOS ordinance and sought, through an initiative ordinance, to tighten the standards (*14*). The initiative would have enacted a more strict technical definition of LOS D based on a 15-minute peak and a 5 percent loss-time factor. It would have required all street improvements to be in place before issuance of the building and grading permits (rather than 1 year later). Planners also would have been prohibited from considering the trip generation reductions of transportation system management (TSM) programs unless the same program were already operating in the city of Newport Beach and had demonstrated a trip generation reduction.

The initiative also would have eliminated the provision whereby the city council could exempt a project that had beneficial effects outweighing its traffic impacts. Such projects would have to meet an LOS E standard but only if approved by a six-sevenths vote of the city council.

The initiative failed to obtain a majority in the November 1988 election; however, it illustrates how residents might respond to a flexible LOS statute.

Walnut Creek

Walnut Creek's LOS standard was created by a citizen-sponsored initiative ordinance, Measure H, that was approved by the voters in 1986 (*15*). Walnut Creek, with a population of 73,000, had experienced a 3 percent population growth and 15 percent employment growth between 1980 and 1985 (*2*).

Measure H prohibits any land development project that would affect an intersection and cause its V/C ratio to exceed 0.85 for a specific list of streets contained in the initiative. Development cannot proceed until street improvements reduce the V/C ratio at the intersections on these streets to below 0.85. Planners are not allowed to reduce the estimated trip generation of a proposed project (for traffic projection purposes) with a TSM program or other assumptions of increased transit use or ridesharing.

The measure allows small projects meeting the following criteria to be exempted from the LOS requirements:

- The lesser of (a) 10,000 ft^2 (930 m^2) of retail commercial development (or its equivalent) or (b) the existing zoning is permitted on any parcel that existed at the time the ordinance was approved. (The timing stipulation was intended to prevent the subsequent division of parcels to take advantage of this exception.) The city subsequently has interpreted this provision to allow the combination of adjacent parcels to allow large development projects.
- Thirty dwelling units in the downtown area or ten dwelling units outside the downtown area on any existing parcel are allowed.
- There is no size limit for projects considered to be in the "public good," including senior citizen housing, medical clinics, hospitals, churches, schools, or community centers.

The city allows parcels to be combined, so that four parcels can support a 40,000 ft^2 (3720 m^2) retail development, if the developers can prove that each parcel could have supported a 10,000 ft^2 (930 m^2) development on its own.

The initiative ordinance itself did not specify a method for calculating the service level. In implementing the ordinance, the city has selected the *Circular 212* methodology. For projects expected to be completed within 2 years, the "operations" method of computation is used, with the *Circular 212* limit of 1,800 passenger car equivalents per hour as the capacity value. For projects to be completed more than 2 years after approval, the "planning" method is used, with the standard 1,500 cars per hour as the capacity value.

Over 30 intersections in the city of Walnut Creek currently exceed the 0.85 limit. The city staff has not been able to find a combination of street improvements and land use that could solve the problem after having tried solutions as advanced as a new freeway in the Ygnacio corridor. City planners, instead, have been focusing on tallying all the 10,000 ft^2 exemptions that could occur in the city and allocating the total to a few large developments in the downtown area.

Concord

In 1986 Concord (population 107,000) enacted Ordinance 86-5 (*16*) to postpone the issuance of city permits for any new downtown development that imposes "significant impacts" on the downtown street system that cause "unacceptable" LOSs. The motivation for passing this strict ordinance was a 29 percent growth in jobs between 1980 and 1985 (*2*) plus the recent successful passage of the Measure H citizen's initiative in Walnut Creek.

The key words in this LOS standard are "significant impacts" and "unacceptable" levels of service. "Significant" has been defined by city staff as 1 percent or 50 evening peak-hour trips. "Unacceptable" has been defined as evening peak-hour LOS E. This ordinance, which has no administrative mechanism for dealing with exceptions, disputes, and overriding community concerns, applies only to the downtown areas, leaving the rest of the city exempt.

The LOS is calculated for the peak hour using the *Circular 212* planning method and 1,500 vphgl capacity.

Based on these criteria, two intersections in the morning and seven intersections in the afternoon currently do not meet the standards set by Ordinance 86-5 (*17*).

A 5-year street improvement plan developed in 1986 for the Downtown and West Concord Redevelopment Areas will mitigate current and planned redevelopment to LOS D during the evening peak hour (*18*); however, this plan suffers from two flaws:

1. The street improvements needed to correct the most critical *existing* deficiencies cannot be completed until toward the end of the plan's 5-year horizon;
2. These street improvements require the cooperation of outside agencies and funding, which the city, to date, has not been able to obtain.

Thus the current 5-year street improvement plan holds out only vague prospects of solving current and future traffic congestion problems and eventually allowing downtown redevelopment to proceed.

Ordinance 86-5 consequently will hold up all downtown redevelopment for several years. This will reduce redevelopment revenues that would have been used to fund the 5-year street program and will shift development pressure to the periphery of downtown Concord.

Concord currently is in the process of amending its general plan and Ordinance 86-5 to expand the LOS policy's coverage citywide and to give the city council the flexibility to approve development projects with significant social and economic benefits to the community. The council will also exempt from the LOS calculations all intersections adjacent to the freeway ramps, because congestion at these locations is a function of freeway conditions as well as local land use decisions.

Conclusions

These four California cities have had statutory LOS standards in effect for several years. All of them have faced the problem of excessive rigidity in their initial ordinances and have sought technical and/or political means to insert more flexibility into their standards.

San Jose has adjusted its LOS technical analysis in certain areas of the city to expand the LOS "envelope" and allow some growth. Walnut Creek is considering adding together 20 years' worth of exemptions and allocating the total to a few large downtown projects. The city of Concord currently is adding an "overriding benefits" provision to its LOS statute plus a provision to exempt certain intersections from the criteria.

Several years ago, Newport Beach established a relatively flexible LOS ordinance that allows the city council to override the LOS provisions by a four-fifths vote for "beneficial" development projects. As a warning to others, however, local residents have attempted to curtail some of this flexibility.

RECENT COURT CASES

Unlike courts in many other states, California courts have established that development is a privilege rather than a right. On this basis, local jurisdictions are allowed to use their police powers to require impact fees, street improvements, and dedication of land to mitigate the impacts of development as long as these actions are consistent with their general plans.

The California State Legislature and the state courts have established the local general plan as the foundation for all zoning, exactions, fees, and virtually any decision made by cities and counties regarding development. It is critical, though, in California that no fee or exaction be interpreted as a "tax," which is prohibited by the California Constitution unless the tax has been approved by a two-thirds vote in a general election (*19*).

Although exactions on development have a long court history, statutory LOS standards have, until recently, been relatively untested in courts. Two cases in California testing the legality of statutory LOS standards are still at the Superior Court and Court of Appeals levels.

Lesher Communications v. *City of Walnut Creek* is seeking to have the citizen's initiative ordinance Measure H invalidated because it is inconsistent with the city's general plan. The Appeals Court has given Walnut Creek approximately 6 months to amend its general plan before ruling on this issue (*20*).

Marblehead v. *City of San Clemente* was successful in having the San Clemente citizen's initiative ordinance ruled unconstitutional because, in the judge's opinion, it "requires property owners to mitigate conditions not only caused by their development (a proper goal) but also to cure the inadequacies of those who developed their property before them" (*21*). This decision has not yet been appealed.

The San Clemente initiative ordinance (*22*) would have amended the city's general plan, but unlike the other LOS statutes, it specifically required that a developer's mitigation measures cause a "measurable improvement" over existing levels for intersections currently operating at conditions worse than LOS D. The initiative also set LOS requirements and other criteria for police, fire, paramedic services, flood control, scenic corridors, regional parks, and animal migration corridors.

These two cases illustrate two key issues in statutory LOS standards as far as California practice is concerned. First, the statute must be consistent with the local general plan. Second, the statute must make clear that a developer is not required to correct *existing* problem conditions.

All statutory LOS standards implicitly require that existing problems be corrected before new development can proceed. However, as long as the city takes responsibility for making these corrections and does not specifically require the developer to do so, the statutory LOS standard merely is a "timing" device and not a method for "taxing" developers to correct existing problems.

Statutory LOS standards are similar to generally accepted "sewer hookup moratoriums" is that, for public health reasons, they delay new construction long enough for the jurisdiction to construct the needed capacity. The developers are not required to build the treatment plant but merely to wait until it is ready.

CRITIQUE

Statutory LOS standards have come about because of a general failure of the planning process to deliver uncongested transportation systems in rapidly growing areas. Long-range general plans provide for a balance between land use and the transportation system that unfortunately will not occur until 20 years in the future. These plans do not specify the rate at which land use and the circulation system will grow. They often include street improvements that are subsequently delayed or abandoned. However, there is no mechanism for "downzoning" the land use when a transportation facility is dropped or delayed.

For relatively stable cities, the fact that some facilities may be delayed is not too serious a problem. However, in cities experiencing rapid growth, the new construction can overwhelm the city's ability to build the needed street improvements. An LOS standard that delays the issuance of building permits is then an obvious and necessary technique for slowing down land development to the pace of street improvements.

The statutory LOS standards that have been adopted to date are well-meaning but rudimentary attempts to tie growth to the ability of cities to construct street improvements. They are usually adopted by individual jurisdictions on a piecemeal basis, not recognizing that regional cooperation is needed to make them work, and they often fail to recognize that sometimes other community goals may take precedence over traffic congestion.

Overriding Considerations

An LOS standard for new development must provide for conditions where the benefits of a particular land development may outweigh its negative traffic impacts. In the environmental review process, these typically are called overriding considerations. If this situation is not provided for, the decision makers are tempted to "stretch" the technical analysis so that a particular project will fit within the standard. The result is a looser standard that then allows all projects to proceed to the new ceiling regardless of their relative benefits.

The LOS standard must also provide for cases where, owing to other considerations, the city does not wish to provide more capacity at a particular location. Further improvements at these locations might cause significant environmental impacts. Fiscal and technical constraints may make it highly undesirable to make further improvements, regardless of the LOS.

Special Circumstances Beyond the City's Control

This issue comes about because of the regional nature of the traffic congestion problem and the fact that individual cities can control only a small piece of the whole picture. The ideal solution is to cooperate with other jurisdictions in seeking joint solutions to the problem. This cooperative approach has been tried before (as in the Golden Triangle Study in San Jose), but it is rarely successful since jurisdictions often compete for new development. Consequently, those cities seeking to control growth usually must proceed alone, adapting their policy as best as possible to take into account the action or inaction of adjacent jurisdictions.

In the absence of interagency cooperation, it is necessary for the city to have a policy for dealing with locations where significant through traffic may be generated by development outside of the city's jurisdiction. It is unrealistic to set a rigid LOS policy for a street where the traffic level cannot be controlled by the city. The city would be put in a position similar to that of the city of San Jose, which is forced to turn down its own development projects while adjacent jurisdictions proceed to approve new development.

Similarly, some street improvements require the approval and/or funding of another agency. The city cannot have its development decisions delayed by required improvements it is unable to implement. One solution might be to raise the overall ceiling everywhere so that everybody can develop. A better and more controlled solution would be to identify these "special circumstance" locations and to give special treatment to these locations only.

This exclusion, however, has to be matched with a commitment by the city to make a special effort to get these locations off the special circumstance list as soon as possible. This means making a special effort to obtain the cooperation and funding of adjacent jurisdictions. Otherwise, the special circumstance locations will tend to act as magnets, drawing in additional growth because of their exemption from the LOS standard.

Recognition of Past Errors

The existing street system may not meet the standards at current development levels. Past errors may have allowed development to proceed too rapidly for the existing street system. There is little legal justification for requiring new development to correct for past errors made by the city. Consequently, the jurisdiction must provide a separate means (outside of the LOS standard) for correcting preexisting LOS problems, or at least a means to avoid penalizing new development for existing problems.

One solution is to require mitigation only to the baseline level. However, this does not correct the current congestion problems that probably motivated passage of the LOS standard in the first place. A better solution is to commit to a publicly funded 5-year street improvement program for correcting existing problems.

Tolerance for Forecasting Errors

LOS standards typically assume that the calculation and forecasting of LOS is a precise science. Predictions of trip generation and when street improvements will be built can prove inaccurate, but there is typically no specific margin of error built into the planning studies to allow for this.

There must be a certain ability to "roll with the punches" when the technical experts make errors in forecasting the impacts of new development and in forecasting the timing and benefits of street improvements. Street improvements may be delayed unexpectedly or cancelled if the necessary outside funding or agency approval cannot be obtained.

Ideally, the LOS standard used for pacing the issuance of building permits should be set to a worse level than is normally used for the planning studies. The general plan street network should be designed for a better LOS than the LOS standard to allow for later zoning changes and amendments and to allow for reasonable traffic forecasting errors. With this allowance a new developer does not have to "pay" for the mistakes made in earlier planning and impact studies at the time he or she obtains the building permit.

Equity

One issue often raised in discussing LOS standards is the question of equity. The equity issue comes up because the first landowner "in" often gets to build his or her project, whereas subsequent landowners may be delayed because of a lack of street capacity. This issue can be resolved by considering the equal opportunity argument. Each landowner has an equal opportunity to apply for development approval from the city at a time of the landowner's own choosing. The delay that a late applicant might face is unfortunate, but it is partly self-induced by the tardiness of the application. This delay is for the public welfare, much as a temporary sewer connection moratorium is imposed until adequate sewage treatment capacity becomes available.

Legal Issues

To date, court cases have focused on whether the LOS statute is consistent with the local general plan (which it must be) and whether the jurisdiction is requiring the correction of previous mistakes (which it cannot). A third legal issue, whether or not an LOS statute can be considered as "taking" a landowner's development rights, has been a concern to the city of San Rafael, California. This city chose to allow "reasonable interim uses" on each parcel until there is adequate street capacity for larger projects (*23*). However, an LOS statute should not be considered a taking since it does not *deny* the privilege of developing but instead *delays* it until it can be accomplished without harming the public welfare.

MODEL STATUTORY LOS STANDARD

The following is a recommended model traffic policy that addresses the issues described above. Generally, it is a hybrid of the LOS statutes described above, designed to provide both the control and flexibility that are necessary when making land use decisions in rapidly growing cities.

The model statute contains findings, a general statement of principle, and sections providing for overriding considerations and special circumstances. Suggested administrative guidelines for implementing the LOS statute are provided after the model.

Findings

1. Traffic congestion, when it exceeds a reasonable LOS, causes increased air pollution and energy consumption, hinders the passage of public safety vehicles, contributes to lost labor productivity, increases stress, and in general degrades the quality of life.
2. The general plan sets an LOS standard for the city street system.
3. The city has a 5-year street improvement program to correct existing street LOS deficiencies and a long-range plan to construct additional improvements to meet the long-range needs of new development.
4. Traffic studies indicate that the cumulative impacts of rapid new development temporarily will exceed the ability of the city to construct new street improvements in a timely manner, thus causing the city to fall behind temporarily in its efforts to maintain the general plan LOS standards.
5. The rate of new land development consequently must be controlled to allow the city adequate time to correct existing deficiencies and to provide new street capacity for new development.

Statement of General Principle

To implement the city's general plan, as requests for new development occur, the city shall determine if the new development would impose significant impacts upon the transportation network that could result in a reduction of existing levels of service to an unacceptable level. Issuance of the building and grading permits for those developments determined to impose significant impacts will be postponed until the city is satisfied that necessary improvements to the affected portion of the transportation network will be in place in time to offset the expected traffic increases from the development.

Overriding Considerations

The city council may, by a four-fifths vote, fully or partially exempt a project from the requirements of the LOS standard if it finds that the social and/or economic benefits of the proposed project outweigh the adverse impacts of the project. Projects categorically exempt from environmental review also would be exempt from the requirements of the LOS standard.

Special Circumstance Locations

The city council may, by a four-fifths vote, temporarily exempt certain street locations from the LOS standards owing to special circumstances that make it undesirable or not feasible to provide further capacity improvements at these locations. These special circumstances may include, but are not limited to, the following: there will be significant negative fiscal, economic, social, or environmental impacts of further construction; a significant portion of the traffic is generated by development outside the control of the city; or there will be a significant delay in obtaining the needed cooperation of other agencies. The city, however, will make every effort to design alternative improvements and obtain interjurisdictional cooperation so that these locations can be removed rapidly from the special circumstance list. Development projects affecting special circumstance locations may be required to implement mandatory TSM programs and other measures to reduce their impacts on these locations as much as possible.

MODEL LOS STANDARD ADMINISTRATIVE PROCEDURES

This section presents some recommended policies and procedures for implementing the model city traffic policy.

Administration

The determination as to whether a proposed development project meets this policy would be made within the environmental review process. Projects categorically exempt from environmental review also would be exempt from the LOS standard. For nonexempt projects an initial environmental study would be made to determine if

- A negative declaration of environmental impacts (including traffic) may be made, or
- A full (or focused) environmental impact report (EIR) with the consequent traffic study may be required.

The proposed recommended practice for traffic access and impact studies for site development by the Institute of Transportation Engineers (ITE) (*24*) recommends that traffic studies not be required for development projects generating less than 100 peak-hour vehicle trips inbound or outbound, since projects under this size are not likely to have a significant impact on peak-hour LOS. However, most of the cities described in this paper generally have adopted lower thresholds of 50 vehicle trips per hour (in and out) or 1 percent impacts on the intersection critical movement.

At the time of project approval (use permit, variance, zoning administrator permit, etc.), city staff would make a determination as to which street improvements must be completed or under construction prior to issuance of the building permit. This would then become a condition of approval that must be satisfied before the building permit can be issued to the applicant.

The construction, occupancy, and the issuance of building permits for larger projects may be staged to coincide with the expected schedule of street improvements.

Maximum Acceptable LOS

The city might pursue several options in selecting a maximum acceptable LOS. The draft practice by ITE recommends LOS D or the baseline level, whichever is worse (*24*).

Contra Costa County, California, recently adopted a growth management measure that sets different LOS standards depending on the character of the neighborhood (*25*). The county recognized that different land use intensities generate different expectations of LOS and consequently set the following maximum acceptable levels of service for each area type:

Area Type	*LOS*	*V/C (%)*
Rural	C	74
Semirural	C/D	79
Suburban	D	84
Urban	D/E	89
CBD	E	94

The method of calculating LOS should be according to the most recent edition of the *Highway Capacity Manual*, with specific saturation flows and other parameters as determined by city staff.

Development Impact Calculation

The development project's traffic impacts should be calculated generally according to the guidelines provided in ITE's recommended practice. Trip generation, distribution, mode split, and assignment are to be based on the best available commonly accepted sources as determined by city staff. City staff should maintain and update a comprehensive citywide list of "approved and under construction" projects for use in the impact analysis. City staff also should maintain and update biannually a data file of intersection turning movements counts and forecasts (from previous studies) for use in LOS forecasts.

Mitigation Measures

Developers would be allowed to include as mitigation all funded street improvements contained in the city's 5-year street improvement program. Other street improvements, including those contained in the city's general plan, also may be included as mitigation only if the developer can show to the city staff's satisfaction that the improvements are likely to be completed at about the same time as the proposed development.

The traffic reduction benefits of a TSM program can be included as a mitigation measure if it can be shown to the city staff's satisfaction that the proposed TSM program

- Is realistic and measurable, with an achievable TSM goal;
- Will be mandatory for current and future building owners, with significant sanctions for failure to meet the TSM goal; and
- Has a designated on-site TSM coordinator responsible for conducting and forwarding to the city annual employee surveys and driveway counts to the satisfaction of the city TSM coordinator.

The TSM program (if required) would be monitored on an annual basis by the city TSM coordinator based on surveys gathered by the building owner. Failure to meet the TSM goals for the second straight year would cause the sanctions agreed to by the city and the applicant (as part of the conditions of approval) to be implemented against the current building owner.

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Suburban Transport Behavior as a Factor in Congestion

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Suburban congestion is among the most pressing transportation problems in large urban metropolises. One of the major causes of this problem is the changing transport behavior of people, created by a series of complex social, economic, technological, and cultural changes. Rapidly developing suburbs are a focal point for congestion in part because they are at the forefront of these changes. A conceptual framework has been established for identifying the channels through which various phenomena affect individuals and households, their orientation in life, and the decision-making process that results in manifest transport behavior. Several national trends in household structure, location patterns, incomes, life-styles, social values, and norms, as well as in technology, are identified in this paper, and their effect on transport behavior is explored. To explore differences in demographics, household structure and commuting patterns among the central cities and growing and stable suburbs, a cluster analysis was performed using data from several suburbs and the central city of Chicago. Cluster results suggest that growing suburbs appear to be quite different from other areas in dimensions related to life-styles and transport behavior. Based on these results, useful solutions to the suburban congestion problem must be based on a more fundamental understanding of the underlying life-styles and transport behavior of suburban residents.

Suburban traffic congestion is one of the most pressing transportation problems in large urban metropolises. Suburbs are growing rapidly—many faster than the nationwide average growth rates. This growth is in many dimensions: housing and residents, office space and jobs, and both vertical and horizontal sprawl. As a consequence, traffic density has increased in the suburbs, in some locations to intolerable levels.

Intuitively, some of the factors behind suburban congestion are as follows: (a) the recent addition of large numbers of suburban jobs that resulted in large numbers of trips destined to those areas, (b) the attractiveness and relative affordability of housing, (c) the often inadequate roadway infrastructure (i.e., infrastructure not designed to carry heavy traffic), and (d) the absence of (effective) public transportation.

An associated factor behind the suburban congestion problem is the accelerated growth in automobile ownership and use in recent years. Sprawling development in the suburbs, along with the inability of transit to provide a reasonable level of service in low-density areas, has given consumers incentives to own more automobiles. However, the growth in automobile ownership may not be explained by these factors alone.

We believe there are complex social, economic, technological, and cultural factors that are changing people's transport behavior—in particular, automobile ownership and usage. Society evolves over time, demographics change, new social values and norms are established, the economy changes, and new technologies become available. All of these changes change transport behavior.

Rapidly developing suburbs are a focal point for congestion in part because they are at the forefront of these changes. To deal with suburban congestion, we must understand not only the trends in transport behavior but also the demographic, social, and economic trends underlying them.

Some recent major changes are briefly listed below.

- *Social changes:* decreasing household size, increasing numbers of working women, the returning young adult phenomenon, and the increasing proportion of never-married people;
- *Economic changes:* increasing incomes for certain classes (i.e., upper middle class) and household types (i.e., multiple worker), decreasing amounts of savings, decreasing operating costs of automobiles, declining heavy industry, and rapid increase of service and high-technology industries;
- *Locational changes:* suburban sprawl and rapidly increasing numbers of both residents and jobs, relocation of companies from central city to suburbs, and "leapfrogging" of new developments to suburban hinterlands—trends generating many trip attractions accessible only by automobile; and
- *Technological changes:* telecommunications enabling companies to create satellite operations or move to low-density locations; many technological advances making automobiles more functional, safer, more comfortable, and far more fuel efficient; cellular telephones helping make travel time productive; technology and retailing trends making many activities easily accessible or directly available to drivers from their cars; and technology enabling the retailing and entertainment industries to become more efficient and attractive.

In this paper we (a) present a conceptual model linking these trends to suburban travel; (b) review aggregate statistics that confirm these relationships; and (c) present our analysis of suburban attributes, showing important travel-related differences among a sample of suburbs.

CONCEPTUALIZATION

To understand all these elements and dimensions, we need a broad framework describing the underlying process generating people's transport behavior. This framework identifies the channels through which various phenomena affect individuals and households and their orientation in life and decision-making processes that result in manifest transport behavior.

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Although individuals can be viewed independently, with their own unique aspirations, goals, and idiosyncratic personalities, as long as they belong to households, their behavior is constrained to conform to certain role assignments defined to meet household as well as individual goals with reasonable efficiency. Therefore, it is important to recognize the effects of changing household characteristics while also trying to account for the personal attributes of each individual in the household.

Figure 1 presents our conceptual model founded upon work by Hartgen and Tanner (*1*), Field et al. (*1*), Ben-Akiva and Lerman (*2*), and Salomon (*3,4*).

Travel or *transport behavior* results from the household's transport-related decisions (*2,5*). These decisions may be classified into long- and short-term decisions. Long-term transport behavior decisions include mobility choices, such as residential location, employment location, automobile ownership, and mode to work. Short-term decisions include travel choices, such as frequency, mode, destination, route, and time of day for individual trips.

The model suggests that there is a set of activity opportunities, defined by location and activity attributes, with certain time and money requirements and constraints (e.g., food store closes at 9 p.m.). The activity locations are connected by the transportation system, which has distinct characteristics (e.g., network structure, modes, performance, and costs to the traveler) and policies.

This is the abstracted environment for each household comprising one or more individuals. The personal and joint needs of individuals create the set of household needs. Some needs must be fulfilled (i.e., maintenance), whereas some others may or may not be fulfilled (i.e., recreational activities). When the needs that can be fulfilled and the activities that will meet those needs have been identified, the adopted activity sequence for each individual determines the chosen activity sequence for all household members, which will result in the fulfillment of needs. This is a dynamic process characterized by much variation around a stable activity pattern, as well as longer-term changes in that stable pattern, both driven by exogenous and endogenous factors.

The activity sequence for individuals and households is the result of a series of long- and short-term decisions. Each individual has a set of values and a distinct personality. These elements interact imperfectly with the surrounding world, generating a *life-style*. Life-style is a construct used by Salomon (*3,4*) and others to describe the outcome of the choice process of people. Life-style, according to Salomon, is the orientation of an individual in life through three major decisions: the decision to form a household, the decision to participate in the labor force, and decisions about spending free

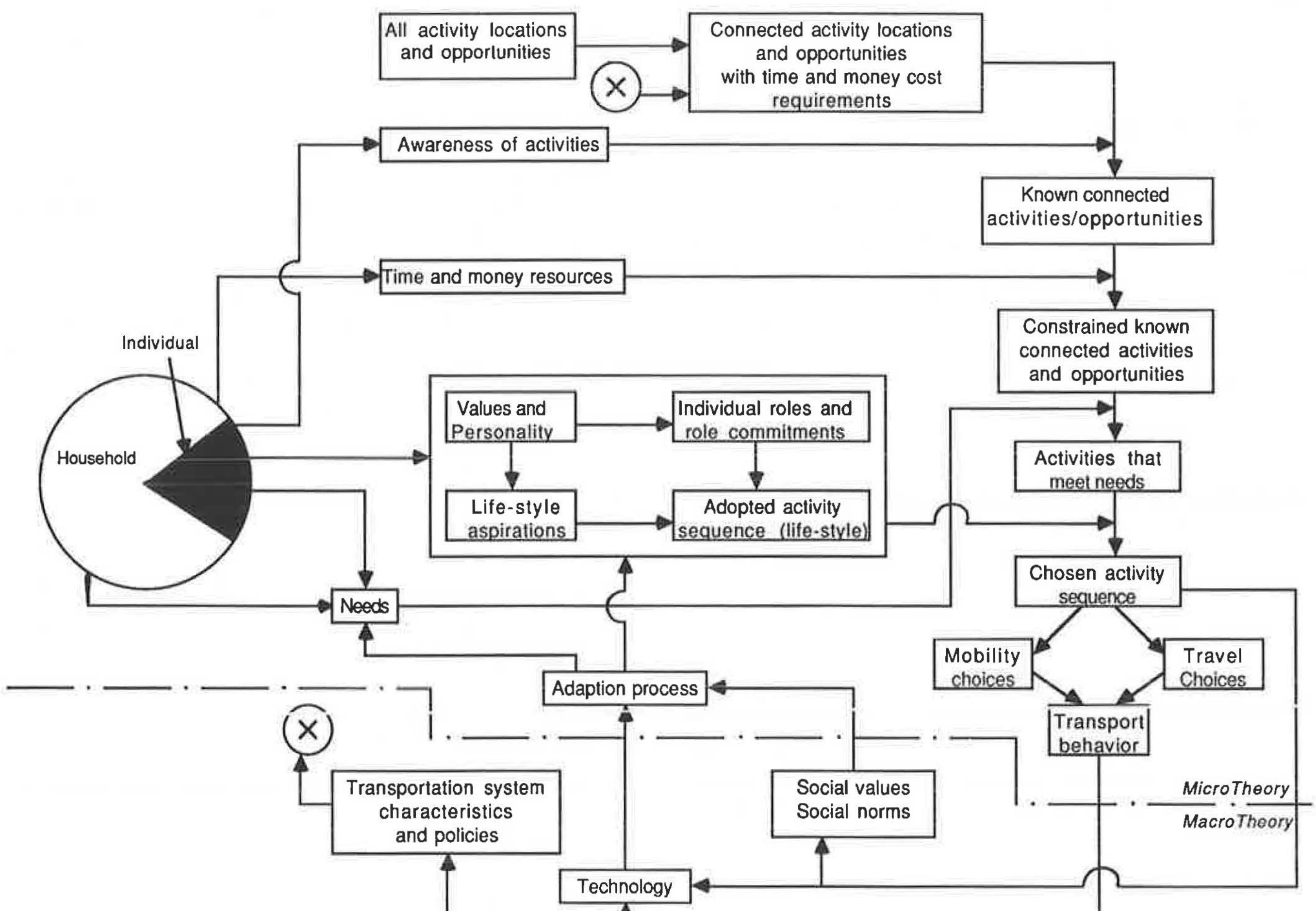

FIGURE 1 Conceptual model of transport behavior.

time (leisure). Many more detailed components that are complements or parts of this broad definition (e.g., preference for suburban living, degree of career orientation, preference for specific types of automobiles, and preference for specific art expressions and types of entertainment) have been attributed to life-style. Life-style is important because it underlies the decision-making process of individuals. Certainly, the chosen life-style for each individual is not a line between the times T and $T + t$; it is rather a corridor in which individuals make decisions and perform activities that broadly fulfill their life-style aspirations.

Another important element for each individual household member is that of role and role commitments (e.g., provision of shelter and food gathering). A broad range of factors, including social norms and economic demands, influences the role of household members. There are short- and long-term role commitments. Over time, roles change for members of a household as it evolves through life-cycle stages (*6*).

All of these result in the activity sequence for the individual household member. This sequence allows the needs of the household to be fulfilled and the life-style aspirations of the individual to be achieved. The chosen activity sequence then serves as the input for mobility and travel choices of household members, choices that define the transport behavior.

The sum of the chosen activity sequence and the transport behavior across individuals in the population feeds back the social values and norms as well as the technology and the transportation system and policies to the household. This dynamic interaction creates the new environment in which individuals live. A complicated adaptation process then takes place, and the household needs and the standards and aspirations for each individual are adjusted. Adaptation is a dynamic process of reacting to perceived imbalances through changes in activity patterns, within the limitations of household role requirements and resources and transportation-connected activity locations (*1*).

The critical elements of this framework are the individual and household *needs* as well as the *life-styles* of the individual household members. There are some basic needs and life-styles that can be found in most individuals at most places (i.e., work, shelter, family formation, transportation). Many factors (e.g., culture, environment, and technology) shape and differentiate needs and life-styles across individuals, households, or places.

The model in Figure 1 suggests that people's transport behavior is affected by factors such as

- Household structure;
- Availability, cost of activities;
- Life-style;
- Transportation system characteristics, policies;
- Location patterns;
- Personal/household income;
- Social values, norms; and
- Technology.

None of these factors logically can be considered to be exogenous (i.e., as a conceptual starting point for understanding and anticipating the others). They must be viewed as an interconnected system within which relationships are driven by a variety of processes at the levels of individuals, households, groups, communities, and society that lead to short-term, homeostatic equilibria and longer-term drift.

TRENDS AFFECTING CHANGES IN TRANSPORT BEHAVIOR

All factors listed above are time variant; we should expect changes in people's transport behavior as both individuals and society, and the factors that affect them, change. For example, moving to a low-density residential area (i.e., suburb), getting a promotion (which typically leads to a higher income), graduating from school or college, or opening a new expressway facility all can be expected to affect individual or household automobile ownership and trip patterns.

Many changes have taken place since 1975 that have given a new shape to the factors affecting transport behavior. Below we discuss some of these changes and their expected effect on transport behavior.

Household Structure

The three major components of household structure are its size, the age of its members, and the number of workers. All three have changed dramatically; household size has decreased while both age and the number of workers per household have increased.

Decreasing household size (Figure 2) can be attributed to the lower fertility rate, the increasing number of single-parent households, and the increasing number of unmarried people (and cohabitation of unmarried couples). This trend is very important because smaller households forego some economies of scale; since the total population continues to grow, and thus the number of households is increasing, more travel may be required to meet these households' needs.

Another major demographic change is the *aging of the population*: the median age of the population has been increasing consistently over the years 1970 through 1984 (Figure 3). This translates into more people being eligible to drive, more people at an age of high-activity participation and mobility (i.e.,

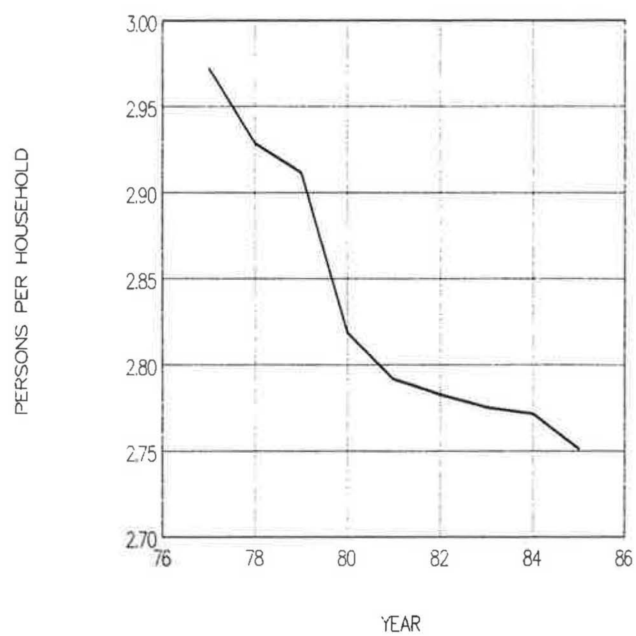

FIGURE 2 Trend in household size (*18*).

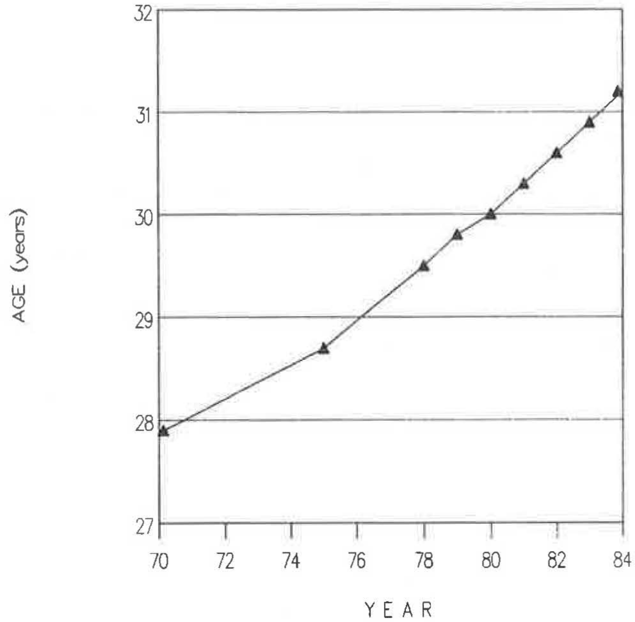

FIGURE 3 Trend in median population age (*18*).

between 20 and 60), and probably more people at an age that enables them to work and earn an income. These effects of population aging clearly increase the demand for both travel and automobiles. Furthermore, Wachs (*7*) points out that the senior citizens of today increasingly are people who grew up in the suburban automobile era. When they reach 65, it is unrealistic to expect them to give up their cars and the associated mobility benefits or to move to the central city where transit is better and vehicular travel needs are less.

The number of workers per household has increased as a result of the *increasing size of the labor force* (Figure 4), which may be attributed to three factors. First, people born in the baby-boom era are presently at their work age (25 to 40 years old), so there exists a large supply of labor. Second, women participate in the job market almost on an equal basis with men, further increasing the supply of labor. Third, one salary often is not enough in multiperson households to cover the basic household needs, enjoy the plethora of consuming opportunities, or improve the standard of living. Therefore, there are real incentives for more members of the household to seek employment. In addition, because of low salaries, high costs, and employment uncertainty, more people hold more than one job.

Personal or Household Income

Income is the resource pool from which the cost of activity participation and purchases are covered. Knapp (*8*) suggests that household income has decreased over recent years (Figure 5). According to him, the reasons for the decreases in income are excess labor supply, the decline of heavy industry, and the expansion of low-paying positions in the service and entertainment industries.

Our interpretation of the distribution of household income over recent years is that it remains rather stable, affected slightly by recession or international crises. Hence, increasing automobile ownership (Figure 6) is an unexpected outcome not only since automobiles are expensive but also because automobile availability in the United States was the highest in the world in the early 1970s. This suggests the existence of powerful factors boosting automobile ownership despite the relative stability in income.

Social Values and Norms

Social values and norms influence choices about life-styles and ways households operationalize them. Three manifesta-

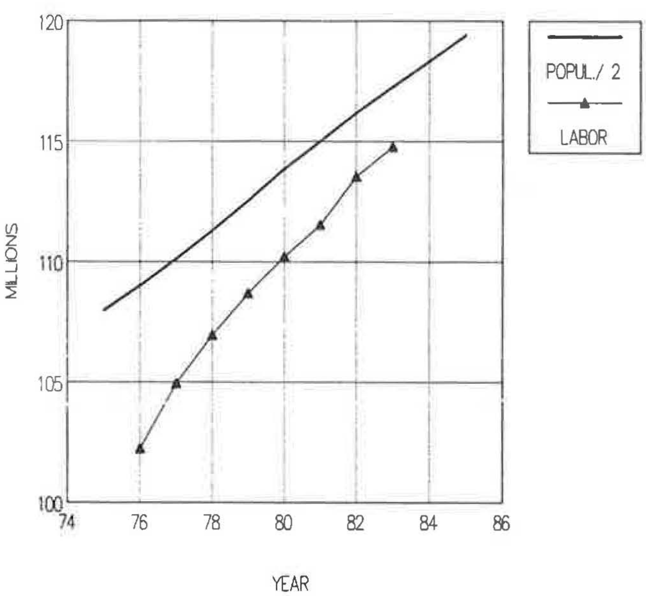

FIGURE 4 Trend in labor force compared to population (*18*).

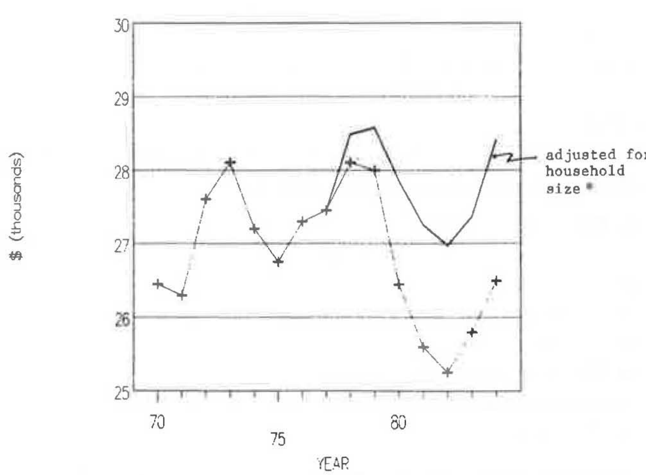

FIGURE 5 Trend in median household income in constant 1984 dollars (*8*).

(*) The adjustment is basic and reflects the logic that, on the average, smaller households have fewer breadwinners and therefore less income. The factor by which incomes after 1977 were multiplied is: household size in 1977 divided by household size in year being adjusted.

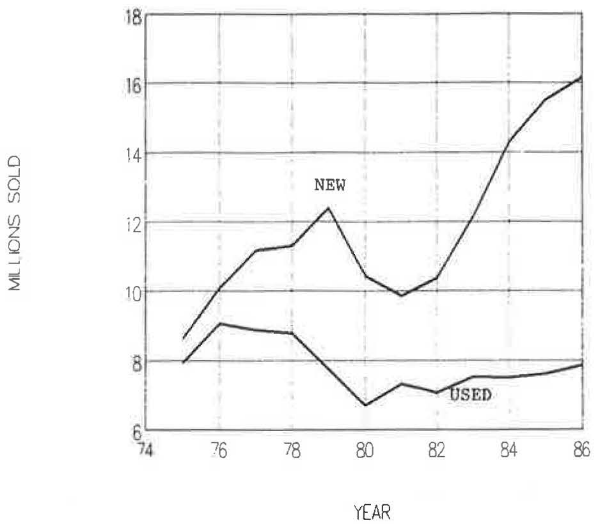

FIGURE 6 Trend in sales of new and used automobiles (*19, 20*).

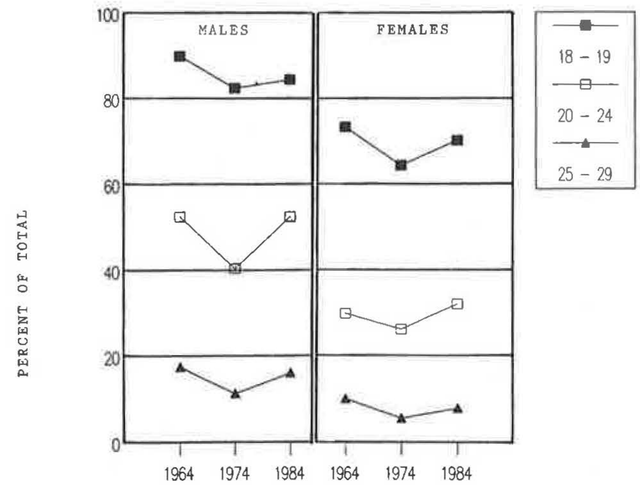

FIGURE 8 Young adults remaining in parental households (*10*).

tions of values related to household behavior for which data are available are the increasing number of never-married people, the returning young adult phenomenon, and the (apparently) increasing social value of the automobile.

There has been a significant increasing trend in the number of *unmarried people* (Figure 7). An important aspect of this trend is the implication of altered attitudes toward life (*9*). Specifically, unmarried people do not usually accumulate money while waiting to marry; instead, they develop a fully independent life and proceed with major purchases such as real estate and automobiles. Furthermore, they are relatively more active (i.e., frequent dining out) and more mobile (locally and regionally). This social phenomenon may result in an increasing demand for both automobiles and travel.

A growing American phenomenon is the pattern of "mature" children returning to the parental household after completing their education. Figure 8 provides evidence for this phenomenon: irrespective of gender and age group, the number of *returning young adults* (RYAs) has grown considerably between 1974 and 1984.

Schnaiberg and Goldenberg (*10*) believe that a strong cause of the RYA phenomenon may be the changing opportunity structure; an increasing number of children have problems meeting their parents' expectations and moving into adult roles. There is also more intense competition for career-entry positions. Even after entry into a career track, young adults find much less stability in career employment than in the past.

Figure 9 illustrates graphically that the RYA phenomenon tends to increase household automobile ownership. On the *y*-axis we have two scenarios: the single-household case in which the young adult stays at the parental nest (RYA) and the two-household case in which the young adult establishes his/her own independent household. The *x*-axis shows the number of cars potentially owned by all households in the scenarios. Rays from the origin show the loci of constant average household automobile ownership.

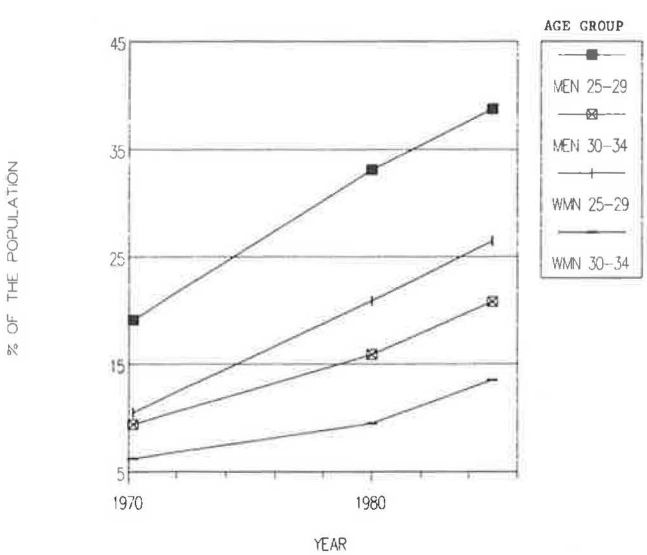

FIGURE 7 Unmarried people as a percentage of the population (*9, 18*).

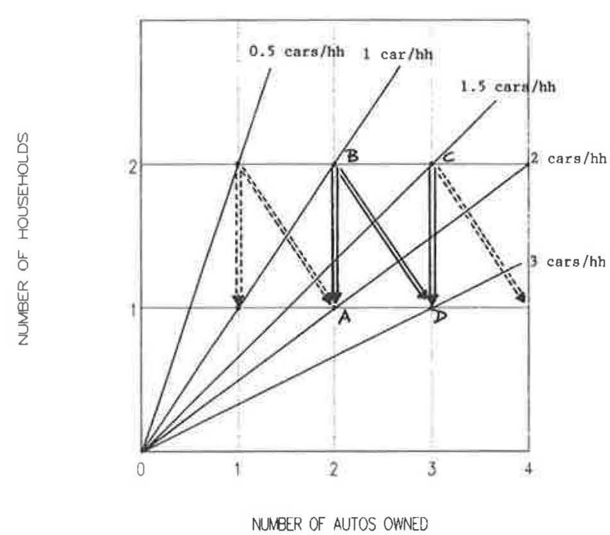

FIGURE 9 Effect of returning young adults on household automobile ownership.

If parents and a young adult live together in one household owning two cars, the average automobile ownership then is two cars per household (Point A in Figure 9). Should the young adult establish an independent household without acquiring an automobile, automobile ownership drops to one car per household, since the two cars are now divided over two households (Point B). If the young adult acquires a car, automobile ownership increases to 1.5 (Point C).

If the young adult returns to the parental household and no cars are added, automobile ownership increases (or returns) to 2.0 (Point A again). Adding a vehicle to sustain the travel needs of the RYA increases automobile ownership to 3.0 (Point D). Figure 9 suggests that, with or without the addition of more cars, the RYA phenomenon, shown as jumps from two to one household, can increase automobile ownership.

Figure 10 shows clearly that the trend is toward multiple automobile ownership (i.e., the top curve shows the rapidly increasing number of households owning at least one automobile). Most significant is the increase in households owning three or more automobiles. These data may suggest that the value of owning and using automobiles exceeds the value of the transportation produced. The automobile may be viewed as an office, a storage unit, a home away from home, a means and place of recreation, and a social instrument of increasing significance; people increasingly define themselves by the number and types of automobiles they own. As a result, automobile mobility may have social status value beyond that reflected in travel forecasting models.

Life-Style

Of particular interest to us is the life-style of suburban residents, especially residents of rapidly growing suburbs. There we notice a strong career orientation, a preference to more and rather distinctive automobiles, more outgoing attitudes, greater participation in exercise or athletic activities, a more active participation of children in various out-of-school activities (e.g., sports leagues and extra tutoring on computers), and a tendency for more comparative shopping in various suburban malls (*11–13*). Later in this paper we try to establish the case that the life-styles of residents of growing suburbs are different from the life-styles of residents of stable suburbs and the central city, which may help us understand one source of suburban congestion.

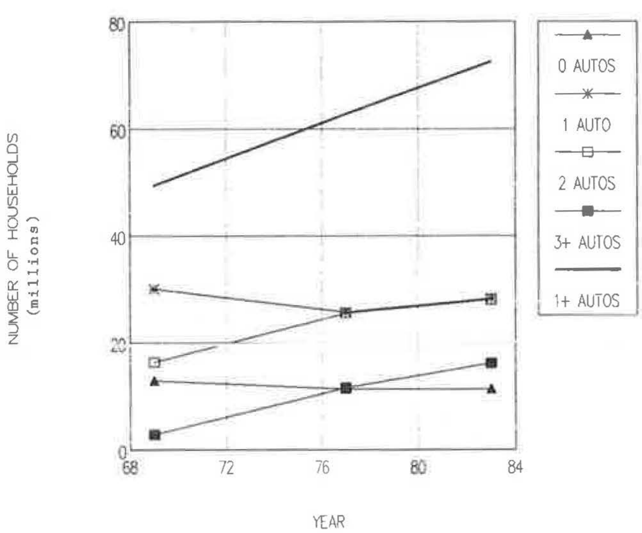

FIGURE 10 Trend toward multiple automobile ownership (*14*).

Availability and Cost of Activities

The more outgoing style of certain categories of people (i.e., the suburban middle class) has been captured by entrepreneurs. Businesses have responded and encouraged social needs and activities by offering more, diverse, and better goods, services, and prices. The mushrooming suburban malls, fitness centers, and food and entertainment facilities are examples of this trend. Suburbs are becoming satellite urban centers, which, as a result, increases the density (i.e., availability) of activities and reduces the distance (i.e., accessibility improves) from neighboring residences. Thus, the supply side of the activity market is supporting travel-increasing trends on the demand side.

Location Patterns

The exodus to the suburbs is a factor that needs no further proof. It started early and quietly by residents in the 1950s and earlier, was accelerated by retailers in the 1960s, and hit record levels when a broad spectrum of businesses followed since the 1970s. By 1980 58 percent of residents (49 percent in 1960) and 48 percent of jobs (32 percent in 1960) in urban areas were in the suburbs.

Technology

Two technological trends affecting transportation systems are important to this discussion. First, automobiles and automobile-related services have changed. The oil crises and competition from Japanese automobile makers led to highly fuel-efficient vehicles with reduced maintenance needs and many on-board amenities at very competitive prices. Furthermore, several industries responded by offering even more amenities or services to motorists: cellular phones, banking, food purchasing, express automobile care, and so on. As a result, automobiles became cheaper and more attractive overall.

A second significant change has been the introduction of telecommunication, computers, and automation into the retail, service, and entertainment industries. Telecommunication systems have helped businesses to create satellite operations or to relocate to suburban locations, where they typically find more floor and parking space at lower prices, resulting in increasing suburban employment.

Small, low-priced computers have made businesses less dependent on centralized locations and have facilitated retail automation, which has cut labor costs, permitting the use of low-skill labor and supporting both product differentiation and multisite businesses. The diversity of small retail and service businesses spread over the landscape, particularly in the suburbs, encourages a dispersed travel pattern for both comparative shopping and purchasing. Moreover, technology has enabled financial institutions and retailers to offer widely accepted credit accounts to millions of customers, further attracting them to a wide variety of shopping and entertainment activities.

Transportation System Characteristics and Policies

A major trend in the supply of transportation over the past decade has been greatly reduced spending on freeway infrastructure. Most of the urban freeway system planned in the 1950s currently is in place. At present, there are two critical problems regarding existing freeways. First, certain segments supply less capacity than needed for providing acceptable levels of service, and second, the orientation of the urban freeway system—aiming to serve commuting from the suburbs to the central city—is obsolete in the sense that the bulk of the demand currently is intersuburban (*14*).

Transit has not filled the gap because available technology cannot provide quality service in low-density markets at reasonable costs. Conventional transit gains efficiency through economies of density (i.e., more riders using the same vehicles in the same corridors); the increasingly suburban trip set is dispersed, omnidirectional, and distributed more uniformly over time. Worse yet, conventional transit must compete for space on congested streets with the automobile.

In addition, urban population has been shifting from places with the most public transportation to places with the least; this is true on both a macro and micro scale (*15*). Transit infrastructure and services have not been able to follow this trend in either scale. As a result, public transportation increasingly is not an option for urban residents.

Increasing highway congestion has led to the introduction of both market and policy incentives to get people to rideshare or vanpool instead of driving alone. Such measures have not reduced the share of the automobile mode to work, and there are indications that public transportation has become the loser because people who drive to work have invited colleagues who rode transit to benefit from ridesharing incentives.

DIFFERENCES BETWEEN CITIES AND SUBURBS

Do the macroscopic trends described above, and other factors, tell us anything about *suburban* congestion? To answer this question, we must determine the extent to which suburbs, or certain classes of suburbs, are substantially different from other parts of urban areas in socioeconomic and cultural characteristics.

Typically and historically, a suburb has been defined as an urban area where the ratio of employment to residents is below 1. That is, suburbs have been viewed primarily as places of *residence*. For example, in 1980 the employment-to-residents ratio for Manhattan was 2.50; for Washington, D.C., it was 2.00; for Fairfax County, Virginia, it was 0.54; and for the Midwestern suburbs in standard metropolitan statistical areas it was 0.86 (*16*). Because of the rapid growth of jobs in developing suburbs, however, this definition may no longer be valid; there are some developing suburbs with heavy concentrations of office malls and light manufacturing.

Such a simplistic, historically based definition of suburbs tends to homogenize the variety of suburban settlements. To develop a better understanding of variations in suburban demographics and economies, we might classify suburbs according to employment and residential density; employment and population growth rates; and/or other socioeconomic indicators, such as average income, household size, and so on. We propose a simpler and more practical classification in two categories: *stable* and *growing* suburbs.

Stable suburbs are largely fully developed, with little unused land and no, slow, or even negative growth. Typically, but not necessarily, they are attached geographically to the central city and have many commonalities with central city neighborhoods, especially in large metropolitan areas. These similarities may include density, household size and income, lifestyle, occupations, and so on. Stable suburbs usually are well connected to the central city by public transit. Urban highway networks were designed primarily to accommodate the commuting needs of nearby suburban residents who work in the central city. Thus, one would expect stable suburbs to be highly dependent on the central city (i.e., a large number of residents of stable suburbs work in the central city).

Growing suburbs may be defined as the portion of the suburban area that currently exhibits a substantial growth in both resident population and employment. We are particularly interested in growing suburbs because they seem to be the focal point for suburban congestion, perhaps in part because they are on the advancing wave of the kinds of the socioeconomic changes identified above. To test the notion that there are important transportation-related differences between growing suburbs and the rest of urban areas, we conducted an exploratory cluster analysis.

A cluster analysis is a statistical tool designed to identify homogeneous groups from a population by grouping population elements according to their similarity over a specified set of variables. The cluster items were 29 northwest suburbs of the Chicago metropolitan area, each with a population of 25,000 or more, as well as the city of Chicago. These suburbs were chosen to avoid strong cultural and economic dissimilarities among them. The socioeconomic and transport-related characteristics used as variables for clustering communities into groups were the following:

- Median population age,
- Percent of workers who work in the central city,
- Population density,
- Percent of workers commuting by car (solo drivers and carpoolers),
- Average number of persons per household,
- Average number of workers per household,
- Population growth index,
- Employment-to-residents ratio, and
- Median household income.

These variables include major socioeconomic, demographic, and transportation-specific measures, which were readily available. A major missing variable is the number of automobiles per household, which was not included in the 1980 Census of Transportation (community-level printouts). The life-cycle stage and life-style variables also are missing. Instead, surrogate variables such as household structure, income, education, and occupation are used. Finally, the distance to the central business district was excluded because it resulted in biased solutions by immediately separating suburbs in stable inner-ring suburbs and growing outer-ring suburbs.

A hierarchical cluster analysis generates 1 to $n - 1$ clusters, where n is the number of items to be clustered. The objective is to identify a few meaningful clusters containing highly similar items. A useful visual product of the cluster analysis is the dendrogram, in which items are grouped together according to the degree of similarity. The higher the similarity, the shorter the distance between clustered items. SPSS-X reports this in a dendrogram with a rescaled distance index between clustered items ranging from 0 to 25 (*17*).

Figure 11 shows the city of Chicago and the 29 suburbs of our sample. The shaded suburbs belong to the stable suburb cluster that resulted from the analysis. All suburbs in the data set, as well as Chicago, are listed in Table 1 in descending order with respect to their population growth between the two most recent censuses.

Figure 12 presents scatter plots of all the communities in our data set for each of the variables tested. The filled squares represent growing suburbs, whereas the empty ones represent stable suburbs as they resulted from the cluster analysis; the asterisk represents the city of Chicago.

Figure 12 indicates that larger households and a noticeably younger population reside in growing suburbs. Household income is lowest for households in Chicago, whereas there are no strong differences in household income between stable and growing suburbs, although the variance seems to be less for growing suburbs than for stable ones. Residential density appears to be a key differentiating measure. Typically, the density in growing suburbs is low, whereas stable suburbs are about twice as dense. A few stable suburbs and the central city are in another class, with densities well above 10,000 residents per square mile.

The dependency of the stable suburbs on the central city, reflected by the percent of residents working in the central city, is clear; a much smaller proportion of the residents of growing suburbs work in the central city. Nearly 50 percent of the central city residents *do not* work in the central city, which leads to a significant amount of reverse commuting. Finally, as expected, growing suburbs exhibit the lowest share of use of public transportation (and the highest use of private automobiles) for the work trip, whereas stable suburbs have a transit share that is twice as high.

More than a dozen alternative specifications (i.e., alternative sets of variables for grouping suburbs) were tested in the cluster analysis. The dendrogram described next was consistently the result from most of the specifications. Two major clusters of suburbs can be identified in Figure 13. The top area contains stable suburbs, whereas the bottom contains growing suburbs.

Evanston, Cicero, and Oak Park initially form a separate cluster, probably owing to the distinct low use of automobiles for the work trip; all are well served by rapid transit to the Chicago Loop. In later stages they are combined with the

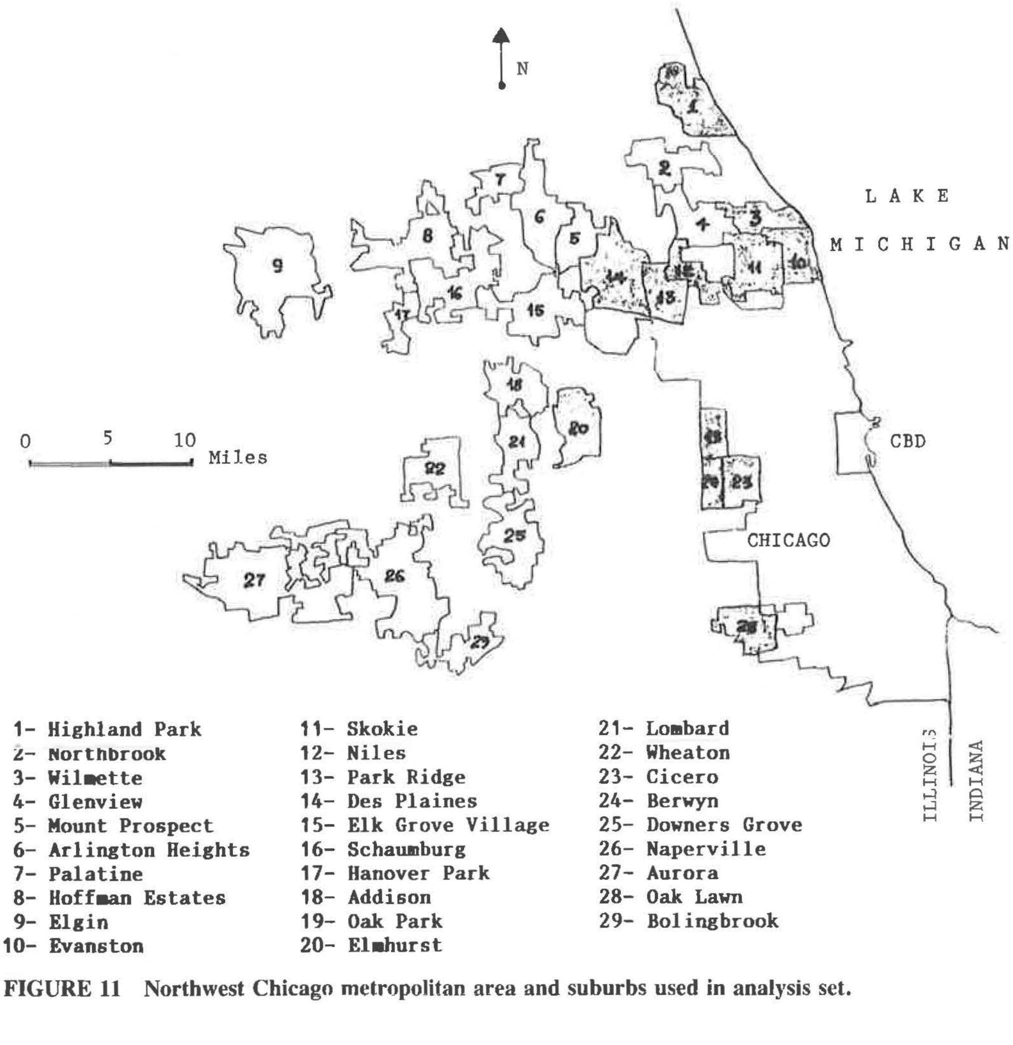

FIGURE 11 Northwest Chicago metropolitan area and suburbs used in analysis set.

TABLE 1 SELECTED CHICAGO METROPOLITAN AREA COMMUNITIES WITH A POPULATION OF 25,000 (IN 1980) OR MORE LISTED ACCORDING TO THEIR POPULATION GROWTH BETWEEN 1970 AND 1980 (*18*)

CHICAGO METRO AREA COMMUNITIES	POPULATION CHANGE (%) 1970-1980
BOLINGBROOK	387.0
SCHAUMBURG	187.7
HANOVER PARK	145.8
NAPERVILLE	85.7
HOFFMAN ESTATES	67.6
MOUNT PROSPECT	50.4
ELK GROVE VILLAGE	42.1
WHEATON	38.2
DOWNERS GROVE	30.8
GLENVIEW	28.9
PALATINE	23.5
ADDISON	21.6
NORTHBROOK	21.1
ELGIN	14.6
LOMBARD	9.6
AURORA	9.3
ARLINGTON HEIGHTS	1.6
OAK LAWN	0.5
NILES	-3.4
ELMHURST	-4.6
HIGHLAND PARK	-5.1
DES PLAINES	-6.4
EVANSTON	-8.0
CICERO	-8.7
PARK RIDGE	-9.2
BERWYN	-10.8
C H I C A G O	-10.8
SKOKIE	-11.8
WILMETTE	-12.2
OAK PARK	-12.2

stable suburb cluster. Interestingly, Chicago is placed in the cluster containing Evanston, Cicero, and Oak Park. The four communities were clustered together, resulting in a distance of 6 units. Eventually, the cluster containing Chicago, Evanston, Cicero, and Oak Park agglomerates with the cluster of other (nine) stable suburbs, but the distance increases to 12. All growing suburbs constitute a rather tight cluster; 15 out of 17 communities form a cluster with a distance equal to 8 (i.e., they are highly similar).

The two final clusters developed have properties that support our expectations. This outcome is consistent among all the specifications we tested. The results portrayed in this dendrogram support both hypotheses—that is, the central city is largely dissimilar to the suburbs, and the suburbs also split in two distinct clusters that we call stable and growing suburbs, respectively. Table 2 shows the resulting groups of suburbs, and Table 3 presents average values for the various characteristics for each cluster of suburbs and the central city. Large differences exist across all examined characteristics among the central city, the stable suburbs, and the growing suburbs. Seventeen growing suburbs had an average population growth rate of roughly 70 percent in 10 years. This figure becomes more significant when compared to the negative average growth of 12 stable suburbs and the central city.

Larger households and younger people reside in growing suburbs, earning incomes comparable to those earned in households in the stable suburbs. Furthermore, the standard deviation of median household income is smaller for growing suburbs compared to that for stable suburbs ($4,690 versus $6,192). This suggests that older, stable suburbs might further be classified into two categories: one with a majority of blue-collar and lower-income residents (e.g., Cicero, Berwyn) and the other with a majority of white-collar/managerial/professional residents (e.g., Wilmette, Highland Park).

The density of growing suburbs ranges between 2,000 and 4,000 residents per square mile, whereas the density for stable suburbs varies greatly between 3,000 and 12,000 residents per square mile. Growing suburbs demonstrate a much lower dependency on the central city, where only 17 percent of their residents are employed, whereas twice this number of residents of stable suburbs work in the central city.

Finally, the share of public transportation for the trip to work is very low in growing suburbs (8.7 percent) because of the lack of efficient transit services, the lesser number of people who work in the central city, and (perhaps) the distinct life-style that favors ownership and use of automobiles.

Thus, the cluster analysis reinforces our belief that growing suburbs differ from the stable ones and the central city. Differences in demographics, household structure and characteristics, and commuting patterns were observed, all of which suggest that differences in life-styles and in transport behavior are likely to exist.

It seems reasonable to argue that congestion in growing suburbs is related, at least in part, to fundamental differences between growing suburbs and other parts of metropolitan areas. While we need to examine these factors in much more detail to confirm this observation, it appears that treating the growth in suburban travel demand as merely the result of more people and jobs is insufficient. Understanding the effects of social and cultural variables is probably critical to the development of infrastructure, service, and policy responses if they are to produce lasting benefits.

CONCLUSIONS

Some of the potential causes of suburban congestion associated with the behavior of people are explored in this paper. We believe that a series of major demographic, social, economic, and cultural trends are leading to changes in people's transport behavior and that the most active locus of these changes is in rapidly developing suburbs. From our conceptual model of transport behavior, we conclude that factors such as household structure, location patterns, availability and cost of activities, personal or household income, life-style, social values and norms, technology, and transportation systems characteristics and policies have a potentially significant effect on people's transport behavior.

The first part of our analysis shows that several of these factors have changed in important ways over the past 10 to 20 years. We have experienced decreasing household size and aging of the population; increasing numbers of returning young adults and of never-married people; reorientation of industry from heavy manufacturing to services, entertainment, and high technology; widespread introduction of computers and telecommunications systems; and relocation and expansion of

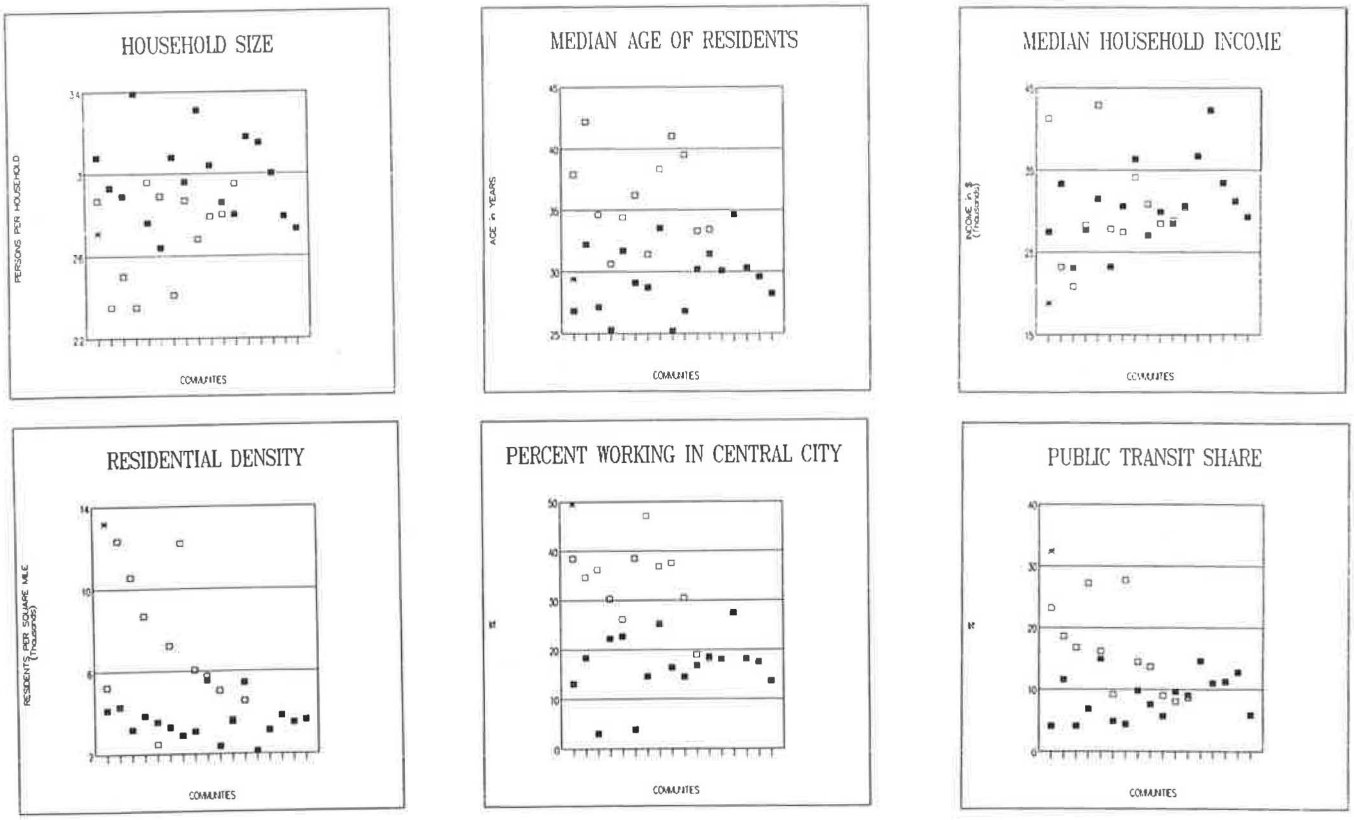

FIGURE 12 Distribution of communities with respect to socioeconomic and transport-related characteristics. (■) Growing suburbs, (□) stable suburbs, (*) city of Chicago.

```
          DENDROGRAM USING AVERAGE LINKAGE (BETWEEN GROUPS)

                              RESCALED DISTANCE CLUSTER COMBINE

                           0         5         10        15        20        25
       T O W N             +---------+---------+---------+---------+---------+

  1.  PARK RIDGE            -I
  2.  WILMETTE              -I-I
  3.  NILES                 -I I-I
  4.  SKOKIE                ---I I---------I
  5.  OAK LAWN              -----I         I-------I
  6.  DES PLAINES           -I---I         I       I
  7.  ELMHURST              -I   I---------I       I
  8.  HIGHLAND PARK         -----I                 I-------------------------I
  9.  CICERO                -----I-I               I                         I
 10.  OAK PARK              -----I I---I           I                         I
 11.  EVANSTON              -------I   I-----------I                         I
 12.  C H I C A G O         -----------I           I                         I
 13.  BERWYN                -----------------------I                         I
 14.  AURORA                -------I---------------I                         I
 15.  ELGIN                 -------I               I                         I
 16.  BOLINGBROOK           -I-----I               I                         I
 17.  HANOVER PARK          -I     I-------I       I-------------------------I
 18.  HOFFMAN ESTATES       ---I---I       I       I
 19.  NAPERVILLE            ---I           I       I
 20.  ADDISON               -I-------I     I       I
 21.  ELK GROVE VILLAGE     -I       I     I-------I
 22.  DOWNERS GROVE         ---I     I-I   I
 23.  WHEATON               ---I-I   I I   I
 24.  MOUNT PROSPECT        ---I I-I I I   I
 25.  SCHAUMBURG            -----I I-I I   I
 26.  ARLINGTON HEIGHTS     -I---I I   I---I
 27.  LOMBARD               -I   I-I   I
 28.  GLENVIEW              ---I-I     I
 29.  PALATINE              ---I       I
 30.  NORTHBROOK            -----------I
```

FIGURE 13 Distinct clusters of growing and stable suburbs.

TABLE 2 CLUSTERED SUBURBS

Stable Suburbs	*Growing Suburbs*
Evanston	Addison
Oak Park	Elk Grove Village
Des Planes	Hoffman Estates
Elmhurst	Bolingbrook
Highland Park	Hanover Park
Park Ridge	Mount Prospect
Skokie	Schaumburg
Niles	Glenview
Oak Lawn	Northbrook
Cicero	Downers Grove
Wilmette	Wheaton
Berwyn	Arlington Heights
	Lombard
	Palatine
	Naperville
	Aurora
	Elgin

TABLE 3 AVERAGE VALUES OF CHARACTERISTICS OF CLUSTERED URBAN SUBSETS

URBAN CLUSTER / CHARACTERISTICS	SUBURBS		CENTRAL CITY (CHICAGO)
	GROWING	STABLE	
Population Growth Rate	68.60	-7.70	-10.80
Household Size	2.98	2.70	2.71
Median Age (yrs)	29.50	36.10	29.40
Median Household Income ($)	30,696	30,361	18,774
Residential Density (res/sq.mi)	3,606	6,975	13,174
% Employed In Central City	16.70	32.80	49.50
% Using Public Transportation	8.70	16.10	32.40

residences, retailers, and businesses to the suburbs. A major center for these changes has been rapidly growing suburbs of large urban areas.

Cluster analysis was employed to identify whether growing suburbs are different from stable suburbs and the central city. The results suggest that larger families with young children and/or young adults tend to reside in growing suburbs. The presence of children as well as the younger population results in a relatively more active society, while high income relaxes the constraints on activity participation.

The growing suburbs we examined appear to form a relatively homogeneous group with a distinct life-style (as implied by surrogate variables and indices), fewer constraints, and plenty of opportunities. As a result, we expect that they display a rather "growing suburb-specific" transport behavior that involves the ownership of several automobiles as well as high values associated with owning and using automobiles as an element of their suburban life-style.

What we actually observe is the tip of an iceberg. The driving forces behind suburban congestion are the household structure and economics, which, along with the distinct suburban life-style, determine the needs, activities, preferences, and choices of suburban households and individuals. There will be no realistic solutions to the suburban congestion problem until the underlying fundamentals are fully explored and understood. To achieve this understanding we must conduct a disaggregate analysis. The results of the work presented here provide a strong incentive for such a study, which is already under way.

The outcomes of our understanding suburban transport behavior may be new approaches to transportation planning (i.e., different techniques for stable and growing areas), improved automobile ownership and trip generation models, ideas for land use planning (i.e., to attract particular types of residents or developments), and new perspectives on policy-sensitive characteristics of individuals and households, all of which may provide better tools for managing suburban congestion.

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Equilibrium Allocation Model of Urban Activity and Travel with Some Numerical Experiments

NORBERT OPPENHEIM

An equilibrium model of urban shopping activity allocation/travel distribution is developed, with endogenous travel costs and zonal prices of goods sold. At equilibrium, revenues in each zone balance the cost of operating zonal facilities supporting the activity. This cost is assumed to be a function of the level of activity (shopping trip ends), whereas zonal demands are a gravity-type function of the prices of goods and costs of travel. A simple "quasi-balancing" algorithm is used to illustrate the sensitivity of the equilibrium solution to values of the system's parameters. The resulting shopping activity/trip ends distributions are in conformance with standard location theory results. Also, when diseconomies of scale are present in activity supply, the equilibrium solution is always unique. Otherwise, discontinuities in trip ends and interzonal travel distributions may take place, depending on the magnitude of the zonal trip ends in the zones. Thus, the model is able to reproduce rich and complex spatial patterns of activity on the basis of the interaction of economic-type variables. In conclusion, further refinements are discussed.

The standard model of travel distribution Y_{ij} may be formulated as

$$Y_{ij} = R_i e_i \frac{X_j^\sigma \exp(\beta C_{ij})}{\Sigma_j X_j^\sigma \exp(\beta C_{ij})} \quad (1)$$

where R_i is the (given) level of residential population in zone i and e_i is the (given) residents' "propensity to travel" (i.e., the trip rate). C_{ij} is the cost of travel from zone i to zone j. Parameter β represents the marginal disutility of generalized cost of travel and parameter σ represents the sensitivity of the traveler to the zone's attractive attribute, X_j (e.g., shopping facility size in the case of shopping travel).

The model also may be interpreted as an activity location (land use) model. Consequently, a possible definition of equilibrium may be that zonal demands (i.e., number of trip ends) balance the cost of supplying the particular activity in a given zone. This latter quantity may be assumed to be a function of the size of zonal facilities, leading to the following equilibrium conditions:

$$Y_j = \Sigma_i \left[R_i e_i \frac{X_j^\sigma \exp(\beta C_{ij})}{\Sigma_j X_j^\sigma \exp(\beta C_{ij})} \right] = bX_j^m \qquad \text{for } j = 1, \ldots, n \quad (2)$$

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where the inverse of b represents the marginal cost of supporting one unit of activity (e.g., a trip end) and m is a parameter representing economies of scale in activity supply. [It is worthwhile noting that this equilibrium also corresponds to the maximum of a certain consumer surplus (*1*).]

In spite of the simple form of the model, the nonlinear nature of Equation 2 implies that the behavior of the solution will depend in a complex manner on the parameter values. Several authors have, in particular, investigated the possibility of discontinuities in the equilibrium distribution of activity/travel. For instance, Harris and Wilson (*2*) have shown that for values of σ less than 1, only one stable, "nonzero" equilibrium solution (i.e., one in which there is activity in each zone) will exist, and for values greater than 1, two will exist. When this parameter goes through this critical value, a discontinous "jump" in the value(s) of (at least) one zonal activity level(s) will result.

Furthermore, other potential discontinuous changes in the values of the X_i's may be induced by changes in the value of parameter b. In this case such discontinuous changes are qualitatively similar to the "fold catastrophe" (*3*). This similarity also was demonstrated formally in the simple case of a two-zone spatial system by Kaashoek and Vorst (*4*), who showed that for values of σ less than 1, the equilibrium depends continuously on σ. In addition, if the number of destination zones is larger than the number of origin zones, there cannot exist a nonzero stable equilibrium for $\sigma > 1$. Eilon et al. (*5*) have shown that there are several nonzero solutions when $\sigma = 1$. Rijk and Vorst (*6*) have shown that for $\sigma \neq 1$, there is always a nonzero equilibrium solution, and there are at least three when the number of zones is equal to two.

The above model thus has the ability to reproduce rather rich and complex spatial patterns of activity—most importantly, the type of discontinous change that has been observed in the recent past (*7*). Nevertheless, the formulation above presents a number of drawbacks. First, zonal attractiveness is represented only by the size of the zone's facilities. It is likely that, on the contrary, travelers will be at least as sensitive to the cost of conducting the activity in the destination zone (e.g., price of goods in the case of shopping). Perhaps an even more serious drawback is that because there is no relationship between the travel times C_{ij} and the interzonal trips Y_{ij}, congestion effects are not represented.

The purpose of the research reported in this paper was to refine the above model of activity allocation/travel distribution. In this case the model is applied to the case of commercial activity/shopping travel. The fundamental improvements consist of incorporating two endogenous cost variables: the zonal prices of goods sold, P_j, and the interzonal travel times, C_{ij}. The model's properties under this more realistic formulation then could be analyzed.

THE MODEL

It is now assumed that the endogenous zonal activity cost, P_j (here the price of goods sold in zone j), is a significant zonal attribute in the choice of destination (shopping) zone. Other relevant zonal attribute(s), X_j, are now assumed to be given exogenously. The demand for interzonal travel from zone i to zone j is then

$$Y_{ij} = R_i e_i \frac{X_j^{\sigma} P_j^{\varepsilon} \exp(\beta C_{ij})}{\Sigma_j X_j^{\sigma} P_j^{\varepsilon} \exp(\beta C_{ij})} \quad \text{for } j = 1, 2, \ldots, j, \ldots, n \qquad (3)$$

The value of parameter ε, which translates the travelers' sensitivity to the zonal price of goods, normally would be negative. Parameter σ, which represents the travelers' sensitivity to the zone's attractiveness, normally would be positive. Parameter β, which represents the travelers' marginal disutility of travel ("distance deterrence") is negative.

In addition, it is now assumed that the cost of supplying the activity in zone j is primarily a function of the level of trip ends, of the form kY_j^{ω}. The parameter ω translates economies of scale in this connection; k has the dimension of a cost per trip end.

Finally, the interzonal cost of travel C_{ij} is made a function of Y_{ij}, the interzonal level of (shopping) travel as specified above, through the standard "B.P.R." link performance function (*8*):

$$C_{ij} = C_{ij}^0\left[1 + a\left(\frac{Y_{ij} + Y_{ij}^0}{Cap_{ij}}\right)^b\right] \quad \text{for } i,j = 1,2,\ldots,n \qquad (4)$$

where a and b have the values of 0.15 and 4, respectively, for typical urban conditions. Cap_{ij} is the "practical capacity" [i.e., the volume at which link cost of travel—travel time—is 15 percent higher than the travel time at zero volume—that is, C_{ij}^0 ("free-flow travel time")]. Y_{ij}^0 is the fixed amount of interzonal travel corresponding to purposes other than shopping.

The condition for equilibrium is again that in each zone the revenue (i.e., trip ends times activity price) equals the cost of operating the facility:

$$P_j Y_j = kY_j^{\omega} \quad \text{for } j = 1, 2, \ldots, n \qquad (5)$$

MODEL PROPERTIES

This section summarizes the existence, uniqueness, and stability properties of the equilibrium activity and travel configurations produced by Models 3, 4, and 5. Details of the derivation of these results may be found in Oppenheim (*9*).

Existence

A nonlinear mathematical program may be devised, in which the necessary conditions are equivalent to the model. An optimal solution will always exist to this program.

Uniqueness and Stability

It is also possible to show that for values of ω greater than 1 (which imply economies of scale in zonal facility operating cost), the uniqueness of the solution values for Y_{ij} and the corresponding zonal prices and travel costs is guaranteed. In this case also, continuous changes in the values of the system's parameters should result in continuous changes in the equilibrium solution.

When $\omega < 1$ but $\varepsilon\ (\omega - 1) < 1$, this will remain true. However, when $\omega < 1$ but $\varepsilon\ (\omega - 1) > 1$, there may now be several equilibrium activity and travel states, depending on the value of the zonal trip ends. The equality $\varepsilon\ (\omega - 1) = 1$ thus defines a critical boundary whose passage may trigger discontinuities in trip ends distribution. (This effect is illustrated in the section below.)

Properties of the Solution

If the utility of a shopping zone is measured by

$$1 + \log Y_{ij} - \sigma \log X_j - \beta C_{ij} - \varepsilon \log P_j$$

then the allocation of shopping trip ends is such that no traveler can decrease the disutility of his/her choice of destination. In that sense the macroequilibrium (i.e., with respect to zonal facilities), which originally defined the allocation of trip ends, also implies a microequilibrium, (i.e., with respect to the users of the zonal facilities and the transportation network).

SIMULATION OF THE ACTIVITY AND TRAVEL SYSTEM BEHAVIOR

In order to get some insight into the nature of the model's output, the effect of changes in the values of key parameters on the equilibrium zonal distributions of activity prices and trip ends was investigated. A hypothetical, simple system of 16 square zones of equal size was used to that effect. The zonal distributions of population (R_i values) and zonal attractiveness (X_j) initially were assumed to be uniform in all 16 zones.

The simplifying assumption that there is only one link connecting any couple of zones was also made, so that the issue of route choice and network equilibrium did not intervene. The free-flow travel time between two given zones was assumed to be proportional to the distance between zone centroids. Intrazonal travel time for all zones was arbitrarily set at 10 percent of the highest interzonal time. The fixed travel flows Y_{ij}^0 for purposes other than shopping were the same on all links. Finally, the capacity of all links initially was assumed to be constant as well and approximately equal to the highest travel volume on the network's links.

A simple algorithm was used to provide illustrative solutions to the model. The algorithm essentially "recycles" successive values of the P_j's according to Equation 5a:

$$P_j = k(Y_j)^{\omega - 1} \qquad \text{for } j = 1, 2, \ldots, n \tag{5a}$$

Given initial values Y_0 and travel costs C_0, the first estimates P_1 are evaluated. Given those, the next values Y_1 are then estimated from Equation 3. Given those, the updated travel costs C_1 are estimated from Equation 4, and the process is iterated until convergence. It may be shown that if

$$-1 < \varepsilon(1 - \omega) < 1$$

the above algorithm will converge. A more detailed discussion of convergence issues and their connection with solution uniqueness may be found in Oppenheim (*9*).

Effect of Travelers' Sensitivity to Travel Cost

β, the distance deterrence parameter, was first varied in the range from 0 to -1 for a large combination of (fixed) values of ε and ω. The results are represented in Figures 1 and 2.

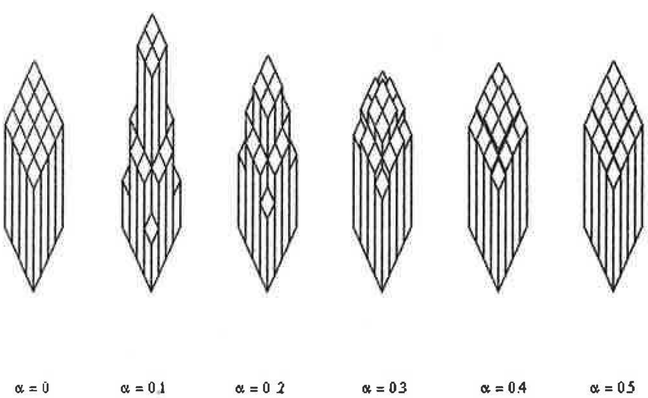

FIGURE 1 Sensitivity of trip ends distribution to changes in travel cost deterrence level.

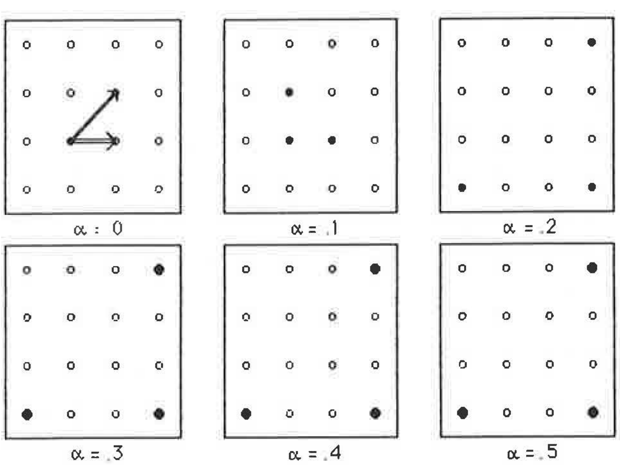

FIGURE 2 Sensitivity of origin-destination pattern to changes in travel cost deterrence level.

They may be explained in the following manner. (In all figures representing interzonal travel flows, the thickness of the arrow is log-proportional to the magnitude of the flow. A circle represents intrazonal travel, with the same meaning concerning the thickness of the diameter.) At either end of the range of values above, the effect of travel cost is negligible. When $\beta = 0$, travel cost is very low. When $\beta = 1$, it is very high so that only intrazonal travel (the cost of which is the same in all zones) is taking place. In both cases each zone should then share equally in the area's total activity, because zones are not differentiated with respect to any of the other intervening factors. Consequently, the distribution of shopping trip ends and prices should be uniform.

As the sensitivity of travelers to distance increases, all other things remaining the same, the spatial distribution of prices and trip ends becomes more concentrated at the center. The distribution of zonal prices, however, is affected differently, depending on the value of ω. For $\omega < 1$, it also becomes more peaked in the center, because the travelers incur a higher activity price as a result of less efficient economies of scale in activity supply (owing to a more uniform zonal distribution of trip ends). Conversely, for $\omega > 1$, the distribution of zonal prices dips in the center. These variations clearly illustrate the compensatory relationship between the travelers' activity and travel costs.

Also, the mean trip length (MTL) decreases monotonically as α decreases from its maximum at $\beta = 0$ (no-cost travel).

Effect of Sensitivity to Activity Price

Next, parameter ε, which represents a traveler's sensitivity to activity price, was varied in the range from 0 to -4, with a value of ω set at 0.6. The effects on the zonal distribution of trip ends are shown on Figure 3. It can be seen that as the activity price becomes increasingly important in the choice of destination zone, trip ends become more and more concentrated in the area's center. Conversely, when price becomes less important, the distribution of trip ends tends to become uniform.

This is due to the fact that at one end of the range, when activity price is all important, the concentration of all activity in a single zone minimizes prices through (positive) supply economies of scale. This is, in turn, a necessary response of zonal facility operators to travelers' increasing sensitivity to price. However, as travelers become less and less willing to

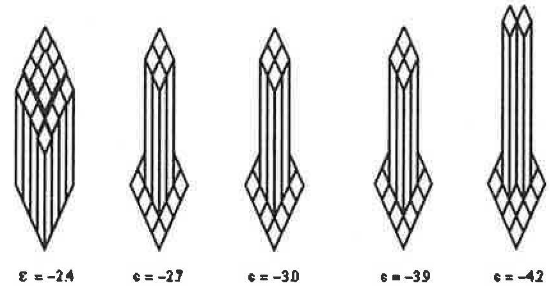

FIGURE 3 Changes in spatial structure of trip ends for changes in travelers' sensitivity to activity price.

pay high prices in nearby zones, they must travel increasingly longer distances.

At the other end, when price is not a factor ($\varepsilon = 0$) and when interzonal travel time does not intervene (e.g., for a sufficiently large value of α so that intrazonal travel, which has a constant cost, is the dominant form of travel), all zones should have the same share of the total trip ends, since a choice of destination is based on factors (i.e., zonal attractiveness and intrazonal travel) that are equal for all zones.

The passage through the critical surface $\varepsilon(\omega - 1) = 1$ identified above occurs when ε goes through the value $1/(\omega - 1) = 1/0.75 = 1.33$. The corresponding sudden change in the nature of the spatial distribution may be considered a discontinuity (*7*).

As shown in Figure 4, the spatial pattern of interzonal travel also goes through two major changes—from intrazonal travel concentrated on the periphery to intrazonal travel concentrated in the inner area and then to travel mainly from the periphery to the center. In this case, a sudden change from a predominantly intrazonal to an interzonal travel pattern takes place. Also, it is worthwhile noting that the MTL increases monotonically with a decreasing ε but does not reflect this discontinuity.

Other experiments, not represented here, confirm the expectation that in the case of negative economies of scale in activity supply (i.e., $\omega > 0$), increasing sensitivity to price implies uniformization of trip ends distribution as a mechanism for minimizing operational costs.

Variations in Economy of Scale for Zonal Activity Supply

Parameter ω next was varied in the range from 0.1 to 1.9 (the value of ε was set at -1.8). The results are represented in Figure 5. As expected from the discussion above, as economies of scale diminish (i.e., ω increases continuously), the spatial distribution of trip ends becomes uniform, although significantly more slowly after ω goes over the value 1.

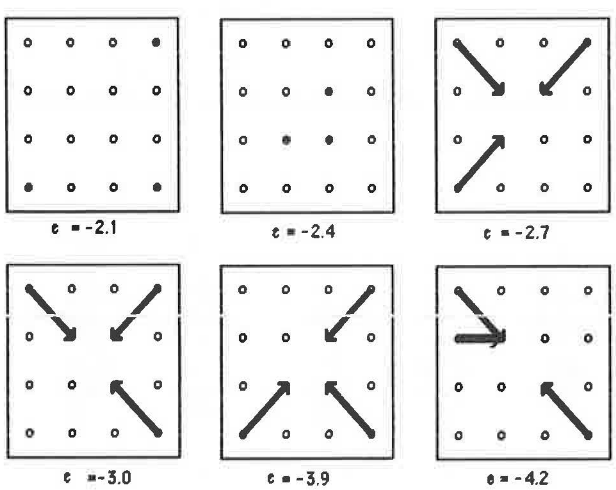

FIGURE 4 Changes in spatial structure of interzonal travel for changes in travelers' sensitivity to activity price.

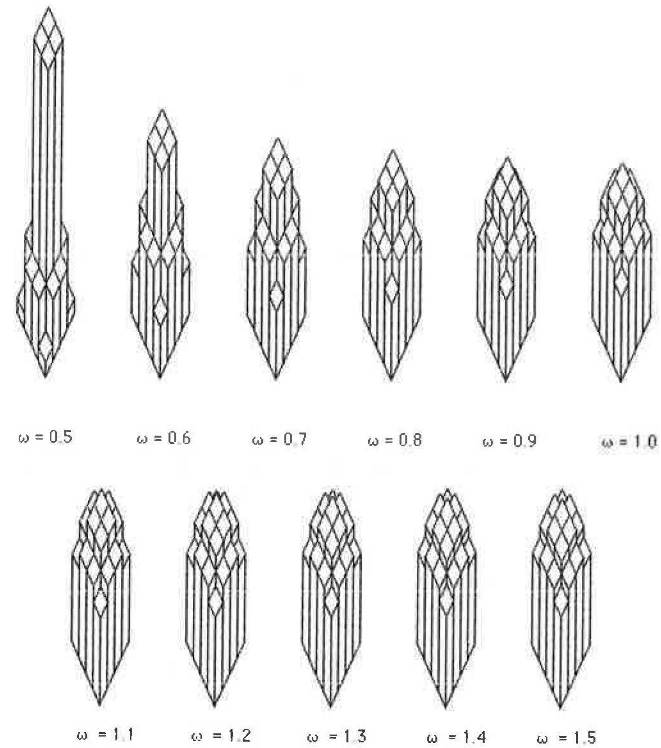

FIGURE 5 Changes in spatial structure of trip ends as a function of activity suppliers' economies of scale.

SUMMARY AND CONCLUSIONS

A one-way production-constrained model of equilibrium trip ends distribution with endogenous zonal prices and costs of travel was developed. A simple algorithm of the "quasi-balancing factor" type was used to investigate the sensitivity of equilibrium activity configurations to changes in the values of the system's parameters. The results are in general agreement with classical location theory concepts. Discontinuities were identified corresponding to critical parameter values.

The model thus is able to reproduce rich and complex spatial patterns of activity/travel on the basis of the interaction of economic-type variables. The potentiality for the occurrence of discontinuities in the model's output as a result of continuous variations in its parameter values suggests that precise parameter identification is critical for this type of model.

Because of its basic simplicity, the model lends itself to several possible extensions. First, the simplifying assumption of a single route from a given origin to a given destination might be relaxed to allow for a more accurate representation of the effects of network congestion on the joint activity/travel equilibrium. This may easily be achieved by introducing another level of spatial choice—that of the travel route—in a "nested" logit formulation. (The demand function is not strictly of the logit type in the present formulation but can easily be made of that type by changing P_i to $\ln P_{i\cdot}$.) Also, the zonal trip production rates (e_i in the model), instead of being fixed, might be determined endogenously—for instance, as a function of the activity prices and/or travel costs.

Finally, the extension of the above framework to multiple activity systems would provide new insights, into comprehensive land use/travel interactions.

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Role and Function of Transit in Growth Management: Current Issues in Florida

CRAIG MILLER, DOUG COOMER, AND RICK JAMESON

This paper explores how transit influences, or fails to influence, growth in Florida and looks at ways to improve the role of transit planning in the growth management process. Needless to say, growth management is a significant concern in Florida. The issues discussed are presented in the context of the Florida experience. The transferability of this work is limited to the extent that some of the issues may not be relevant in areas where growth is not occurring. However, it is hoped that many will find the material instructive and helpful.

Growth management is a significant concern in Florida. Therefore, the purpose of this paper is to explore how transit influences, or fails to influence, growth in Florida and to look at ways to improve the role of transit planning in the growth management process.

Some of the suggestions in the paper are not necessarily new or innovative, and some of the issues discussed may be useful to certain policy makers while others may not be. For some, who have been very close to the transit planning and growth management business, perhaps part of this discussion will be fairly obvious. Hopefully, other items may be of interest. At any rate, in that many policy makers still appear to be confused about what can and cannot be done to control growth effectively, we maintain that the material covered in this paper is fair game, and we hope that many will find the material instructive and helpful.

GROWTH MANAGEMENT COMPONENTS

Growth management means different things to different people. This is one of the issues that was tackled by the research efforts of the authors. Two basic categories of growth management exist. One category may be termed a "land use planning" category. Land use planning, when properly linked to zoning, provides one of the most, if not *the* most, effective types of growth management. This activity set can control two key decisions effectively: the type of land use permitted in an area and the maximum intensity or density of that land use.

A second category of growth management might be called the "development decision" category. This category of growth is market driven, for the most part, and is difficult to control from the public sector. Development decisions revolve around what properties to develop and when they should be developed.

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Naturally, these decisions are driven by a variety of market forces. These forces include (a) the retail value of raw land, (b) the market demand for various development products, (c) the labor and material costs required to deliver a product, and (d) the regulatory costs required to prepare the land for development. The public sector enters the game by creating regulatory pricing strategies.

TRANSIT ROLE

One of the primary issues addressed in the research is "What role should transit play in this game?" The term "game" is used here in the "systems theory" context, not in the sense that this is a trivial matter.

The first category of growth management mentioned was the land use planning category. The formulation of transit policy and plans historically has not been viewed as an essential input into the land use planning process in Florida. There are one or two notable exceptions, which will be mentioned later. Compared to the older industrialized cities to our north, Florida cities are young. They grew up around the highway and around the automobile, normally occupied by a mysterious one-and-one-third persons. Old, entrenched transit usage behaviors are not among our more notable characteristics. Compact, high-density land use corridors are not found in Florida. In a word, the behavior and the land use patterns in Florida are not conducive to high transit patronage.

These, of course, are two significant strikes against the idea of doing something highly significant in the transit business in Florida. A transit market must be created alongside a transit system for it to be successful in Florida. The following is a discussion of how this ties in with the state's growth management goals.

IMPORTANT DISTINCTIONS AMONG TRANSIT SYSTEMS

One of the issues addressed in the research concerned the distinction between capital-intensive, fixed-guideway transit and labor-intensive, over-the-road transit services. The distinction between these two categories is essential for the purpose of analyzing the effectiveness of transit in growth management. The need for this distinction is obvious; nevertheless, there appears to be some confusion or blurring of this issue by some policy makers. The error that we see made is simply this. Some policy makers seem to suggest that transit, in all its forms, can have an effect on growth in the same way that highways influence growth. To most professionals this is obviously an untrue hypothesis. Based on our experience, it is less obvious to some policy makers.

Without belaboring the obvious, let it suffice to say that over-the-road transit services are services and not infrastructure. As such, they do not play the same role as highway, pipeline, or other infrastructure. These services, likewise, do not play the same essential role in relation to land development as do infrastructure investments.

Secondly, fixed-guideway transit assets do qualify as infrastructure in the traditional sense. They therefore exert influence on land use policy and on development decisions. This is accomplished in some of the same ways that other infrastructure systems influence development.

This presents a bit of a problem:

- The category of transit that has the most influence on land use and development decisions is also the most costly.
- The more costly the transit system, the less likely it is to be implemented.
- The less likely it is to be implemented, the less likely it is to influence growth.

The upshot of this is that a solid financial plan is essential if transit is going to make a serious mark in growth management.

IMPORTANCE OF FINANCIAL PLANNING

To Florida's credit, the state has passed new comprehensive planning legislation containing "concurrency provisions." These new laws mandate that realistic financial plans and policies be developed in concert with land use and infrastructure plans. This has contributed a much-needed touch of realism into the planning process (along with some significant consternation on the part of many local officials).

The worst thing we can do is to plan a capital-intensive transit system, modify land use accordingly, and then implement the land use and not the transit system. Adequate financing is one of the keys to effective use of transit as a growth management tool. The most effective action that can be taken at the state policy planning level is to adopt policies that enhance the revenue stream for transit. If a reliable and predictable revenue stream can be found, then debt financing can be used to support a significant near-term capital project.

One possible suggestion could be a system of special benefit districts tied to planned rail system stations. Land use and permitting concessions could create a win-win scenario, where the landowner could profit while the state would receive the assessment revenue from the transportation districts. The special assessment revenue could be used to float a bond to finance the construction of all or part of the rail line and its stations.

If the land use and permitting concessions are significant, it is possible that private collateral and private capital also could be brought to the table to assist the project. Joint development of stations also could produce significant revenue streams for the public agency through ground leases or through other joint development partnership devices.

In short, the land development game, in fast growing areas, is a powerful economic force. If harnessed properly, cooperative public-private partnerships could lead to significant improvements in transit. Needless to say, the leveraging power of all of these techniques is much greater when the land in question is undeveloped and zoned at low intensities.

HIGHLIGHTS OF CASE STUDIES

The Metrorail and Metromover systems in Miami have had some effects on growth patterns. Metro Dade County has upzoned areas around stations and has created incentives for cost-effective development products at these sites. At the Government Center Station, land values soared from $35 per square foot in 1980 to $112 in 1984, when the system opened. In addition, the county has put together some attractive joint development deals that are netting substantial revenue yields. In addition, the Metromover system has been financed, in part, by special benefit districts.

Viewed together, Dade County's transit policies, financing policies, and land use policies are achieving mutual goals in the public and private sectors simultaneously and in an integrated and planned manner. Naturally, Miami's healthy economy and growth play an important role in this success formula.

A second project is the Florida High Speed Rail Program. This is a private franchise transit development project sponsored by the Florida High Speed Rail Commission. The state has solicited competitive proposals from consortia that are interested in privately financing, building, and operating a high-speed rail line from Miami to Orlando to Tampa. In return, the successful franchisee can receive certain land use and permitting concessions in order to create development projects connected to the system. The profits from the land development venture are to be used to build the system, to cover any operating deficit, and to provide financial rewards to the investors who are willing to risk their capital in the project.

At the time of this writing, two firms remain in the running for the project: the TGV Company and the Florida High Speed Rail Corporation. As consultants to the Florida High Speed Rail Corporation, the authors are more familiar with the Florida High Speed Rail Corporation franchise proposal. The following are some highlights of that proposal.

The Florida High Speed Rail Corporation is led by a large, prestigious Florida land developer. This is significant, because the engine that drives the High Speed Rail is land development and not a locomotive. The Florida High Speed Rail Corporation proposal calls for a full system from Miami to Orlando to Tampa costing a little over $2 billion. Electric trains will operate at over 150 mph along the route, carrying over 2.5 million passengers beginning in 1995. This proposal spells out a real estate program and a market-driven package of debt financing that will fund the system with private sector dollars.

More than many other projects, this joint public-private partnership is one of the best examples of integrating the desired relationships between land development, transit financing, and fixed-guideway transit development. If successful, this could become a model for a variety of fixed-guideway systems throughout the free world.

The following section contains additional case studies for those readers interested in reviewing this issue in greater detail.

ADDITIONAL CASE STUDIES

BART Case Study

To view transit's role in influencing growth more closely, consider the Bay Area Rapid Transit (BART) System serving the San Francisco, Berkeley, and Oakland area. The 71-mile system includes 20 miles of subway, 24 miles of elevated structures, and 27 miles of ground level service. There are 34 stations, and approximately 150,000 to 200,000 one-way trips are made each day. The system was opened in five stages between 1972 and 1974. Planning for BART began in the 1950s. A map of the system is included in Figure 1.

Within a number of cities served by BART, the system has been both a direct and indirect cause of a shift in new development in station areas. For example, in downtown San Francisco over 90 percent of the 22.5 million square feet of office space built since 1965 is within 1,500 feet of the four downtown BART stations. Two events primarily attributed to BART, a $35 million Market Street Development Project and new zoning codes adopted by the city, have contributed to the redirection of growth.

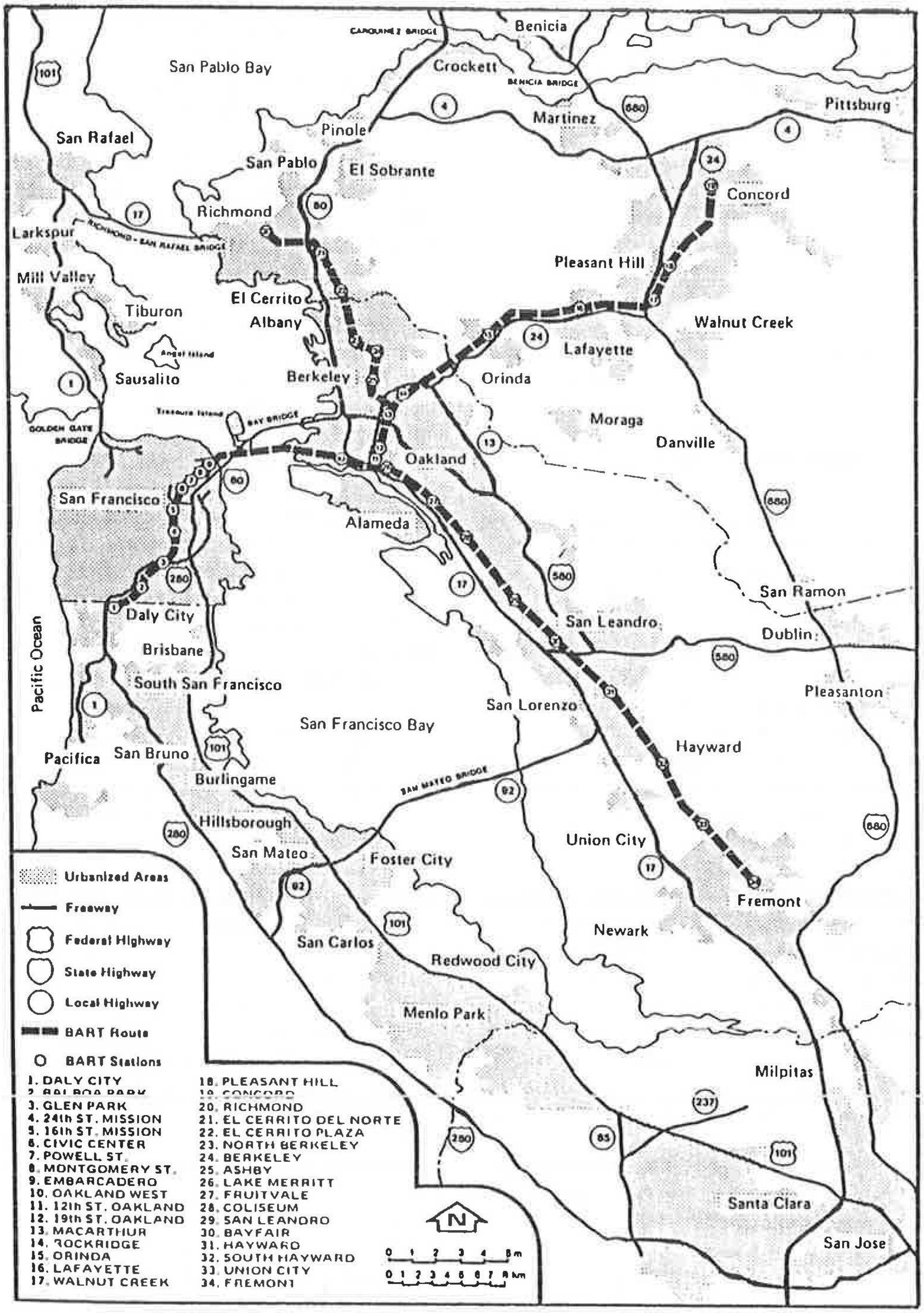


FIGURE 1 BART and Bay area system.

Office construction in BART station areas also has increased in the cities of Oakland, Berkeley, and Richmond. The total amounts of new office space in these cities have been much smaller than that added in San Francisco. About 2 million square feet of major new office space has been added in downtown Oakland since 1965. About 1.5 million was built within 1,500 feet of the two downtown Oakland stations, and BART was one factor that influenced the location of 80 percent of this new space. Another major influence was the City Center redevelopment project, which is located at the site of BART's 12th Street Station. Zoning regulations generally have encouraged commercial development around the downtown BART stations.

BART's influence on housing construction has been less pronounced than its influence on office construction. No high-density nodes of residential development have occurred around the BART stations. This is due, in part, to public policy decisions. Nine residential or mixed residential and commercial areas around BART stations were downzoned in response to residents' wishes to preserve the existing character of the neighborhoods.

Property price gains attributable to BART have been small to date. The program's findings do not support the theory that a rapid transit system is likely to cause large increases in the price of properties near its facilities that could be taxed to help pay for the system. BART's effects in this regard have been too small to be a useful source of financing for the system. However, it should be recognized that BART has no entrepreneurial authority that would permit it to exploit the potential it creates.

BART's influence on people's choices of residence, work place, and shopping locations suggests that its most significant impacts on land use and urban development may occur in the future. If BART continues to influence behavior patterns, some redistribution of homes, work places, and shops is likely to result. Moreover, BART's relative attractiveness as a transportation mode can be expected to grow as its service and reliability improve and as the highways, particularly the bridges into San Francisco, become more congested. BART is then likely to become more important in the location decisions of both individuals and businesses. Finally, large-scale land use changes tend to occur slowly. Therefore, it may be too soon to expect substantial land use impacts as a result of BART.

A large portion of the development attributed to BART occurred in areas conducive to development. In addition to BART's influence on growth, growth probably could not have occurred to the extent it did without new zoning codes. BART illustrates that fixed-guideway transit can play a role in growth management, but transit's influence is controlled by the development environment. Transit-influenced development will occur in areas conducive to development, but transit may have little or no influence on development in areas that are not conducive to development (such as the Oakland Station). In summary, BART illustrates that transit can play a role in growth management when the right environment exists (*1*, pp. 106–110).

Cause-and-Effect Relationships of Transit and Land Use

Since fixed-guideway transit requires a high level of capital investment and is therefore capital intensive, its impact on the location and timing of new development is very significant. When developers see that the government is willing to invest millions of dollars in transit to build stations at predetermined locations, they are willing to develop along the corridor and around the stations. High investment for rail transit shows a permanent commitment by the government. Developers know that with major funds supporting transit, a transit system is likely to be implemented, and development can occur profitably. However, with bus and paratransit, there really is a much smaller capital investment. These forms of transit are labor intensive. The government can provide a bus line from Point A to Point B, but it can also cancel that service in 6 months. Because the investment is not fixed, the government later can choose to neglect servicing the area. Thus, labor-intensive forms of transit will not influence development significantly. In these cases there is a relatively small (if any) influence on development. Table 1 illustrates the levels of influence on development by various forms of transit.

As illustrated in the table, transit tactics with the greatest potential influence on development have the lowest probability of implementation. Therefore, if the goal is to take advantage of transit options with the greatest potential for influencing growth, investments to finance high-capital transit options must be found. Basically, there are two options: private funding or increased government funding. But even with sufficient funding, a risk exists. Although commitment to high-level transit may result in a commitment by developers, relatively few developers (the Green Companies in Miami are an example) will risk major up-front investments until sufficient ridership is demonstrated. For example, on the Metrorail system in Miami, initial development did not occur until after construction began, and intense development is not anticipated until higher ridership levels are established. A case study of the Miami Metrorail and Metromover systems follow.

Dade County Metrorail and Metromover Case Study

Metrorail operates in Metro Dade County and currently serves approximately 25,000 to 30,000 passengers daily. The 21-mile Stage I system has 20 stations. Planning for Metrorail began in 1964, and the first stage of the system, costing almost $1 billion, opened in 1984. Figure 2 illustrates the system. Miami's Metrorail system influences growth by shaping development along its high-density corridor. Dade County, through the Metro Dade Transportation Administration (MDTA), acquired more than $80 million worth of real property along the system alignment.

The Metrorail system has, in fact, influenced growth along its alignment, particularly at south end and downtown stations. The type of growth and the extent of growth also were affected by land use plans and zoning policies. The Metro Dade County Comprehensive Development Master Plan (CDMP) provided a general policy framework for the implementation of development projects in conjunction with the Metrorail system. The CDMP sought to initiate high-intensity growth centers near transit stations using joint-use development as much as possible.

Initial development along Metrorail ranged from high-tech "Futureworks" development downtown to the Green Datran Center, consisting of three office towers at the Dadeland South

TABLE 1 INFLUENCE ON DEVELOPMENT BY TRANSIT TYPE

Investment Levels	Transit Investment Types	Level of Investment	Effect on Location and Timing of New Development	Probability of Funding & Implementation
Capital Intensive Investment	High Speed Inter-City	Very High	Very Significant Influence	Very Low
	Heavy Rail/Grade Separated Conventional Rail/Light Rail	Very High	Very Significant Influence	Low
	Grade Separated Busways	High	Significant to Low Influence	Low
	Surface Light Rail	Medium	Significant Influence	Fair
	HOV Lanes/ At-Grade Busways	Medium	Low Influence	Fair
Labor-Intensive Investment	Bus	Low	Very Low Influence	Good
	Para-Transit	Low	Little known Documentation of Influence Created by Para-Transit Investment, but Probably Very Low	Good

Source: Kimley-Horn and Associates

Station, which is the terminal station for the south line. These developments were not launched until the Metrorail system was under construction and implementation of the system was assured.

In addition to Metrorail, Metromover (a 1.9-mile downtown people mover that interfaces with the 21-mile Metrorail system and serves approximately 10,000 passengers daily) also had an impact on development; opened in the spring of 1986, the people-mover system provides convenient service to the high-rise office core along Biscayne Bay. A map of the system is shown in Figure 3. The influence of the Metromover on the increased commercial development can be seen along its service area. The Downtown Development Authority (DDA) established a special assessment program to require property owners to help finance the Metromover. Political and business leaders want to spend an additional $240 million to extend Metromover 2.4 miles to the north and south edges of downtown Miami. The project has received powerful backing from the Metro Commission, the Greater Miami Chamber of Commerce, and business people who own property close to the proposed legs. The commission will vote to create a special tax on property to help raise revenue to pay for the extension. Metromover can be viewed as a tool in the revitalization of downtown Miami. The Metromover is, according to Maurice Ferre, a former Miami mayor and supporter of Metromover, "a quantum leap into . . . the future of Miami."

The county expects to entertain numerous requests from private businesses to provide commercial development and transit-related services on Metrorail and Metromover property and around stations. Now that Metrorail and Metromover are on-line, developers anticipate that Miami's business district will double in size over the next decade. By the year 2000, developers estimate that nearly 25 million square feet of new development will be built around Metrorail's 20 stations and the proposed legs of the Metromover extensions. Dade County planners also anticipate that employment in the downtown area served by Metrorail/Metromover will increase from 109,650 in 1985 to 156,000 in the year 2000.

Dade County's fixed-guideway transit system creates the needed traffic, according to the Green Companies, a Miami developer, and the county's rezoning of the station areas allows developers to build to the desired density. Also, the county used incentives to facilitate development. At the Dadeland South Datran Center site, the county and the developer, Green Companies, established a partnership: in exchange for leasing the station site to the developer, the county will get 4 percent of the gross revenues ($1 million in 10 years).

Moreover, instead of waiting for builders to show interest

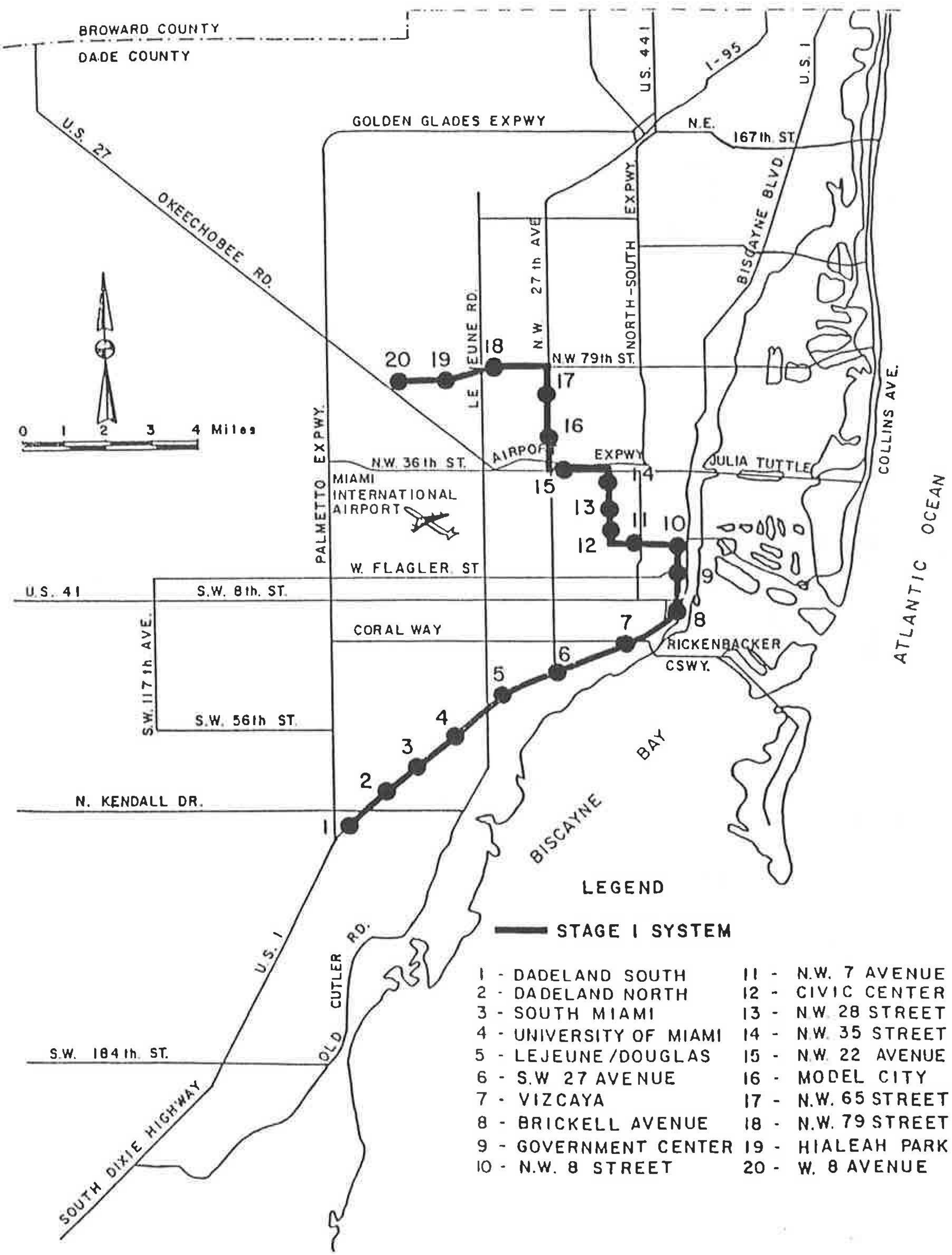


FIGURE 2 Metrorail system, Dade County.

by purchasing land, Dade County initiated development by assembling parcels and offering the private sector incentives to build on them. Before construction started, undeveloped land at Government Center sold for approximately $35 per square foot in 1980. After construction of the Metrorail system, land value soared to $112 per square foot when the station opened in 1984. According to a knowledgeable Dade County commercial real estate broker and developer, land values in the general area away from the Government Center Station ranged from $35 to $50 per square foot. These values have remained approximately the same from 1984 through 1986 owing to low inflation rates and an overbuilt office space inventory in the Miami area. Joint-use development and upzoning policies coupled with special benefit district assess-

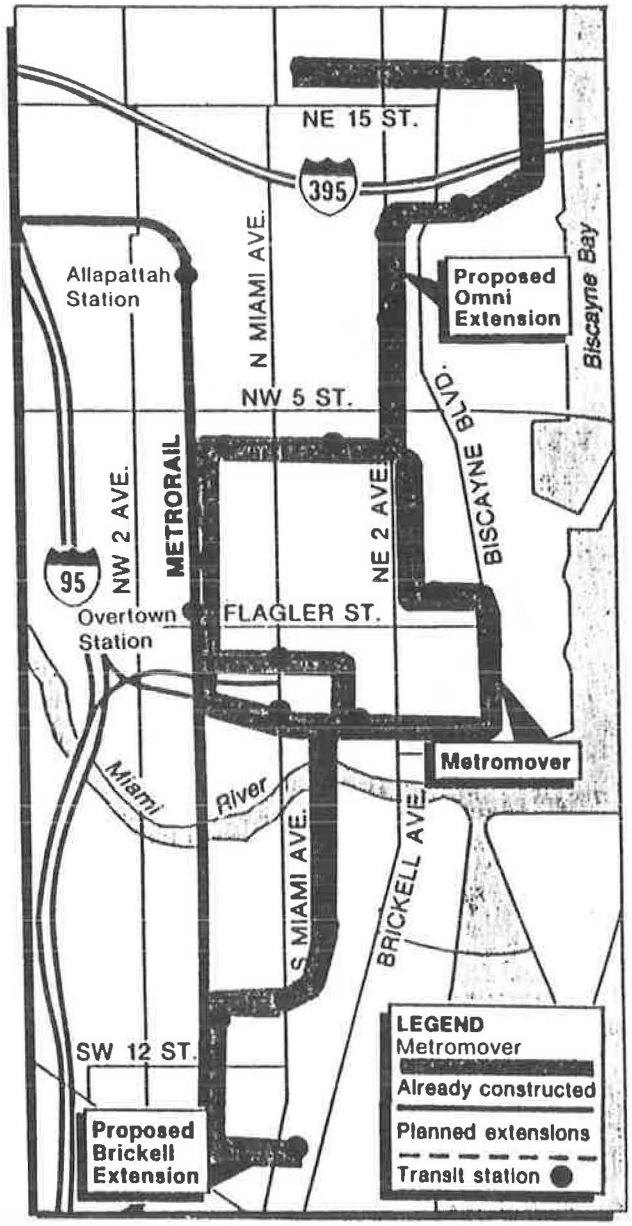


FIGURE 3 Metrorail and Metromover.

ments appear to be one of the keys to financing transit and, ultimately, to managing growth in Dade County.

Optimistic early plans have slowed since ridership has not yet reached anticipated levels. However, it appears that planning, development, and growth around Metrorail stations in Miami are further along than other systems (BART, Washington Metropolitan Area Transit Authority, Metropolitan Atlanta Rapid Transit Authority) at the same point in time.

The Metrorail and Metromover systems further illustrate that a development-oriented environment is necessary for transit to play an effective role in growth management. Land values around some stations increased, whereas values around others did not. The value of key stations often depends on feeder stations on the fringes of the system. Peripheral stations contribute to the value of key stations, because peripheral stations serve as collectors for the main lines. However, these outer stations may not influence development in the surrounding area. Residential development and overall growth will hinge more on demographics than on fixed-guideway transit. It is important to emphasize that collector stations do contribute to development and growth around other stations in development-oriented environments (*2*).

Effect of Latent Demand

Latent demand means that demand for transit travel, which is currently not being served, would increase if a reasonable level of transit service were provided. The influence of transit on land use in developed areas typically is small in Florida and elsewhere where buses and other vehicles provide the bulk of mass-transit service.

Over the past several decades, with the increase of automobile availability and usage, bus transit has declined to the point that most ridership is composed of transit-dependent patrons (*3*, pp. 33–74).

Typically, these transit-dependent riders are the elderly, those persons who are physically incapable of driving, or those who cannot afford to operate a motor vehicle. Other transit-dependent riders include those too young to have a driver's license, own an automobile, or have one available. Thirdly, transit-dependent riders have also included the second and additional working members of low-income families where only one automobile is available to the family and is used by one member for travel to work. Transit-dependent riders also are typically minority more often than would be represented by their percentage of the total population (*4*, pp. 17–37).

The usual process for dealing with transit's role within developed communities is the Transit Development Plan (TDP). The TDP is a 5-year transportation implementation program that most transit operators in Florida update periodically. One approach used in preparing the TDP is to perform an on-board survey of the local transit operation to determine characteristics of the patrons using the system and then to evaluate the socioeconomic characteristics of the community in terms of characteristics of existing riders. This procedure allows the identification of latent demand along particular corridors or segments of the community and aids the decision-making process concerning location of new routes, levels of service, headways, and areas of coverage.

Experience has shown that bus transit has little or no impact on land use changes, but it may be a factor in the choice of employment location by persons within the community who meet the socioeconomic characteristics defined above. Bus transit seldom increases intensity or increases the density of development or changes existing patterns of development. A major fixed guideway, along with a long-range commitment to transit service, does have an impact in a corridor in terms of redevelopment and increased density of land use. The resulting impacts of transit on an area that has previously developed is similar in effect to the impacts of transit on an undeveloped area where bus transit and low-capital-intensive, high-labor-intensive transit does little to influence development.

Cause-and-Effect Relationships of Transit and Land Use

The cause-and-effect relationships of transit and land use are not really clear. Does transit affect land use or is transit a result of land use? The density requirements associated with transit and the impact that transit appears to have on land use raise a serious challenge to growth management. For transit to have a positive role in growth management, transit and land use planning must be coordinated, yet coordination is quite difficult.

To provide further insight into the cause-and-effect relationships of transit and land use and the importance of coordinated planning, a case study of the Tri-County Commuter Rail follows. The proposed Tri-County Commuter Rail project will add a new dimension to transit in Florida. The new rail service will provide an incentive for growth around commuter rail stations, and it will also expand the market area for existing development cores by virtue of its connection, using new bus service and Dade County's Metrorail, to major employment, shopping, and industrial centers.

Florida's Tri-County Commuter Rail Case Study

For more than 10 years, the Florida Department of Transportation (FDOT) has been evaluating various transit alternatives to serve the rapidly growing West Palm Beach–Miami corridor. In conjunction with UMTA, FDOT designed a study of the engineering and economic feasibility of instituting commuter travel service in Palm Beach, Broward, and Dade counties. The purpose of this Tri-County Commuter Transit Study (TCCTS), begun in mid 1983, was to identify various transportation options using existing rights-of-way and to select a preferred alternative in terms of its engineering, economic, and institutional feasibility.

Recognizing that many previous studies had developed significant information about the West Palm Beach–Miami corridor, the objectives of this study were to

- Develop reliable and consistent travel demand estimates for each transit alternative,
- Develop comparable capital and operating costs for each option,
- Evaluate alternatives with respect to a consistent set of criteria,
- Investigate innovative financing options for commuter service,
- Identify appropriate management structures for the implementation of commuter service, and
- Enable governmental agencies to reach logical decisions regarding implementation of commuter services.

Throughout the study process, a considerable effort was made to keep the region informed and to obtain inputs from the public on decision issues. The most important factor in this effort was the participation of regional representatives on the Study Advisory Committee (SAC). Staff members from each of the three county Metropolitan Planning Organizations (MPOs) provided timely input and direction on a number of key issues throughout the study process, particularly in the decisions leading to a preferred alternative. The project team maintained extensive coordination throughout the study with public agencies and the public at large.

The SAC established the following goals:

1. Provide for the mobility needs of the region;
2. Meet the travel demands of existing and planned land use;
3. Encourage compatible future development;
4. Promote fiscally sound, safe, and efficient travel;
5. Preserve and improve environmental qualities;
6. Promote energy conservation; and
7. Coordinate with state and local transportation plans.

These goals, particularly the first three, relate to land use and development needs. The needs of the area are addressed at the planning stage of a major transit system. Effects of such planning should create a desirable environment for transit to positively influence growth. In this case, the transit system's purpose is consistent with growth management goals. Monitoring its impact on growth offers an opportunity for further exploration of the relationship between transit and growth management.

The TCCTS concluded that a commuter rail service should be established using an existing railroad to tie together south Palm Beach County from the I-95/Glades Road interchange in Boca Raton to the Amtrak station in Hialeah. However, local officials were concerned that this section would be insufficient and that continuity was not provided with Dade County's Metrorail project (although the Amtrak station is close to Metrorail in Hialeah). Recommendations therefore were made, and the alignment is now anticipated to include an extension north to West Palm Beach and south from the Amtrak station to a new transfer-only station at Metrorail. Two public hearings on this recommendation were held during May and June 1986. In addition, a subsequent meeting was held with the governor and local officials in an effort to identify possible funding options and sources. It is anticipated that a study will be undertaken shortly to identify opportunities for joint public/private development at stations along the alignment. Initiation of this development could probably be anticipated after 3 to 5 years of operation, when patronage levels and service continuity have been established (*5*, pp. 1–3).

Checks on local land use planning and zoning must be established to ensure that contiguous counties are working together to foster compatible patterns of growth. The emphasis here is that transit's role in growth management must be coordinated and comprehensive: a development-oriented environment must be created uniformly for transit to perform effectively. The time horizon of transportation planning and funding needs to be extended, and the division of responsibility between state and local government for different facets of the transportation system needs to be sorted out so that it reflects actual conditions (*6*).

This case study illustrates that the cause-and-effect relationships of transit and land use grow out of the land use and zoning policies associated with the implementation of transit as well as necessary coordination among involved agencies. Transit's role in growth can be affected greatly by land use policies, and transit's ability to influence growth management depends on whether it is in an environment conducive to development. As stated earlier, transit is only one part of a growth management package, and effective coordination is necessary to enable transit to operate in that role. As it stands now, transit can influence growth, but by itself transit cannot manage growth, especially with the current inconsistencies in planning and coordination.

San Diego Trolley Case Study

The San Diego Trolley represents a unique opportunity to study the impact of light rail transit (LRT) on the modern urban environment because it is the first light rail system to be built in this country in the past several decades. Planned, designed, and constructed by the San Diego Metropolitan Transit Development Board (MTDB), the trolley started operation in the summer of 1981.

The San Diego Trolley is classified as an LRT system. The vehicles are operated manually, and there is minimal grade separation. Most of the line operates in an exclusive right-of-way shared with freight operations. The trolley uses an overhead power source (catenaries) and has the capability of operating on city streets that remain open to automobile traffic.

The trolley system is 15.9 miles in length and operates between Centre City San Diego and the International Border with Mexico at San Ysidro. A map illustrating the system's route is given in Figure 4. The system operates on existing streets for a distance of 1.7 miles in Centre City. In Centre City the vehicles travel at-grade on an exclusive, reserved path, typically in the center or at one side of the street. There are seven "stops" within Centre City with approximately one-quarter-mile spacing.

For approximately 14 miles the system operates on the rehabilitated mainline facilities of the San Diego and Arizona Eastern (SD&AE) Railway. All grade crossings are protected by automatic crossing gates that are activated by approaching light rail and freight trains. Although service was initiated as a single-track operation, a double-track system has been operating since February 1983.

The 11 suburban stations are modest, low-level platforms with a waiting shelter, benches, light standards, transit information, ticket machines, public telephones, and trash receptacles. Except for the International Border facility, the stations are not manned, and no restroom facilities are provided. A television surveillance system is monitored by the trolley central controller. Approximately 2,000 free parking spaces are provided at six suburban stations. All suburban stations have pedestrian access, bus access, and bicycle storage facilities. Local bus routes and schedules have been modified to provide feeder service to the trolley.

Major developments in the area served by the trolley include a major remodeling and redevelopment by McDonald's for a large restaurant and retail/office suites in a two-story building located adjacent to the San Ysidro–International Station; development of a discount department store and grocery store shopping center (Target-Ralphs) near the Chula Vista–Palomar Street Station; and development of the Great American Federal Savings and Loan Computer Center, which currently employs 600 people, adjacent to the National City–24th Street Station. The approval of the San Diego Convention Center, and its imminent construction just outside the land use impact study area, should result in improved development potential at the Imperial Station on the southeastern edge of Centre City. The intensive development and redevelopment in Centre City San Diego reflect the extensive redevelopment policies of the city in this area.

Developers report that proximity to the trolley was an important part of their leasing marketing program and has contributed to success in leasing space. Benefits cited were the convenience and low cost of the trolley for clerical and service workers who might be commuting from the South Bay and the colorful and active atmosphere created by the trolley operations on C Street.

The existence of the trolley is seen as an advantage in locational choice for land uses, particularly in the areas outside Centre City San Diego. The development and market forces at work in Centre City and the typically intense scale of development tend to overpower the trolley's role as a factor in development decisions. However, the benefits of the trolley to building tenants are recognized and used as an important part of a leasing program.

Given the positive response of development interests to the opportunities provided by locations in the vicinity of a trolley station, little has been done by local governments to consider changes in land use policy around the stations. This may be due to other planning considerations, which preclude action in some areas. However, most of the station sites present opportunities to increase the intensity and activity levels in currently built-up and developing areas, which are typically encouraged or allowed by local land use policy (7).

Tampa's Harbour Island People Mover Case Study

Harbour Island, a residential, commercial, and hotel development in Tampa, features a people mover that connects the island with downtown Tampa. Although the developer originally envisioned an automobile-free environment, financiers required automobile access. Despite this compromise, one of the advantages of the people mover is the reduced need for automobile travel to the island (visitors can park in the Fort Brooke parking garage and take the people mover to the island). Roadway improvement requirements were not as great as they would have been without transit. The people mover helped to mitigate transportation impacts of the development. Although the public provided the right-of-way, the people mover was privately financed, and because the development was a DRI, it became a required part of the Development Order. Another unique aspect of the development is that the developers used the people mover as a marketing tool: residents can live on the island and travel to work in downtown Tampa without the need for a car. It is also important to point out that this development is marketed to upscale single and childless couples (i.e., working persons, not retirees).

Currently, the transit service operates at a deficit. But the developer may receive benefits from the system in the future: land value may increase or additional development will be able to occur as the result of the transit service. New development and/or increased land value may offset the operating deficit. Although Harbour Island does not necessarily indicate that privately financed transit will be operationally self-supporting, it does indicate that jointly sponsored transit may have a chance to serve both the public and private sectors profitably and beneficially over the long term, considering value added to the development and increased densities that can be allowed as a result of transit.

Financing Sources

Assessments, exactions, and impact fees and taxes have been used to finance the costs of public improvements for many years. The finances to implement transit can come only from the public sector, the private sector, or some combination. Charging developers fees or increasing taxes can finance transit, but laws authorizing local governments to impose special

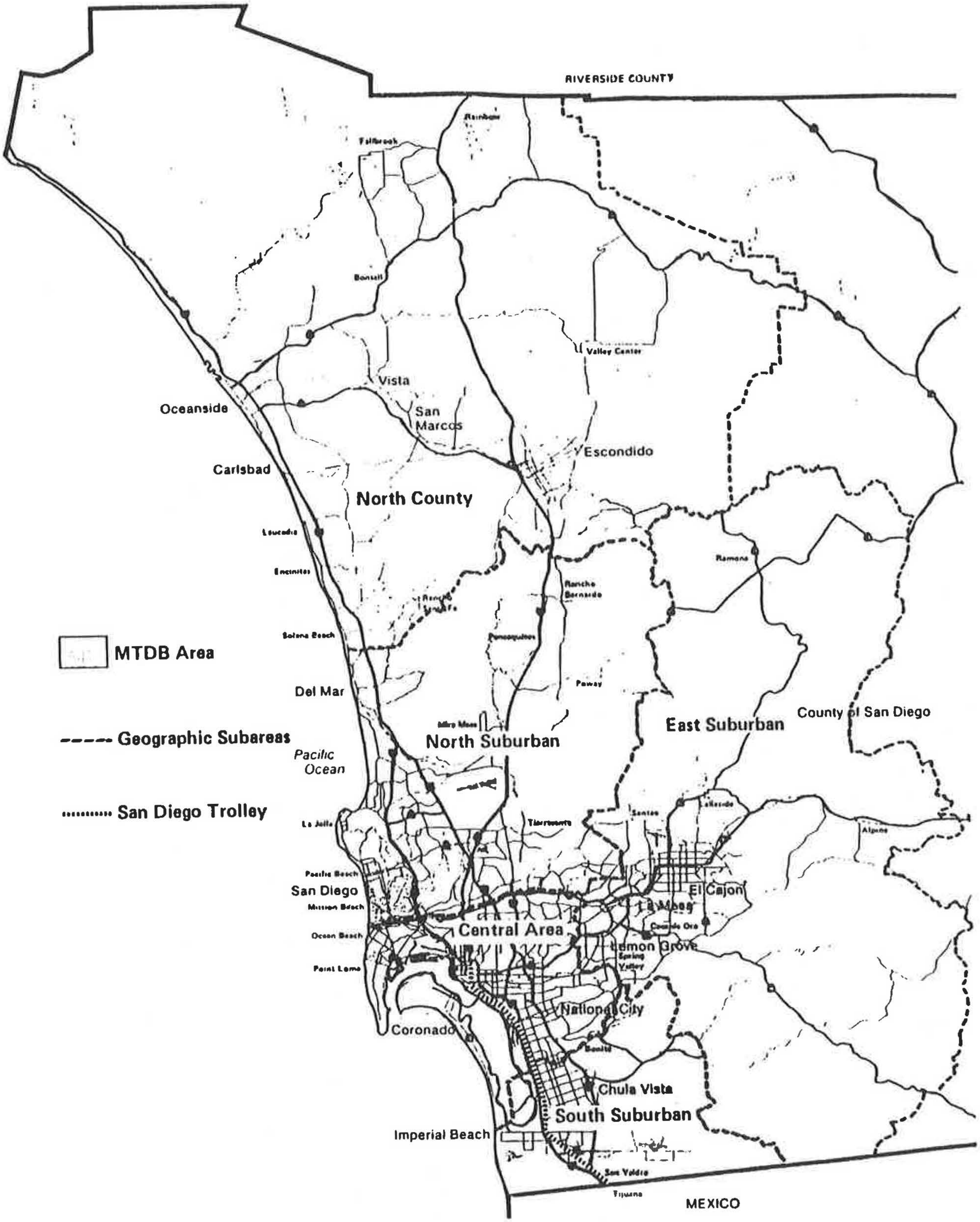


FIGURE 4 San Diego Trolley.

assessments, taxes, and impact fees vary with the types of improvements that can be financed, the manner in which the funds can be collected, and the manner in which the funds may be spent.

Special assessments can be levied on a development to collect some or all of the revenue required to finance transit. Special assessments are collected for improvements that directly benefit particular properties as opposed to improvements that benefit the public or community as a whole. Also, new or additional taxes can be levied, or developers can be required to pay impact fees for transit services. These revenue sources can be coupled together synergistically and woven into a debt-retirement schedule that can float a significant bond issue.

MARTA Case Study

The Metropolitan Atlanta Rapid Transit Authority (MARTA) was created in 1965 by an act of the Georgia General Assembly, and the first phase was opened in 1979. In November 1971 the citizens of Fulton and DeKalb Counties and the city of Atlanta voted approval of a $1.4 billion mass-transit system. The approved rapid-transit program provides for 53 miles of rapid transit, 41 stations, park-and-ride facilities for nearly 30,000 vehicles, and a fully integrated network of 1,500 route miles of feeder and express bus lines. The system is structured in a cruciform arrangement, with the east-west and north-south rail lines intersecting in downtown Atlanta at the center of the region. Average system station spacing is just over 1.2 miles, with outlying station spacing approaching 3.0 miles and downtown station spacing averaging 0.5 miles. A map of the system is included in Figure 5.

Atlanta has been a pioneer in comprehensive city planning. Its Comprehensive Development Plans, Urban Framework Plan, and Transit Station Area Development Studies (TSADS) are examples of the importance that MARTA rail stations play in land use planning. Creation of Special Public Interest Districts and Planned Development Districts are policies in Atlanta's latest zoning ordinance designed to promote growth and mixed-use development in station areas. The TSADS are of particular relevance because they provide a blueprint to guide development in MARTA station areas as the system matures.

The decade of the 1970s saw a 30 percent increase in downtown office construction in major U.S. cities. This increase required major infrastructure improvements, including major transportation improvements. Joint Development (a public/private partnership) has become an important element in implementing these transportation improvements. Several federal assistance programs (e.g., Urban Mass Transportation Act of 1964) have contributed to the interest in joint development, now commonly referred to as a public-private coventure. Among the mechanisms utilized to stimulate coventure are tax increment financing, special benefits assessments, dedicated property taxes in station areas, and zoning controls designed to shift some of the financial burden for transit from the public to the private sector. Those growth management strategies that have proven to be most successful and therefore gained the widest acceptance are as follows:

- Development agreements,
- Early developer involvement in planning,
- Leasing and/or selling air rights,
- Public underwriting of initial feasibility studies, and
- Land banking.

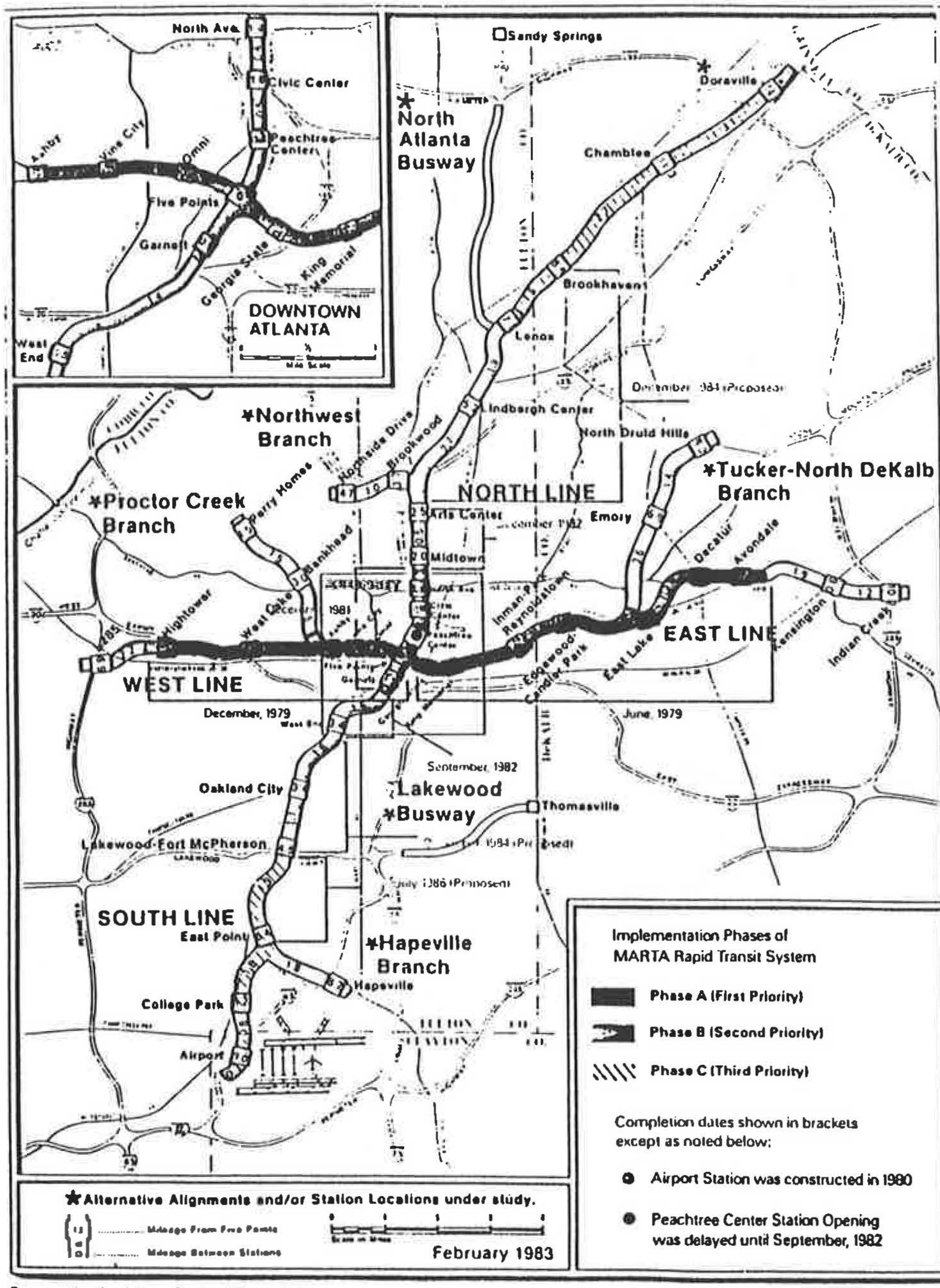
Transit-linked development in Atlanta parallels national trends, with high-intensity mixed-use development clustered around stations located in strong markets. There are also a few instances of actual joint development (public/private partnerships). Notable developments (or proposed developments) in transit station areas include the Rouse Company's redevelopment plans for Underground Atlanta. Called the "Heart of Atlanta," this $120 million project is designed to be the major entertainment complex in downtown needed to support the convention industry. Located adjacent to the Five Points Station, the project expected to gross $70 million during its first year of operation in 1987. With expectations of attracting 11.5 million visitors, planners see a multiplier effect spilling over into the Garnett Street and Georgia State Station areas with new intown housing construction. Expansion of John Portman's Peachtree Center, the addition of several major luxury hotels, and the opening of Georgia Pacific's new corporate headquarters are the major developments located near the Peachtree Center Station.

Southern Bell's $100 million, 1.9 million square foot office and retail complex at North Avenue, the Peachtree Summit (with direct access to the Civic Center Station) office complex that houses MARTA and Coca-Cola among its major tenants, and speculative office space at the Midtown and Arts Center stations are examples of the tremendous impact these rail stations are making in the North Line corridor.

Since 1978, major completed or announced construction on the North Line from the Peachtree Center Station to the Lenox Station adds over 7.0 million square feet of office space, nearly 5,000 new hotel rooms, more than one million square feet of retail space, and several new residential complexes. All of this development is occurring within a 1,500-foot radius of North Line transit stations.

Atlanta's experience suggests that the following actions promote successful joint development projects:

1. Developer involvement in initial transportation planning promotes developer interest in future development projects at transit sites.
2. Transit agencies must take an active role in joint development. MARTA opted for a passive role, allowing the free market system to guide development. As a result, development concentrated at North Line stations, whereas the East and West Line and South stations experienced little or no development. Joint development potentials should be a part of route alignment and station location decisions.
3. Direct station access seems to foster developer interest.
4. The local government and transit agency must establish clear policies supporting joint development. Two examples of public policies designed to encourage station area development in Atlanta are the city's zoning ordinance, which created Special Public Interest Districts in MARTA station areas, and MARTA's September 1982 disposition policy for surplus property, including subsurface, surface, and air rights.
5. Transit agencies should create an office of joint development. This office could provide a single access point that has authority to make deals and assist developers in putting together development packages.



Prepared by the Atlanta Regional Commission

FIGURE 5 MARTA system.

A study of Atlanta's MARTA system reveals that although linkages do exist between land development and transit, development is not automatic. Instead, development is fostered, and ultimately managed, through supportive zoning, special incentives, and strong markets. MARTA is an integral part of a viable, coordinated growth management package, and it operates in a development-oriented environment (*8*, pp. vii–ix).

GOALS, POLICIES, AND OBJECTIVES OF THE FLORIDA TRANSPORTATION PLAN

Florida intends to use transit investments to aid sound growth management principles designed to provide timely and efficient access to services, jobs, markets, and attractions. Another important goal identified in the transportation plan stresses improved coordination among the various government levels, with special emphasis on planning and funding. Florida plans to develop and implement transit programs that promote integrated planning and urban infill. Ultimately, these transit programs should be designed to manage or effectively influence growth.

PROBLEMS WITH THESE GOALS, POLICIES, AND OBJECTIVES

Some problems with the goals, policies, and objectives in Florida arise from the authority to enact ordinances imposing exactions or developer fees. In addition, many courts have struck down ordinances where there was no statute to serve as a legal basis for a local ordinance because the local ordinance exceeded the scope of existing enabling legislation or because a particular requirement exceeded current/local legislation (*9*, pp. 12, 14).

In some instances, current legislation is not consistent with the management goals of the Florida transportation plan. The FDOT is pursuing legislation to support its growth management goals. This legislation will be critical to the overall success of various growth management tools, including transit.

Most litigation concerning growth management tools—the products of policies, goals, and objectives—has centered on whether a particular ordinance is equitable. Ordinances designed to provide growth management tools must be the result of a regular legislative process. A major problem with passing legislation is that governments can become too regulated. There are legal limits on the extent to which legislation can promote growth management (*9*, p. 14).

Coordination at all levels must exist for transit's role in influencing growth to be optimized. In addition, transit can positively affect development when supportive conditions such as zoning policies, community and government support, and market demand are present. One major concern with Florida's policies is consistency and acceptance. For example, as reported in the Statewide Transit Needs Plan, Phase I, the Suwannee Valley Transit Authority (SVTA) has a goal to maximize efficiency of existing transportation systems. This policy conflicts with the FDOT's policy to support high-speed rail, since SVTA would prefer to expand their existing system rather than opt for a new high-speed rail facility. This conflict is not necessarily direct, but the policy does not exactly correspond with the FDOT's policies. For a positive relationship between transit and growth, Florida's policies, goals, and objectives should be uniform, accepted, and supported at all government levels.

SUMMARY

The following suggestions appear to be in order if a growth state is serious about engaging transit in the growth management process:

1. A clear distinction must be made between fixed-guideway and over-the-road transit services.
2. Transit planning should be linked with the land use process to maximize its influence in growth management.
3. Equal if not heavier policy emphasis should be given to financial policy planning for transit.
4. Fixed-guideway assets that do not have a reasonably clear and acceptable financing policy should not be used in formulating land use policy.
5. More effort should be exerted in promoting joint public-private funding ventures for transit.
6. Government incentives to improve the profitability of land development should be coupled with exactions, fees, or other forms of taxation. This should create a favorable win-win climate for the developer, for our transit systems, and for influencing growth.

It is suggested that more demonstration projects involving joint public-private financing be implemented in the transit arena and that stronger relationships among financial policy, transit policy, and land use policy be developed at all levels of government.

ACKNOWLEDGMENT

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Land Use and Transportation Planning in Response to Congestion Problems: A Review and Critique

ELIZABETH DEAKIN

Concerns over traffic congestion are producing an upsurge of interest in coordinating land development and transportation. This paper reviews land use and transportation planning at the local government level and assesses planning and policy issues raised by various strategies being utilized to address congestion problems. At the local level transportation and land use planning often are carried out as largely separate functions. This separation reflects differences in education and training of the planners responsible for land use and the engineers responsible for transportation and occurs in part because many transportation facilities and services are provided by state and regional rather than local agencies. One result is that transportation and land use plans are rarely coordinated and often are inconsistent. Such inconsistencies were less of a concern in the past, when the tradition of providing transportation services on demand lessened the need for detailed plan coordination. Today, however, shrinking revenues, escalating costs, and concerns about social and environmental impacts have combined to constrain state highway building; financial problems and difficulties in attracting riders have deterred transit expansion. Consequently, it is no longer possible to rely on state and regional transportation agencies to build a way out of congestion problems, and local governments are having to shoulder greater responsibility for transportation. Three approaches increasingly are being used by local governments as responses to congestion. First, developer exactions and impact fees are being imposed as ways to speed transportation project delivery. Second, transportation systems management programs and ordinances are being implemented to encourage the use of alternative modes and reduce the number of trips generated. Third, general plan, subdivision control, and zoning revisions are being made in order to tie land development more closely to available and planned transportation capacity. All three approaches suffer from uncertainties about their effectiveness and acceptability, particularly when applied piecemeal. Many local governments are not fully equipped to carry out these new tasks. Planning departments have few staff members with training in transportation planning and analysis and have left these matters largely to engineering departments. But many engineering departments also lack in-house transportation expertise, particularly concerning demand management and land use-transportation coordination. In addition, methodological and data shortcomings limit the ability of local planners and engineers to tackle land use and transportation planning issues. Equally importantly, the highly politicized circumstances under which many traffic mitigation efforts take place thrust planners into roles for which many have little training or experience. Planners often find themselves devising compromises between pro- and antigrowth interests, carrying out negotiations with developers and community groups, and preparing development revenue forecasts and financing plans. These findings suggest a need for additional research on methods to coordinate transportation and land use; more rigorous requirements and incentives for local transportation-land use coordination; greater cross-training of planners and engineers; and greater exposure of planning and engineering students to the techniques and issues of project evaluation, negotiation, and the political process.

Traffic congestion, particularly during the journey to work, is a growing public concern. Yet shrinking public revenues and escalating costs have constrained government's ability to respond by delivering new transportation facilities and services—a response that is sometimes questioned, in any event, on environmental and efficiency grounds (*1–4*). Consequently, a search has been undertaken for alternative strategies that might offer congestion relief or at least avoid a worsening of conditions.

Local governments have explored a number of such strategies (Table 1). Specific measures being investigated and tested include methods to increase capacity and improve traffic flow (including strategies for funding such projects); strategies for encouraging the use of alternatives to the automobile, especially for commute trips; and strategies for reducing overall trip making. Because many of these local government efforts are triggered by analyses of the likely impacts of proposed developments (and, occasionally, by the actual impacts of recently approved developments), there has been an upsurge of interest in transportation-land use relationships and in methods for coordinating land development and transportation.

This paper examines the nature of transportation-land use planning at the local government level and assesses planning and policy issues raised by strategies being utilized to address traffic congestion problems. The paper is based on the findings of two related studies. The first study examined public-private partnerships and development exactions for traffic mitigation in major metropolitan areas across the United States. It focused on transportation requirements imposed as a condition of development approval, but it also collected information on other traffic mitigation policies as well as on other types of exactions in use. Policies in 62 cities and counties were examined in some detail, and case studies were carried out in 20 jurisdictions (*4–8*). The second study examined traffic mitigation practices in California. Telephone interviews with city and county planners and engineers in over 100 jurisdictions were used to identify the scope of traffic mitigation activities, and 15 jurisdictions representing a wide range of experiences were selected for detailed investigations (*8–11*).

In the next section the practice of land use and transportation planning at the local government level is reviewed briefly.

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TABLE 1 TRANSPORTATION/LAND USE STRATEGIES TO ALLEVIATE CONGESTION

A. Increase capacity

increase funding so that more facilities and services can be delivered
- increase state funding: bonds, sales tax, gas tax, tolls and fares, license fees
- develop local funding sources: special districts, fees, local taxes
- develop private sector funding sources (exactions, in-lieu fees, benefit assessments)
- improve methods of allocating available funds
- advocacy with federal, state and regional agencies for discretionary funds

faster delivery of new facilities
- accelerate construction of all "funded" projects (increase public agency staff capabilities; contract out; use more efficient construction management strategies, use new technologies)

B. Improve traffic flow

traffic engineering strategies
- preferential treatment for HOVs
- traffic signal timing
- on-street parking management
- corridor management and route guidance
- accident clearance

work rescheduling policies
- flextime
- staggered work hours

C. Encourage use of alternative commute modes/ auto trip reduction

provision, promotion, subsidy by public agencies, developers, employers
- transit
- ridesharing
- bicycling
- walking

improvements in transit level of service
- express services
- timed transfers
- more direct routes
- denser networks - reduced access time
- park-and-ride
- increased frequency
- preferential treatment: express lanes, signal preemption

parking management policies
- control of supply and location
- pricing policies to reduce/remove subsidies to SOVs
- preferential allocation, location, and price for HOVs

land use strategies
- match land development to transportation capacity
- restrict traffic-intensive uses
- conditional zoning and point systems
- jobs/housing balance
- annual development quotas, caps
- restrict annexations, public service expansions
- mixed use development
- on-site/near-site services
- clustering of buildings
- density increases/bonuses in areas served by transit
- exactions for transit, pedestrian, bike facilities
- on site convenience stores, banking facilities, etc.
- delivery services, automatic payroll deposits, etc.

other trip reduction strategies
- telecommunications substitutes for travel
- work-at-home options

Then three approaches that are being used by local governments to respond to congestion concerns—transportation exactions and impact fees; transportation system management programs and ordinances; and general plan, subdivision control, and zoning revisions—are discussed, and issues they raise are considered. The paper concludes with a discussion of the implications for planning practice.

Local Transportation and Land Use Planning

Land use planning and regulation traditionally have been activities of local governments. In contrast, transportation planning (as distinct from traffic engineering) has tended to be less visible at the local level—so much so that some respondents in our studies commented that transportation planning was a new issue in their communities. The reasons for local governments' relative inattention to transportation planning, at least until recent years, are deeply rooted in government organization, staffing practices, and assignments of responsibility.

Several factors have contributed to transportation's secondary role in local planning efforts. First, governmental responsibilities for land use and transportation traditionally have been divided, with land use assigned to the planning department and transportation assigned to engineering. Many planners have had little training in transportation and have been satisfied to leave what they view as a technically based matter to another department. Many engineers similarly are unskilled in land use planning and lack interest in the policy issues it entails. Land use and transportation activities thus have tended to proceed along separate paths, reflecting differences in the training of the respective staffs as well as differences in the scope of responsibility. Often, there is little coordination between the two (*8*).

This tendency to not coordinate transportation and land use is exacerbated by low levels of local government staffing for transportation. Table 2 presents findings from telephone interviews with planning and engineering departments in California cities and towns. The interviews explored staffing levels, staff training and experience, and assignments of responsibility for land use and transportation planning. The interviews clearly revealed that transportation planning receives relatively little attention in city planning departments—and also indicated that perhaps less transportation planning is done in engineering departments than the planners assume.

Among the planning departments, a distinct minority—about 17 percent overall—had assigned one or more staff members to work primarily on transportation. As one might expect, very few of the small cities (those with a population in the 10,000 to 50,000 range) had a transportation planner, whereas about 21 percent of those in the midsize category (50,000 to 120,000 population) and about 45 percent of the larger cities (120,000 plus) had at least one such staff member. A somewhat larger number assigned at least half a person-year of effort each year to transportation-related activities; this was the case for 18 percent of the jurisdictions in the 10,000 to 50,000 population category, 38 percent of the mid-sized cities, and 64 percent of the larger cities. Overall, most departments estimated that transportation activities accounted for 10 to 15 percent or less of the total planning staff's level of effort.

Many planning departments reported that they simply could not afford to devote as much as half a position to transportation, although several also said that a transportation planner position was among their unfunded requests. For those that did have transportation planning expertise on staff, the assignments given to this person (or persons) tended to be short-range and projectoriented, with responsibility for environmental impact report analyses, residential street design, bike programs, transportation systems management programs, and parking requirements and programs the most common. The planning departments without special expertise in transportation commonly stated that they depended on the city's engineering staff to carry out the more general, longer-range transportation planning and analyses, and indeed even those with in-department transportation planners reported that they relied on engineering for much of the jurisdiction's transportation planning work.

In view of these latter comments, it is noteworthy that engineering departments also tended to lack staff with specific training or experience in transportation. Among the cities with populations under 50,000, for example, most obtained transportation engineering services via consultant contract rather than direct staffing. In the 50,000 to 120,000 population category, under half (43 percent) had one or more in-house traffic engineers; nearly as many (39 percent) used consultant contracts for transportation services, and the rest relied on civil engineers without specialized training in transportation. Only among the largest cities was it common to find one or more transportation engineers on staff.

Many engineering departments reported that it was barely possible to keep up with immediate transportation safety and enforcement needs (signal repairs, signing, curb painting, accident investigation, and so on) with their available transportation engineering staff; except in the handful of cities with more than two transportation engineers, there was a consensus that engineering divisions were falling behind in their transportation responsibilities. To cope with the workload, many jurisdictions reported that they had cut back on once-routine data gathering efforts and increasingly relied on studies conducted for development applications to obtain updated traffic counts and parking surveys. Only a handful reported that they had staff with training or experience in such matters as ridesharing or parking management strategies, and a number of engineering managers stated that such skills would have to come from the planning department. Also, a number reported that they now conducted work on such matters as circulation plan updates only when specifically directed (and funded) to do so.

The general picture in California, then, is that at the local government level, transportation in effect is falling between the cracks: neither planning departments nor engineering departments are staffed to carry out more than a minimal level of transportation planning, most of the work that is being done is aimed at specific projects and programs, and no one is taking the lead on comprehensive planning for transportation. While the situation in California clearly worsened following the passage of Proposition 13, anecdotal evidence from other states suggests that conditions elsewhere are not significantly better (*6,7*).

One result of not planning for transportation comprehensively has been that the amount of development that would be permitted under adopted land use plans and zoning frequently is not consistent with available and planned transportation capacity or has never been checked for consistency

TABLE 2 STAFFING LEVELS FOR TRANSPORTATION IN CALIFORNIA PLANNING AND ENGINEERING DEPARTMENTS

Percent of each population category:

	10-50K	50-120K	120-250K	>250K
1) planners:				
0	82	62	50	29
.5	12	17	25	14
1+	6	21	25	57
	100	100	100	100
# responses	34	24	4	7
2) engineers:				
contract out	66	39	--	--
CE, not TE	30	18	33	--
1	4	38	33	--
2+	--	5	33	100
	100	100	100	100
# responses	54	37	3	6
# cities in CA	179	65	10	7

Notes: Based on interviews conducted in 1985 and 1986 with 100 transportation engineering divisions and 69 planning departments in California cities. City sizes are as of 1980 Census.

in any detail. Of course, whether permitted development levels would indeed materialize often is questionable. In most communities land use plans and regulations set forth the community's aspirations for physical development and the housing opportunities, jobs, and tax revenues that development would imply. But because land development is overwhelmingly a private sector initiative, communities have relatively little ability to ensure that their plans will be realized. Many local governments have plans and zoning that would permit development far in excess of what market forces are likely to generate, at least over a planning horizon of 10 to 20 years. Coordinating transportation plans with such land use plans would lead to massive overestimation of transport needs (*11*). Other communities, in contrast, operate with relatively conservative plans and zoning but repeatedly approve developers' requests for plan and zoning amendments, permitting larger projects than were anticipated in the planning and zoning documents. In such cases coordination of transportation capacity with planned land uses would lead to an underestimation of transportation needs.

Another consideration working against consistency between land use and transportation plans is the impermanence of land use plans and regulations. Indeed, much of the activity of the typical planning department involves dealing with requests for plan amendments, rezonings, and other exceptions to or modifications of the community's plans and regulations in order to permit development that differs from that envisioned in the planning instruments. Because land use plans and regulations change so often, continual revisions to transportation plans also are needed to maintain consistency. Major transportation facilities can take 10 years or more to plan and implement, however, making such revisions impractical and difficult to accomplish.

Second, whereas land use planning is almost entirely a local responsibility, state and regional agencies are major actors in transportation planning and implementation. State agencies have long played dominant roles in the provision of interjurisdictional roads (arterials and freeways), while regional transit agencies have been the providers of transit services. There has been a strong tendency to rely on these other organizations for planning and implementation of all but relatively small-scale road facilities. Thus, local engineers' transportation responsibilities have been focused on only a limited subset of transportation—namely, the streets and parking under local control.

Sometimes, local plans as approved would create the need for major investments in state highways, in transit, or in both; without these improvements levels of service would deteriorate to F (sometimes for many hours a day). Local governments in California face a requirement that their circulation elements be consistent with their land use elements, but many get around this requirement by adding language to their plans calling for cooperation with state and regional transportation agencies to obtain improvements on the affected facilities—even when the state and regional agencies have made it clear that there are no funds available for the needed improvements.

Traditional notions of public responsibilities for transportation have served to limit the scope of local transportation planning activities even more. Transportation has been viewed as a public utility to be provided on demand and not something to which access should be restricted or conditioned. Although it has commonly been agreed that local government has a legitimate role in guiding private development decisions (or at least in deciding whether or not to accommodate private sector development requests), local government's role in transportation, in contrast, has been seen as providing the public facilities needed to ensure safe, fast, and efficient movement. Particularly among the engineering profession, there has been concern about the legitimacy of managing demand or denying requests for service. This concern has been shared by legislators and even the courts in some states, who have restricted local government attempts to limit growth by refusing to provide public services (*8*).

Together, the separation of land use planning and transportation functions, the reliance on state and regional agencies for implementation of major highway and arterial facilities and transit services, and concerns about the legitimacy of managing transportation demand or limiting access have meant that many local governments have played partial and limited roles in guiding transportation development or coordinating it with land development.

The lack of coordination between transportation and land use plans was perhaps of less consequence when the funds were available to deliver transport facilities and services to meet, or even anticipate, demand. Then, land use plans and zoning might permit development at levels that would swamp available transportation facilities, but there was a reasonable expectation that capacity expansions would soon be forthcoming to correct the shortfalls. Land developments could even be approved that exceeded planned transportation capacity; the prevailing attitude was that transportation officials simply would revise their plans to ensure that adequate facilities would be provided. With both highway departments and transit agencies adopting a "can do" posture, these expectations and attitudes were not as unreasonable as they might seem at first glance.

Today, however, traffic volumes are growing much faster than state and regional transportation agencies can deliver projects. Moreover, public concerns about the impacts of large-scale transportation projects have led many to question the advisability of continual expansion. Thus, the ability of state and regional agencies to "build their way out" of congestion problems has come into question, and local governments are finding it necessary to shoulder an increasing share of the responsibility for transportation.

At the same time, local governments have had their own difficulties in delivering local transport facilities, particularly in newly developing areas. In the 1960s and 1970s, many of these areas found that growth was occurring faster than their budgets could absorb the costs of needed infrastructure (including sewers, water, and schools, as well as local roads). A common response was to adopt an adequate public facilities ordinance or other growth-pacing device in order to tie the rate of subdivisions and subsequent development to the availability of capital improvements. These ordinances provided the impetus for site-impact studies, which were used to determine the effects of the proposed development on community facilities and services.

For transportation, the usual procedure was to estimate a proposed project's trip generation, adjusting for anticipated mode shares, and then to load the estimated automobile traffic onto nearby roads and intersections and calculate capacity effects. The approach almost always was done on a project-by-project basis and usually considered only those facilities most directly affected (i.e., adjacent roadways and intersections). When capacity problems were anticipated, the developer could help fund needed improvements or face a delay in approvals until such time as the community was able to deliver the facilities.

Meanwhile, concerns about air pollution, energy dependence, urban quality of life, and transport finance produced major initiatives to increase the efficiency of the transportation system and encourage the use of alternative modes of travel (transit, ridesharing, bicycles, and walking.) Gradually, these transportation systems management (TSM) options came to be considered in site-impact analyses as well. Developers sometimes proposed TSM as a way of reducing the need for costly infrastructure. Citizen pressures to minimize traffic impacts, coupled with resistance to new highway building, also made TSM an attractive option to many local governments.

Impact analyses of new developments thus became the main mechanism for resolving incompatibilities between land use and transportation plans through a combination of developer financing and TSM. This analysis approach is the state of the practice in most communities today; it is used in analyzing subdivision requests, in reviews when a rezoning or other exception to local regulations is sought, and in meeting the relatively recent requirements for environmental review of proposed projects. But the analysis approach has a number of shortcomings. Local data rarely are available for many of the analysis steps, leaving the analyst dependent on "default values" or data borrowed from another area. Numerous assumptions about future travel behavior, origin-destination patterns, and facility operations must be made. The results necessarily are highly approximate. Furthermore, the project-by-project focus of these analyses omits many important concerns. Cumulative impacts, for example, are not easily addressed via project-level analyses. In addition, most site-impact analyses focus only on local infrastructure; there usually is no parallel set of requirements for the facilities under state and regional control.

Environmental impact reporting requirements in force in some states do call for the examination of cumulative impacts, including impacts on state and regional transportation facilities. However, this remains a weak link in most analyses, especially where an overall analysis of land use and transportation has not been done. In addition, most environmental regulations call for a transportation analysis but are silent about standards for the acceptability of the predicted impacts. Thus, in most cases a city can approve a plan that produces gridlock on state highways and requires millions of dollars of unfunded transit services; it is obligated only to conduct an adequate analysis of how bad conditions will be—not to correct those conditions or fund the needed facilities and services.

Today, an increasing number of local governments are recognizing the problems raised by the separation of land use and transportation planning and the deficiencies inherent in project-level analysis. There has been growing use of subarea planning approaches to overcome some of these problems. Usually, the land use plan for the area at buildout (or estimated development in some planning year 10 to 20 years in the future) is analyzed with respect to a set of alternative transportation facilities and services. Perhaps not surprisingly, many such analyses have shown that the kinds of transportation projects that could be implemented under current financing could not handle the amount of development proposed (*8*). Thus, many local governments now are struggling to deal with transportation needs through a combination of financing, demand management, and coordinated land use-transportation strategies, including revised land use plans.

APPROACHES IN RESPONSE TO TRAFFIC CONGESTION

As the above discussion suggests, traffic congestion variously has been diagnosed as the result of insufficient funds to deliver needed projects, insufficient attention to travel demand management and the provision of alternatives to the solo-occupant auto mode of travel, and insufficient attention to coordinating transportation and land use. Local governments have subscribed to each of these views (and sometimes to all of them). Consequently, planning approaches in response to traffic congestion concerns emphasize funding, demand management, and/or transportation-land use planning. Approaches receiving considerable attention at the present time include the following:

- Requirements that developers and/or employers help provide or pay for the transportation facilities and services they necessitate via exactions and impact fees and, occasionally, benefit assessment districts. This approach puts emphasis on financing from other than traditional sources for continued capacity improvements to meet expected demand.
- Policies that call for the implementation of TSM measures, especially demand-modifying measures such as ridesharing, flextime, and transit user subsidies, either through incorporation into the conditions of approval for new development projects or through special-purpose TSM ordinances. This approach emphasizes reductions in automobile travel, especially peak-hour automobile travel, rather than its continued accommodation.
- Policies that coordinate development location, density, and/or site requirements with transportation capacity and mode choices through general plan provisions, subdivision regulations, and zoning. This approach may emphasize reducing activity levels to those that can be accommodated by existing and planned transportation capacity, or alternatively it may focus on site designs and development concentrations that would create environments conducive to travel by transit, bicycles, and walking.

Each of these approaches is discussed below.

Exactions and Impact Fees

Exactions and impact fees can help address traffic congestion problems by providing for the expansion of transportation facilities and services. Local governments are increasingly imposing requirements on developers to help provide or pay for a wide variety of programs and projects, both on-site and off. Today, exactions are being imposed on downtown office buildings and suburban office parks, as well as on residential subdivisions and high-rise condominium projects, and in addition to the streets, sewer and water facilities, and sites for schools, parks, and fire, and police stations required for some years, developers now are being asked as well for traffic mitigation programs, housing for low- and moderate-income households, job training and local hiring agreements, child care centers, and public art (*6*).

Transportation facilities are one of the most common types of exaction in use in the United States. Land dedications for roadways, intersection improvements and road widenings, traffic signals, and even freeway interchanges frequently are required. There also has been a growing trend toward the use of traffic impact fees either as an in-lieu option or instead of specific performance (*12, 13*).

Exactions must be consistent with the legal authority granted to local jurisdictions by the various states, so it is not surprising that considerable variation from state to state is exhibited. Even after accounting for differences in legal context, however, a remarkable variety of formulations are in use. Some local jurisdictions impose exactions only when a variance, rezoning, or other exception or deviation from local land use plans is requested; some tie exactions to incentives (e.g., density bonuses); and others routinely apply exactions to all projects. Still others use all three approaches, depending on the development proposal and the type of exaction being considered. Exactions may apply to all types of development, or only to housing or commercial development. Exemptions of certain uses (e.g., neighborhood retail, low-income housing) or of developments under a certain size are permitted in some communities but not others. The developer may be held responsible for 100 percent of needed facilities and services (or full-impact mitigation) or may be permitted cost-sharing with the local government or credits for future tax payments. Implementation procedures also vary considerably: the timing and form of required action (or payment) can range from up-front investments to contractual performance agreements or bonds, and sometimes they are even contingent on future occurrences, such as the exceeding of traffic volume or level of service thresholds (*14, 15*).

Some states do not permit exactions per se. However, this does not mean that exactions are not in use there. A representative story is related by a planner from a state that officially bans exactions. He tells of local planning commissions that routinely ask the developer-applicant if he will agree to "voluntarily contribute" the list of exactionlike items proposed by the local planners. The developers usually do agree. (The reader should note that recent court decisions, particularly the U.S. Supreme Court's 1987 decision in Nollan v. California Coastal Commission, are likely to substantially alter local governments' approaches to exactions, principally by requiring a clearer relationship between the exaction and the project impact. Whether local governments restrict their use of exactions or turn increasingly to point systems and other mechanisms for obtaining desired items from developers remains to be seen.)

At least three objectives have motivated the rapid growth in the use of development exactions for transportation. The most common reason for using transportation exactions is the need for money: exactions provide the facilities and services necessitated by new development while permitting local governments to avoid (or at least minimize) public outlays. Increasingly, however, transportation exactions also are being used as a way of obtaining traffic mitigations. Ridesharing promotion, flextime programs, transit pass sales, and bicycle and pedestrian facilities are being required as conditions of project approval in such places as San Francisco, Los Angeles, Berkeley, and Orange County. The cost of these programs is less at issue than the desire for a commitment to their implementation. Finally, transportation exactions sometimes are used to obtain amenities that otherwise could not be provided, especially when the project proponents are seeking a variance, rezoning, or other special treatment. Pedestrian plazas, transit kiosks, and showers and lockers for cyclists are among the measures that have been obtained in this fashion (*4, 6, 16*).

Many of these exactions are determined through case-by-case negotiations, although sometimes (especially when an impact fee is used) the basic requirements are set forth in an ordinance or regulation (*12, 13, 17, 18*). Negotiations are often a sore point for both developers and city officials, and both groups report that they feel themselves at a disadvantage in the negotiation process. Developers complain that local governments sometimes impose excessive requirements, knowing that the developer's only recourse is a series of time-consuming and costly appeals that could put their projects at risk. Another developer concern is that because of the vagaries of negotiations, similar projects (often the ones to come along later) end up with considerably different requirements. For example, developers tell of cases in which a series of projects was approved without exactions; then, because those projects used up available capacity, the next application was subjected to requirements for extensive impact mitigations. Local officials, on the other hand, report that they are often "outgunned" by developers who can hire well-known experts to plead their cases and can afford to spend much more time and money on analyses than can staff. They also charge that some developers use "economic blackmail"—threats to develop elsewhere, taking existing as well as future jobs with them—in an attempt to avoid paying their fair share of the costs they impose (*6, 19–22*).

The growing interest in impact fees reflects, in part, the desire to reduce complaints about inequitable treatment, lack of predictability, and excessive costliness of negotiated exactions. It is not always clear, however, that the fee approach succeeds on these counts. For example, developers sometimes complain that the methods used to determine costs and assess fee responsibility are unsupported by hard data, contain flaws in logic, and/or that the fees' timing or payment mechanisms put an undue burden on their projects (*21, 22*). In contrast, city officials report that the fees tend to be set too low, cover only obvious and uncontestable costs, and require significant investments in collection and accounting procedures. And both developers and city officials note that the impact fee approach makes it much more difficult to adjust requirements to meet the particulars of a project—something that, on occasion, raises its own equity questions.

Because exactions apply only to new development (only occasionally are major renovations or significant changes of use covered), they are much more effective in addressing future transportation needs than in helping to restructure the transportation system or alleviate current problems. Thus, the sufficiency of exactions is a concern. Developers may be held responsible for interchanges or traffic signals needed because of their projects, for example, but they rarely can be required to help pay for the impacts of widespread congestion problems owing to cumulative traffic growth. For this reason, some jurisdictions are utilizing benefit assessment districts as a way to address the broader, less project-specific issues; exactions are used to obtain the facilities and services that can clearly be tied to particular projects (*3*).

Transportation System Management Approaches

Over the past decade a variety of TSM measures have been utilized to combat air pollution, energy consumption, and congestion. Measures that increase capacity, such as improved traffic signal timing and supplementary transit services, have been pursued to the extent that budgets permit. Increasingly, however, emphasis has been given to demand-modifying measures, such as ridesharing promotion and transit user subsidies, parking price increases aimed at solo drivers, parking supply restrictions, and work rescheduling programs.

In most cases TSM efforts have produced positive results. On the whole, however, these results have been modest: increases in vehicle throughput or reductions in peak-period automobile use on the order of 5 percent are typical (*5, 11*). For example, systematic retiming of traffic signals has improved average speeds and cut stops and delays by about 4 to 7 percent in a number of cities, and aggressive institution of carpool and vanpool programs has produced shifts from drive-alone to shared-ride commuting on the order of 2 to 8 percent (with the higher percentage found principally when increases in parking fees also have been instituted.) It also should be noted that in areas where traffic is particularly severe, the TSM measures increase carrying capacity but do not result in noticeably less congestion; rather, more travel can be accommodated because of the measures.

In part, TSM's modest performance reflects the difficulty in changing travel behavior in an automobile-oriented society; given today's land use patterns, activity systems, income levels, and time constraints, the single-occupant automobile frequently is the most rational travel mode choice for the individual, although it may not be so for the community as a whole. But three other factors are at least partially responsible for TSM's limited effectiveness:

1. The tendency has been to implement TSM as a series of separate projects, with different agencies and offices handling rideshare matching, transit promotion, high-occupancy-vehicle lanes, and parking policy. This division of labor reflects the specialization of transportation professionals, but it also sharply increases the difficulty of coordination. As a result, the potential for cumulative and synergistic effects is often lost, and sometimes different projects even work at cross-purposes (as, for example, when carpool incentives draw riders away from transit).
2. It has been difficult to obtain broad-based participation in TSM efforts, particularly among the private sector actors whose endorsement of TSM can make a major difference in its success rate. Projects to encourage commute alternatives do best when implemented with employers' support; flextime projects necessitate employer sponsorship; and parking management, trip-shortening, and trip-reduction strategies depend on both developer and employer involvement. But voluntary employer and developer participation has not been widespread, and even when it has been obtained, it has not always been sustained over time (*21*).
3. Financing and staffing of TSM programs have been problematic. Many ridesharing programs struggle for survival and spend a significant portion of their time securing next year's funding. Financial insecurities make it hard for TSM organizations to promote their services aggressively and nearly impossible for them to experiment with innovative concepts.

Recently, however, there has been growing recognition of the need to implement TSM measures more systematically. Proposals to develop multifaceted, integrated TSM programs, to put TSM activities on a stable financial footing, to broaden their client base, and to target specific TSM measures to appropriate markets are being put forth. Also, local initiatives put together "packages" of TSM measures, combining mutually supportive supply enhancements with demand management strategies.

In most cases the objective is to increase the range of travel options available to the public and to provide incentives for using commute alternatives; disincentives to automobile use, such as higher parking prices or restrictions on parking supply, are used less frequently. In addition, participation in many of these programs is voluntary, or required only for those developers or employers who elect to take advantage of incentives or quid pro quos such as density bonuses or government-backed financing. Some jurisdictions, however, are beginning to develop TSM programs with "sticks" as well as "carrots," particularly when TSM is tied to the approval of new development. In particular, increasing numbers of local governments are adopting policies that call for TSM measures to be incorporated into conditions of approval and are enacting ordinances requiring the ongoing implementation of demand management programs such as ridesharing, flextime, and subsidies for users of commute alternatives. The ordinances are being implemented primarily because they offer a more uniform and certain approach to traffic management than the case-by-case approach commonly used for exactions and because they can be used to establish procedures for ongoing program implementation and monitoring, including employer-sponsored program development, annual report requirements, and annual employee commute surveys.

Two different approaches are found in TSM ordinances today. Some TSM ordinances establish standard requirements or incentives for the support of transit use, ridesharing, bicycling, walking, and flexible or staggered work hours, and/or they mandate supportive site design and parking management practices and low-cost operations improvements such as traffic signal retiming. Examples of this type of ordinance include those developed for Sacramento City, Sacramento County, and Seattle. Other TSM ordinances call for developers and employers to establish a traffic management program, leaving it up to the individual respondent to evaluate the options and put together a plan of action. The TSM ordinances in Pleasanton, California, and Los Angeles are of this type. In either case it is common for the ordinance to apply uniformly to broad groups (e.g., all employers of over 100 employees), although increasingly stringent requirements may be imposed on larger developments and employers, and some exemptions by size or type of business may be available. (Implementing in-house TSM programs can be difficult for small developers and employers and for businesses requiring numerous out-of-office trips or irregular, unpredictable work hours.)

At present, most TSM ordinances are of limited scope and applicability. Most address only peak-period travel or commute trips; other trips, which constitute the greater part of the trips made daily, are unaffected (except, perhaps, indirectly through linkages with peak-period or commute trips). Perhaps more importantly, the majority of ordinances apply only to new development projects and employers, although application to existing developments and employers is becoming increasingly common.

The ordinances also tend to be quite weak on performance matters. Most mandate that certain TSM activities be carried out, but only a few set accomplishment targets (i.e., output objectives) for these activities—the emphasis is on implementing programs rather than ensuring specific results. For a number of programs that do set performance standards, the technical basis for the standards is weak. In some cases the performance standards reflect calculations of the maximum traffic levels that the local street system can bear rather than estimates of the feasibility of mode shifts, flextime use, and so on. In addition, estimates of mode-shift potential often are "borrowed" from successful programs elsewhere without careful checking that the situations are analogous.

Finally, monitoring and enforcement often are problem areas. Some of the ordinances are silent on these matters; others establish extensive monitoring and reporting requirements but omit enforcement provisions. In a number of cases, the public administrative costs of the monitoring and enforcement are substantial—tabulating and evaluating employer surveys is a major task, for example—but no additional funds have been provided to support these activities. And how to handle cases of noncompliance or substandard performance is an issue even when enforcement provisions are in the ordinance; there is doubt that enforcement actions will ever be taken against recalcitrant developers or employers, given the city attorneys' workloads and the presence of numerous higher-priority matters on their agendas. Sometimes, enforcement becomes a matter of jawboning and is left to the planners and engineers in charge of the program to handle.

How effective are TSM ordinances likely to be? Evidence of their results is limited; most are too new for definitive conclusions to be drawn. Clearly, the ordinance approach avoids some of the limitations inherent in case-by-case exactions, and when applied to existing as well as new developments, the ordinances can address a much larger share of the trips made in congested conditions. Early results suggest that benefits are being produced; automobile trips are being shifted out of peak periods, for example, and modest increases in ridesharing and transit use are occurring.

Nevertheless, questions about effectiveness remain. In many areas through traffic and spillover traffic from neighboring communities is a problem, but this traffic is beyond the reach of a local TSM ordinance. For some TSM measures, cost effectiveness has been questioned; for instance, showers and lockers for bicycle commuters or shuttle services to remote transit stations may not be sufficiently effective to justify the investments of time and money necessary to plan, implement, and maintain them.

In addition, the sustainability of desired effects is at issue. For some TSM measures (e.g., signal retiming and ridesharing), continuing efforts are necessary to maintain the programs' effects. In the signal retiming case it appears that timing plans should be developed every 3 to 5 years in order to maintain benefits—a far cry from most local governments' usual practice, which tends to be to retime signals only when serious complaints develop. In the ridesharing case, ongoing efforts are needed to maintain pools, whose average "life" is less than 2 years absent concerted efforts to find replacement members.

Secondary impacts that could offset the benefits or cancel them out are another concern for certain TSM measures. For example, parking restrictions or high parking prices often are proposed as a way to reduce automobile use; in some cases, however, drivers simply shift to unregulated spaces in residential neighborhoods. And carpooling incentives have led to reductions not in drive-alone commuting but in transit use in some corridors.

Finally, TSM's sufficiency is sometimes in doubt. Shifts to alternate modes on the order of 5 to 10 percent may be attainable through aggressive TSM programs, but this may not be enough to produce acceptable levels of service on freeways and arterials. In Orange County, California, for example, the addition of a high-occupancy-vehicle lane to a congested freeway produced a substantial increase in average automobile occupancy but did nothing to reduce congestion in the peak period since additional travelers quickly took up any slack.

Despite these limitations, TSM programs and ordinances currently are enjoying considerable popularity among local officials pressed for action in response to congestion. TSM is not only affordable but is seen as a relatively painless approach to traffic management—one that is unlikely to arouse much voter hostility (at least as long as commuter participation in the programs is voluntary). It has become an important element of many politicians' plans for "doing something" about traffic.

An interesting new occurrence is the attempt to develop multijurisdictional TSM programs and ordinances, underway in such places as Santa Clara County, Marin County, and Orange County, California. Interest in multijurisdictional approaches appears to have developed because local officials, pressed by citizen activists to take decisive action, feared that developers would simply move to communities without regulations unless there was consistent areawide policy on TSM; because it was feared that spillover effects would undermine the effectiveness of individual localities' TSM efforts; and (perhaps) because areawide planning efforts were seen as less subject to pressure by parochial interest groups. Reaching agreement on the need for areawide, consistent action and on the appropriate measures to undertake has proven difficult so far, but there appears to be a willingness to keep working on these joint efforts (impelled, in part, by the threat of citizen initiatives to stop development until traffic problems are under control). Whether these efforts can succeed in the long run, in the absence of a reward structure for cooperation, remains to be seen.

General Plan, Subdivision Control, and Zoning Approaches

General plans, subdivision control regulations, and zoning ordinances play two different roles in congestion management. First, they are used to establish the basis for or provide the means of implementing transportation exaction and TSM policies such as those discussed earlier. For example, some jurisdictions have added policies to their general plans and subdivision regulations calling for private sector funding of transportation facilities needed to serve new development adequately; these policies provide the basis for exactions. Other jurisdictions have added policies calling for the encouragement of developer and employer participation in ridesharing and transit programs. These policies support TSM requirements.

Another approach to congestion management is to revise general plans, subdivision regulations, and zoning to provide for development patterns and levels that will help reduce overall automobile use. A variety of policies have been utilized, including focusing development in those areas where transportation capacity is available, clustering development and increasing densities to create an environment that makes good transit service feasible, restricting uses that generate large numbers of peak-period automobile trips, and/or reducing the total amount of development that will be permitted. Among the many strategies being used are the following:

- Requirements for consistency between transportation capacity and land use plans and zoning;
- Downzoning to reduce permitted densities to levels that can be accommodated with existing and planned transportation capacity;
- Restrictions on uses that generate large numbers of trips;
- Jobs/housing balance requirements;
- Growth management approaches (e.g., caps on the number of housing permits that can be issued per year and/or the number of square feet of commercial development that can be approved per year, restrictions on annexations and/or public service expansions, etc.);
- Adequate public facilities provisions requiring compliance with minimum performance and level of service standards;
- Conditional zoning setting a range of permitted uses and densities but allowing the more intense uses if impacts are fully mitigated and/or sufficient points are earned for additional publicly desired uses, services, and amenities;
- Density increases and/or bonuses in areas well served by transit or as incentives for developer provision of transit and ridesharing;
- Site design requirements for clustering of buildings to make walking, bicycling, and other commute alternatives more feasible and attractive;
- Subdivision and site plan requirements for bicycle lanes, pedestrian pathways, transit turnouts and shelters, preferential parking areas for carpools and vanpools, and so on; and
- Requirements for the provision of on-site services (e.g., convenience stores in housing developments and restaurants, bank facilities, and child care facilities in office parks) to reduce the need for automobile access to and on the site.

Although each of these strategies has proponents, there remains considerable disagreement about whether they are useful in managing congestion. First, most of the strategies are future oriented; they arguably could shape land use and transportation patterns in the long run but (except when very large projects are at issue) will not necessarily produce an immediate benefit. Moreover, there is no consensus on which strategies are effective. For example, many of the strategies being pursued would restrain development to levels that permit relatively free-flow automobile use. Critics argue, however, that the low-density development that would result practically guarantees that transit provision and rideshare matching will be difficult. In contrast, some experts advocate increasing densities so that transit and walking will be feasible.

Jobs/housing balance proposals illustrate the kinds of arguments that arise. Citing the lack of affordable housing as a cause of lengthy automobile commuting, jobs/housing balance has been proposed as a way to shorten trips. But others question its effectiveness, noting that many factors in addition to commute distance influence housing location decisions. And still others point out that trips in the 3 to 10 mile category would increase under most jobs/housing balance schemes—trips that are too long for walking but too short for most ridesharing schemes to be attractive.

Methodological problems constrain attempts to investigate these issues through analysis and forecasting. The project-level impact analysis approaches most local governments utilize are not particularly useful in considering the kinds of long-term, cumulative effects many transportation-land use measures are intended to produce. Although models of the sort used by regional agencies permit cumulative, areawide analysis, they too have serious limitations. Most require data that are not readily available in the detail needed for subarea analysis, and many represent both land uses and transportation systems at too aggregate a level to be useful for addressing local concerns. In addition, development and application of these models require expertise that rarely is available in local planning and engineering departments. As a result, most jurisdictions must hire consultants to set up such a model for them and often must rely on consultants to do the subsequent analyses of alternatives.

Political acceptability, however, is probably the most important issue concerning coordinated land use-transportation planning. Local officials tend to resist proposals to increase controls over land use despite concerns about congestion; the issues are too controversial. Making land use and transportation plans consistent with each other often would mean either downzoning or developing considerably more transportation facilities and services. Downzoning could lead to conflicts with property owners over development rights or could be unattractive from an economic development/tax base perspective, whereas transportation expansions would raise financial and environmental issues—all problems of the sort local officials try to avoid if at all possible.

Nevertheless, citizen agitation is increasingly forcing more and more communities to take a closer look at the land use strategies, and in some areas citizen initiatives are imposing these strategies. Consequently, local officials are beginning to talk seriously about managing land development and transportation as a system. Efforts are under way in several areas to review land use and transportation plans and programs for consistency, and a few multijurisdictional transportation-land use planning efforts are even being undertaken. How far these efforts will proceed, considering both the stakes involved and the uncertainties, remains to be seen.

IMPLICATIONS FOR PLANNING PRACTICE

Transportation and land use planning in response to congestion raises a number of important issues for planning practice. First, it is apparent that there is a need for greater attention to transportation project and program development at the local level, coordinated with land use planning and zoning efforts. In earlier days it was possible to rely on higher levels of government to provide the needed transportation facilities and services, but those days are over. Local plans that exhort state and regional agencies to provide transportation improvements for which there is no known source of funding do a disservice both to these other agencies and to the local citizenry. Transportation programs developed at the local level and capable of providing a reasonable level of mobility are needed. It must be recognized, however, that local governments will need clear incentives to take on this responsibility—in the first instance, funding will be needed. State action probably will be a prerequisite to more responsible transportation-land use coordination.

Second, it is clear that current methods of analysis are inadequate to the tasks at hand. Estimates of development levels and occupancies, trip generation rates, origin-destination patterns, mode shares, and route choices are needed to arrive at an estimate of congestion levels on particular facilities, but the fact is that local data often are unavailable, so national data sources or regional averages must be used. Projections into the future involve a pyramid of assumptions that are critical to the outcome of the analysis but are difficult to test against real-world experiences. Furthermore, project-by-project analyses are unable to adequately address many areawide and cumulative impacts. These facts suggest that additional case studies, analyses of effectiveness of various measures, and the like would be highly desirable. In the meantime, and at a minimum, professionals should be more explicit about the number of assumptions that have to be made in analyses of traffic, and they should make more use of monitoring and feedback procedures both as a method of control for projects' as-implemented impacts and to fine tune their assumptions and analysis procedures for future use.

A third finding is that lack of training in transportation analysis and land finance/project feasibility analysis limits the ability of local planners to tackle many land use and transportation planning issues; lack of training in planning similarly restricts the ability of engineers to contribute to the policy debates over growth and congestion. Differences in viewpoint between planners and traffic engineers exacerbate these problems. Broader training in transportation analysis methods and land use planning and policy matters would be advisable for both planners and engineers who intend to work at the local government level.

Finally, but equally important, the highly politicized circumstances under which many traffic mitigation efforts take place thrust planners and engineers into roles for which few have had preparation or experience. As the staff responsible for land use and transportation, planners and engineers increasingly find themselves being asked to advise on policy and to get involved in devising compromises between pro- and antigrowth interests, carrying out negotiations with developers and community groups, and developing revenue forecasts and financing plans. Currently, many planners and engineers are uncomfortable in these roles. Education and training in negotiation skills, greater knowledge of government and politics, and more exposure to the techniques of real estate finance and project feasibility analysis would be of considerable value.

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