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Economic, Social, and Energy Effects of Highway Transportation

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Transportation Planning for National Forests

J. S. MATTHIAS AND R. H. WORTMAN

Recent legislation requires that comprehensive national forest planning be accomplished by each National Forest organization. A response to these requirements, methods, and approaches was developed to integrate the transportation planning element into the forest planning process and linear programming as used by the U.S. Forest Service. The paper describes potential planning approaches, planning processes, and the application of linear planning techniques that relate transportation planning to forest resource output and scheduling.

In response to the Forest and Rangeland Renewable Resources Planning Act of 1974 as amended by the National Forest Management Act of 1976, the U.S. Forest Service developed a set of regulations for the purpose of guiding land and resource management planning for national forests and grasslands. During the summer of 1979, the Forest Service through its Rocky Mountain Experiment Station in Fort Collins, Colorado, began the development of a series of training sessions that dealt with land management planning. The basic intent of these sessions was to present pertinent information regarding the integration of the multitude of elements into the planning process to the interdisciplinary teams that would undertake the planning efforts.

Transportation was recognized as one of the important elements in the planning because of the role and implications of access in all forest and forest production activities. The discussion that follows describes the planning concepts that were developed to ensure that transportation planning concerns were placed in the proper perspective and integrated in the forest planning process. Although these concepts focused on forest planning, they could also be applied to other types of comprehensive planning efforts.

Conceptual approaches are presented to the overall forest planning problem as well as a technique that permits the inclusion of the transportation element in linear programming solutions.

The Forest Service planning approach is to use linear programming by means of a program named FORPLAN. FORPLAN identifies resource output quantities and schedules the time the outputs or activities are to be harvested or accomplished. At present, FORPLAN cannot directly accommodate the transportation planning element of forest planning. This study is a report on an initial attempt to develop a procedure that permits the inclusion of transportation planning in forest planning that is compatible with linear programming in the FORPLAN model.

ROLE OF TRANSPORTATION IN FOREST PLANNING

The transportation system includes all modes such as roads, trails, waterways, airports, utility corridors, trail heads, parking lots, and any other facility or means of travel. Although the discussion of transportation usually concerns roads, it should be remembered that all types of transportation are meant.

The forest planning process must include adequate transportation systems analysis, as required by the regulations, because (a) all uses of forest resources and all forest management activities require transportation--either the transportation of the resources to the users or of the users to the resources, (b) scheduling transportation systems development can control resource systems development scheduling, (c) the money cost of transportation is a substantial percentage of any forest agency's expenditures, and (d) the potential physical, biological, social, and economic effects of developing and operating a transportation system are sometimes very significant. Proper transportation systems analysis can be a major factor in minimizing costs and negative effects and maximizing positive effects of transportation.

Any forest resource use requires access by means of the forest transportation system. Whether or not the resource is timber harvest with the consequent timber haul from stump to mill or the arrival of people for recreation, the transportation system provides the means to use the resources. The cost of reaching and using the resources depends on their spatial location, the initial (or ultimate) location of the users, and the means of access. A portion of the resource cost is directly attributable to its cost access. In the case of timber, the cost of hauling from stump to mill partially determines its value. No analysis of forest resources is complete unless an adequate analysis of the transportation cost is included. Transportation costs are production costs.

The integration of the transportation plan and the forest plan will aid in identification of existing and future deficiencies in the transportation system. All resource outputs can be translated into traffic units and assigned to links of the transportation system by using standard transportation planning techniques. Analysis of traffic loads for any time period can reveal when an existing or proposed link will be overloaded, too narrow, or otherwise deficient.

Transportation does provide access and serves to integrate various forest activities. In some forests the problem is developing a road network. For the forests that require additional access, the planning problem is more related to the development of new access. For the forests that have a well-developed road or transport system, the problem is associated more with the management of the existing transportation system, such as limitations on use of roads, operations and maintenance activities, control of access, and abandonment of roads that are no longer needed. Transportation planning is required to ensure that there is a well-organized effort to identify either new access needs or manage the existing access.

CONCEPTUAL APPROACHES TO PLANNING

Three concepts were defined as basic approaches for incorporating transportation planning into the forest planning process. For purposes of discussion, these approaches were identified as

1. reactive,
2. simultaneous, and
3. iterative.

The reactive approach concept is shown in Figure 1. In this approach, the transportation system is planned in response to a given forest resource land allocation and schedule. Little or no consideration is given regarding transport costs in terms of land allocation and resource production scheduling. The concept reflects the traditional transportation planning approach in that the land uses define the

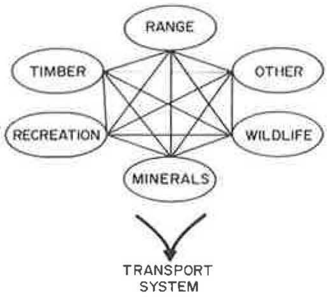


Figure 1. Reactive approach.

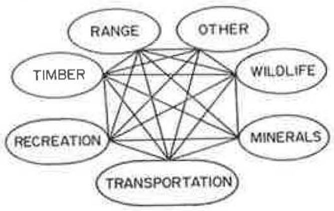


Figure 2. Simultaneous approach.

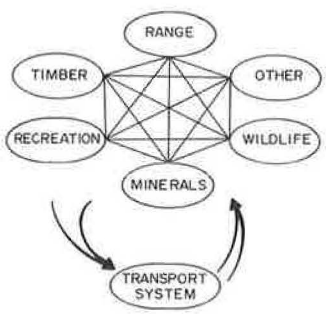


Figure 3. Iterative approach.

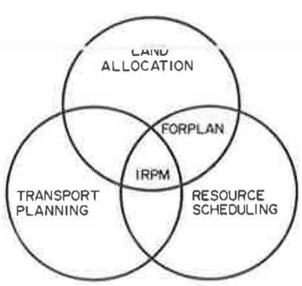
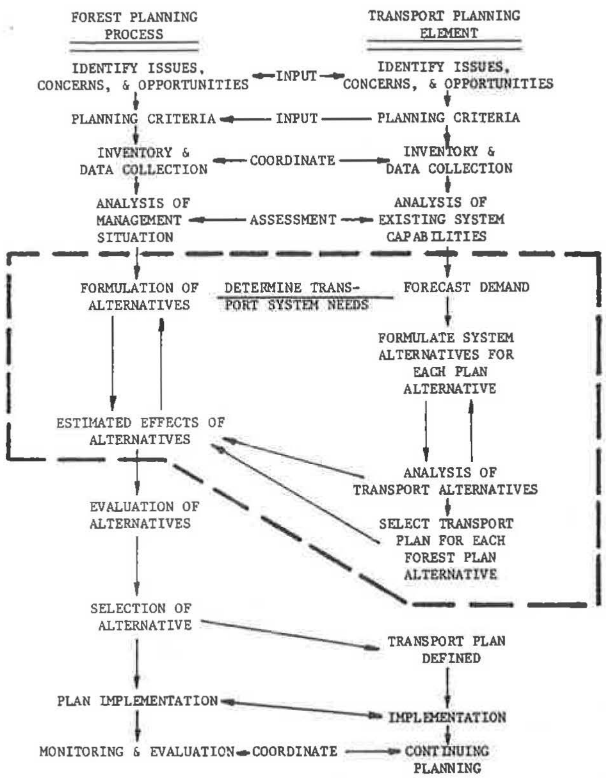


Figure 4. Relationship of planning models.

required transport system. If there is little or no choice in land allocation and resource scheduling, then there is little opportunity to seek other use allocations based on the transport cost input.

Figure 2 reflects the concept associated with the simultaneous approach. In contrast to the reactive approach, the simultaneous approach includes transportation as an integral element in the determination of the optimal comprehensive forest plan. Certainly, this would be the more desirable approach in that transportation is included in the computation of the least-cost solution for achieving forest outputs. In this approach, spatial land use allocations and the transportation system are determined

Figure 5. Forest planning process and transportation planning element.



simultaneously for a given desired resource output level.

Computationally, this approach is very complex because of the variables that must be considered. A model, known as the Integrated Resources Planning Model (IRPM), has been developed by the Forest Service staff. At present, however, this model is limited in the number of land units that may be included because of the computational time requirements. The model does represent the simultaneous approach to the comprehensive planning question.

Figure 3 represents the iterative approach to planning and indicates a method of including transportation as an active element in the allocation and scheduling problem while avoiding the computation difficulties of the simultaneous approach. The concept is a series of iterations in which the transport system defined by the reactive approach is evaluated for the effects on the land allocations. The land allocations are then reassessed and the new transport system requirements are redetermined. The process is iterated until land allocations and transport system requirements are stabilized.

The overall relationship of planning models is depicted in Figure 4. Three general areas of planning are depicted. They are

1. land allocation,
2. resource scheduling, and
3. transportation planning.

IRPM represents the incorporation of all three areas and reflects the simultaneous approach. The Forest Service currently uses a model, FORPLAN, that incorporates the land allocation and resource scheduling areas. Basically, FORPLAN uses linear programming in the solution for an optimal plan. An iterative approach, therefore, must be used in incorporating the effects of transportation in determining a comprehensive forest plan.

PLANNING PROCESS

The regulations developed by the Forest Service governing land management planning specified the steps to be included in the forest planning process. The task, therefore, was to develop a transportation planning element that could be integrated with the forest planning process.

Figure 5 shows the forest planning process and the conceptual approach to integrating the transportation planning element. Each step of the forest planning process has a related step in the transportation planning element. One process cannot advance or even be completed without the other being addressed. In essence, the whole planning effort must be closely coordinated. The portion of the process enclosed by the dashed line will be discussed in a later section of this paper.

The issues and concerns are identified by public response to forest service requests, public hearings, and forest service management concerns. The forest plan is developed to respond to the issues and concerns from local, regional, and national sources. Most, if not all, issues and concerns will either be transportation oriented or at least involve access requirements.

Planning criteria are developed both for evaluation of alternatives and for decision purposes. The criteria selected for transportation should reflect the broader forest goals and objectives.

For the inventory and data-collection phase, there is the need to coordinate the requirements for the transportation element with those for the forest plan. The nature and format of data must be well defined in order to eliminate duplication of data collection for the various disciplinary areas. For example, the traffic analysis zones should be coordinated with the boundaries of the forest plan analysis and management areas.

The analysis of the management situation is the determination of the range of forest resource outputs that can be obtained based on various management levels, one of which is a stewardship level, or simply maintain the forest as it is. Another level is the maximum timber output. This section of the planning process will determine the range in which feasible forest plan alternatives can be developed. For this part of the process, it is necessary to assess the capabilities of the existing transport system to serve those management levels. In essence, potential transport system deficiencies are defined.

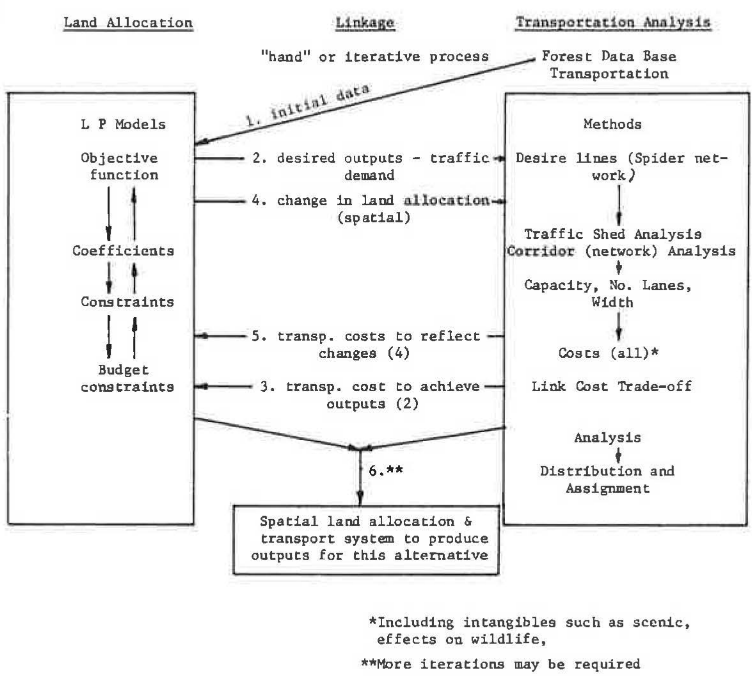
Those steps enclosed by the dashed line reflect the interactive process of developing a transportation plan for each of the forest plan alternatives. Given a forest plan alternative, the transport system needs are defined and the travel demand forecast is made. Transport system alternatives are generated and assessed. The effects of the transportation system are input to the forest plan alternative to determine the effect on the plan. If necessary, the forest plan is modified and the transport system alternatives are reassessed. The process is cycled until no further adjustments in the forest plan or the transport system are required. The output of the process is the definition of a transportation plan for a given forest plan alternative. It is necessary to undertake this analysis for each of the forest plan alternatives that are being considered.

Once the forest plan alternatives are evaluated and a plan is selected, the transportation plan is automatically defined because of the earlier analysis. At this point the effort focuses on implementing the forest plan along with its corresponding transportation plan.

APPLICATION OF LINEAR PROGRAMMING

Because the FORPLAN model used linear programming techniques, it is advantageous to develop analysis methods that can integrate transportation cost effects into FORPLAN. Figure 6 shows the linkage process by which transportation analysis can be accomplished, cost coefficients developed, a transportation system developed for a given set of forest resource outputs, and a schedule. This process uses an iterative approach in that linear programming coefficients are adjusted based on changes to land allocation of resources and schedules caused by changes in the transportation system and costs. Figure 6 again reflects that portion of Figure 5

Figure 6. Land allocation and transportation system linkage.



outlined by the dashed line, except that Figure 6 depicts the analysis in terms of a linear programming approach. The initial step, shown as (1), is the inclusion of the cost coefficients that reflect the existing transportation system.

FORPLAN will produce land (resource) allocations and a schedule for producing the resources. This will indicate traffic demand shown as (2). Normal transportation analysis techniques are then used to develop the transportation system required for the desired outputs. Revised transportation costs (3) are developed and placed into the FORPLAN and a new allocation (4) is made. This is the iterative process and it can be continued until changes in the land allocation and/or schedule cease to require significant changes in the transportation system.

In the FORPLAN model linear programming is used to allocate forest resource outputs and schedules the outputs. To illustrate the application of linear programming the following example was developed by using only timber and recreation as resource outputs. This example was developed by the land management planning staff. In this example there were 100 000 acres that could be allocated to timber and recreation. There was also a requirement to produce at least 20 000 000 board feet (BF) of timber, and there were between 40 000 and 400 000 recreation visits. In this example, timber can be cut at 400 BF/acre, but this results in no use for recreation. If timber is cut at a rate of only 100 BF/acre, then 20 recreation visits/acre can be realized. These conditions are shown in the total cost column and include the initial cost of transportation. The objective function equation is maximize net revenue (Z) = $60_2{}^1 + 95_2$ where 1 refers to acres of timber emphasis and 2 refers to acres of recreation emphasis.

The formulation of the linear programming model is shown in Figure 7a and the graphical solution is shown in Figure 7b. The optimal solution is vindicated by point C. This graphical solution indicates an allocation of 80 000 acres to timber and 20 000 acres to recreation emphasis.

But what happens if the transportation system will not permit the use of the resource levels determined by the timber specialist and the recreation specialist? The existing transportation system cannot safely accommodate the traffic generated by the resource levels that the land can generate, for example.

There are several options. Outputs can be reduced to a level that will not overload the transportation system. This is shown as option 1 (see Figure 8a): 20 $_2$ ≤ 300 000 and/or 400 $_1$ + 100 $_2$ ≤ 20 000 000 to 375 $_1$ + 75 $_2$ ≤ 20 000 000. This says that the system can handle no more than 300 000 recreation visits and no more than a timber harvest of 375 BF/acre and 75 BF/acre if the transportation system capacity (as planned) is not to be exceeded.

Figure 8a shows graphically the effects on the optimal solution of changing only the recreational constraint: 20 $_2$ < 300 000; $_1$ = 85 000 acres, $_2$ = 15 000 acres. The changes in costs are shown in Figure 8b.

Another option might be to upgrade the road system so that the resource output levels determined in Figure 8a might be achieved (remove transportation system constraints).

This will increase the costs of the resources due to the costs required to improve or upgrade the transportation system. This would include construction, maintenance, operational, and user costs. For example, timber costs increase from $10.00 to $15.00 and recreation from $1.00 to $2.00.

The resulting changes in the objective function are shown in Figure 9a; in the graphic illustration in Figure 9b, note there is no change in the feasible region.

A third option is to change the existing road system in such a way as to maintain costs used or even reduce costs. For example, the existing road network may be shortened by construction of a new link; an entirely new route may be substantially

Figure 7. Formulation of linear programming model: (a) basic timber and recreation allocation and (b) basic graphical solution.

(a)

Resource Emphasis	Timber Revenue Volume (Bd. Ft/Acre)	Net Value*	Recreation Revenue Visits/acre	Net Value**	Total Network	Total Cost
Timber	400	$150 x 0.4 = $60	0	0	$60	$ 4
Recreation	100	$150 x 0.1 = $15	20	$4 x 20 = $80	$95	$21

Max. Net Revenue = 60 x_1 + 95 x_2 Max. Z = 60 x_1 + 95 x_2

Subject to: 1. X_1 + x_2 100,000

2. 400 x_1 + 100 x_2 20,000,000

3. 20 x_2 40,000 * $150/thousand board feet

4. 20 x_2 400,000 ** $4/visit

5. x_1 0, x_2 0

Budget cost 4 x_1 + 21 x_2 + $740,000

(b)

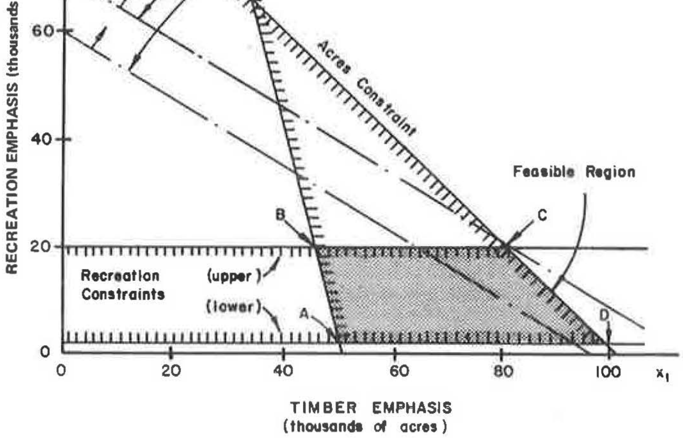
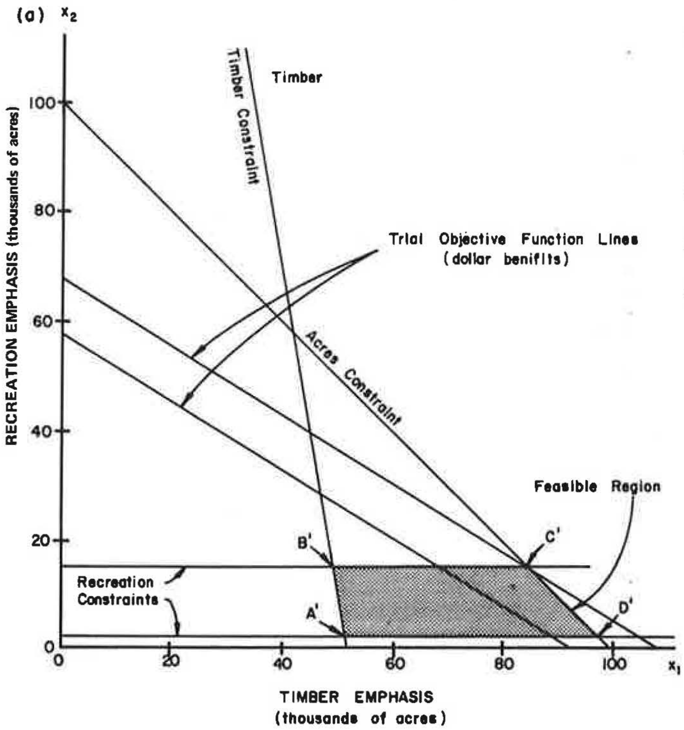


Figure 8. Option 1: (a) graphical solution and (b) changes in cost–problem formulation.



(b)

Changes in cost functions

	Timber			Recreation		
Volume		Value	Volume	Net Value	Total Net Value	Total Cost
Timber 375	$150 x .375 =	$56.25	0	0	$56.25	$ 3.75
Recreation 75	$150 x 0.75 =	$11.25	25	$4 x 20 = $80	$91.25	$20.75

Max. net revenue $56.25 x_1 + 91.25 x_2 = $6,150,000, a decrease of $550,000

Costs:

3.75 x_1 + 20.75 x_2

3.75 (85,000) + 20.75 (15,000) = $630,000, a decrease of $110,000

Figure 9. Changes in cost: (a) option 2 problem formulation and (b) graphical solution.

(a)

	Timber		Recreation			
	Volume	Net Value	Visits	Net Value	Total Net Value	Total Cost
Timber	400	145 x .4 = $58	0	0	$58	$ 6
Recreation	100	145 x .1 = $41.5	20	3 x 20 = $60	$74.5	$41.5

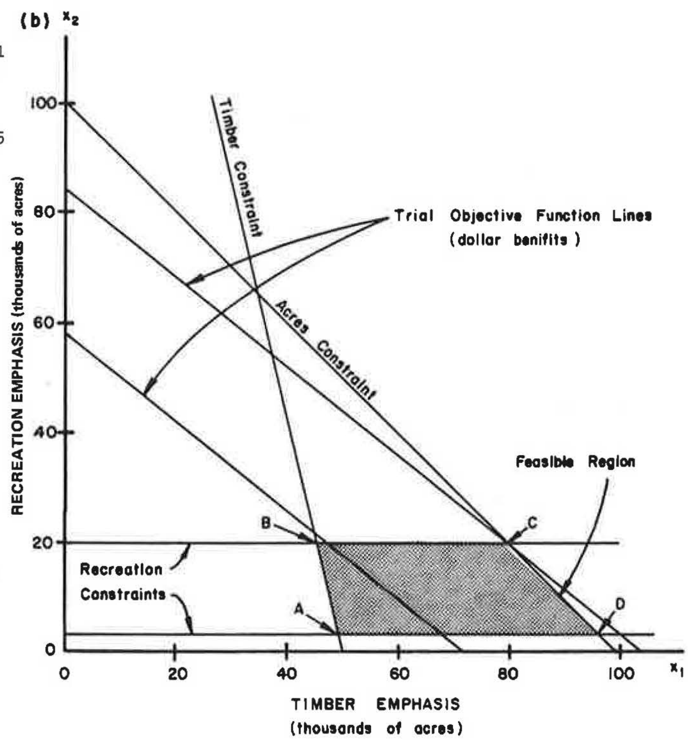
Max. net revenue = 58 x_1 + 74.5 x_2 or 58 (80,000) + 74.5 (20,000)

= $6,130,000, a decrease of $570,000

Costs:

6 x_1 + 41.5 x_2

6 (80,000 + 41.5 (20,000)) = $1,310,000, an increase of $570,000



cheaper (construction, maintenance, operating, and road user costs) than upgrading (or reconstructing) the existing route, with reduced operating and maintenance costs. Abandonment of excess mileage can also save operating and maintenance costs.

Assume a road system can be built that is shorter and thus will reduce maintenance, operating, and road user costs (new roads normally do this). This will change the production costs for timber and recreation. Figure 10a shows the changes and Figure 10b shows the graphic illustration. Costs for timber were reduced by $2.00, from $10.00 to $8.00, and costs for recreation were reduced from $1.00 to $0.50.

Figure 10. Changes in cost: (a) option 3 problem formulation and (b) graphical solution.

(a)

	Timber		Recreation		Total	Total
	Volume	Net Value	Volume	Net Value	Net Value	Cost
Timber	400	152 x .4 = \$60.8	0	0	\$ 60.8	\$ 3.20
Recreation	100	152 x .1 = \$15.1	20	\$4.5 x \$20 = \$90	\$105.20	\$10.8

Max. net revenue: $60.8\ x_1 + 105.2\ x_2$

Cost: $3.2\ x_1 + 10.8\ x_2$

For $x_1 = 80{,}000$ & $x_2 = 20{,}000$

Revenue = 60.8 x (80,000) = 4,864,000

105.2 x (20,000) = 2,104,000

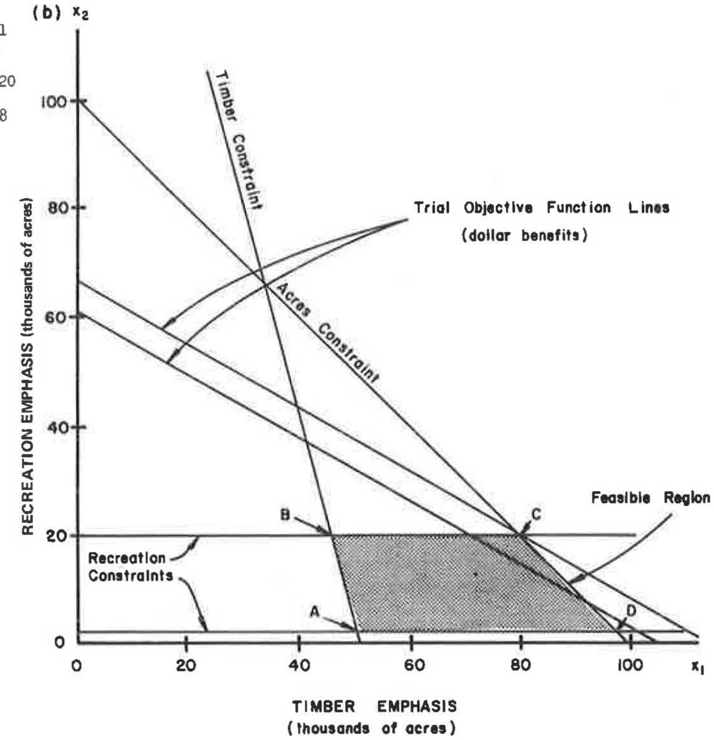
6,968,000 and increases of \$268,000

Costs = 3.2 (80,000) = 256,000

10.8 (20,000) = 216,000

472,000 a reduction of \$268,000

(b)



This example problem shows the manner in which transportation costs can affect the cost of resource outputs. This is true for forest outputs or for any resource that requires transportation.

Although this example did not address the spatial location of the allotments to timber and recreation, the same rationale can be used to determine the land use arrangement that will produce the desired resource outputs at the most efficient transportation costs.

The process developed should ensure the integration of transportation planning to produce a land use plan and schedule that will result in cost-efficient production of forest products.

CONCLUSIONS

The development of a transportation planning approach for use in forest planning presented a rather unique challenge because of the comprehensive nature of the planning process and the potential trade-offs between transportation and forest use allocations. Also, the process and models had to be compatible with those used in other aspects of the forest planning process.

Ideally, a simultaneous approach would be the most desirable attack on the problem. For a large-scale area, the solution of a problem of this magnitude is restricted by computational capabilities at the present time.

The alternative to the simultaneous approach is one that uses an iterative process whereby use allocations are adjusted based on the transportation requirements. In this case, it is possible to incorporate the transportation element into the linear programming models that are currently used in forest land use allocations and scheduling.

Although this effort focused on forest planning, it does represent an attempt to deal with planning on a comprehensive basis. The concepts and approaches that were used certainly merit consideration for application to other comprehensive planning situations even though considerable work remains prior to having a fully developed planning process.

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Abridgment

Economic Impact of I-78 in Allentown, Pennsylvania

FRANCIS X. MAHADY AND DIANNE C. TSITSOS

One of the remaining gaps on the Interstate system, I-78 in Allentown, Pennsylvania, has had a controversial history. Despite the existence of an approved final environmental impact statement, the Pennsylvania Department of Transportation agreed to a re-study of an alternative alignment to that recommended in the environmental impact statement. The re-study was a result of local officials' dissatisfaction with the economic analyses performed and their fear that the recommended route would enhance suburban development potential at the expense of Allentown's central city. Their fears were grounded, in part, in a study of the probable economic impacts of I-78. The study, sponsored by the City of Allentown and conducted by Economics Research Associates, found that construction of the roadway would lock in existing investment trends that heavily favored a suburban alignment. An alternative route would improve access to the central city, enhancing its development potential. Following publication of the study, a central city development committee was formed. This group included public officials, center city business representatives, and local bankers. Meanwhile, state and federal officials agreed to reconsider an alternative alignment for I-78.

Interstate 78 in the vicinity of Allentown, Bethlehem, and Easton, Pennsylvania, has had a long and controversial history. Now one of the remaining essential gaps on the Interstate system, construction of a new roadway or reconstruction of existing and heavily traveled TR-22 between Easton and Allentown would connect points west with northern New Jersey and the greater New York metropolitan area. A final environmental impact statement (EIS) was approved in 1980 for construction of a 54.4-km (34-mile) bypass segment south of the three cities. By then, the cities--with the assistance of environmentalists and suburban groups--had successfully argued for a reduction in the number of suburban interchanges from 11 to 3. However, Allentown officials still feared that, in spite of the reduction, the highway's planned alignment would encourage suburban development at the expense of the city's economy and tax base.

The city's tax and employment bases had, in fact, eroded in recent years during a time in which significant residential, industrial, and commercial investments were being made in outlying areas. Exacerbating these concerns were reported development plans for major tracts of land south and west of the city, which contributed to Allentown officials' fears that the prevailing trend toward suburban investments might worsen with the accessibility improvements to be provided in these areas by I-78. Controversy centered on the 20.8-km (13-mile) segment of the approved Southern Bypass route immediately south and west of Allentown.

In September 1979, the City of Allentown contracted with Economics Research Associates to prepare an independent assessment of how I-78 would affect downtown business in particular and the city's economy in general. The study had three major components: a critical literature review to examine how other bypass facilities had affected cities of similar size and characteristics elsewhere, a transportation analysis (conducted by Alan M. Voorhees and Associates), and an analysis of these two components along with the particular characteristics of the Allentown economy.

The analytic framework used was applied to five alternatives for I-78:

1. The South, or suburban bypass route, as approved in the final EIS;
2. The North route, which would be constructed along an existing highway corridor (TR-22);
3. The no-build, with no major improvements in the existing network;
4. The no-build, with major improvements to existing east-west and north-south collector/distributors; and
5. A modified version of the Southern Bypass that would substitute the planned suburban western portion with reconstruction of an existing highway (Route 309) closer to Allentown.

STUDY METHOD

Local officials were particularly interested in actual cases of bypass effects on central city economies of similar communities, so the first step of the method was a review of the literature (see 1-15). The majority of the studies examined were retrospective in nature. Since the Allentown study required projecting impacts, a simultaneous investigation of the local economy was undertaken. Field inspections, extensive personal interviews, analysis of available statistical data, and critical review of past reports comprised the research. This approach resulted in the development of two alternative local investment scenarios under which each of the I-78 alternatives could be evaluated. The final document contained recommendations to the city regarding the alternative most likely to produce the optimum development climate for Allentown's central city.

ECONOMIC CLIMATE

Under any I-78 alternative, the single most important factor affecting the magnitude and direction of future growth in Allentown's economy was found to be the degree of commitment by private and public leadership to investment in the central city. This finding is consistent with past studies in similar areas, which have generally found that preexisting trends in local economies have been the real determinants of how the construction of a particular highway affects an area. The roadway may intensify certain trends but is unlikely to create new ones.

This result of the literature review provided a framework within which to investigate the economic climate of Allentown's central city. The investigation included the city's development context, local employment characteristics, and retail activity.

Development Context

On the public side, Allentown now provides financial and tax incentives to encourage economic development, as well as services and amenities that research cites as increasingly important variables in business and work force location decisions. The city's labor force, economic base, and infrastructure are adequate to support existing and prospective new development.

On the private side, however, Allentown's financial personnel had not been aggressively pursuing central city investments. Their past behavior had contributed to a conservative attitude regarding such investments that had tended to discourage other venture capitalists. This posture had resulted, in part, from the influence of the preferred alignment of I-78, which appeared to have encouraged investment in suburban areas.

Employment and Retail Activity

In both of these areas, the City of Allentown has held a fairly strong and stable position relative to the rest of Lehigh Valley (Lehigh and Northampton Counties). The city holds approximately 55 percent of the county job total and more than 60 percent of county manufacturing employment.

The city has shown per-capita retail sales consistently higher than the average for the two-county area and has held a constant share of regional sales since 1974. It appears that, at least with respect to retail sales, suburban growth has not had a deleterious effect on Allentown's economy.

TRANSPORTATION SYSTEM

Travel demand forecasts for each of the I-78 alternatives were reviewed by Alan M. Voorhees and Associates under subcontract to Economics Research Associates. The review concluded that travel forecasts were reasonable, given expected growth in the area, and that use of the alternative alignment (an existing state route) for I-78, as preferred by the City of Allentown, would require reconstruction of the facility from four to six travel lanes.

The service to be provided by I-78 is considered critical to development in the area. The no-build alternative is unacceptable because of predicted service failures on other state routes in the near future. Purely on transportation grounds, the analysis found both the alignment recommended in the final EIS and that favored by city officials to provide adequate travel service.

ECONOMIC IMPACTS OF I-78 ALTERNATIVES

Review of case studies documenting the impacts of bypass highways on central city economies suggests that trends in evidence prior to the highways' construction are likely to be reinforced. Since the positioning of the financial community in Allentown is significant to the establishment of positive or negative trends in the city's economy prior to the implementation of any transportation improvement, two impact scenarios were posited for each of the I-78 alternatives: The first assumed an altered position in central city investments, with core development significantly increased over the next 10 years, while existing city businesses receive capital support for their maintenance and improvement. It would tend to enhance development potential and other beneficial effects associated with accessibility improvements.

The second scenario assumed no change in prior investment trends, which would have tended to depress development potential and exacerbate other negative central city effects associated with accessibility improvements in outlying areas.

STUDY CONCLUSION

The study concludes that the I-78 alignment along the reconstructed state route, coupled with an altered investment scenario, offers the best opportunity to provide needed interregional and local travel improvements without damaging a healthy central city economy.

Since circulation of the study, a development committee was formed to bring together representatives of financial institutions, the central city business community, and public officials to consider the research recommendations, with very positive results reported since that time. Meanwhile, state and federal transportation officials have agreed to back up the process somewhat, in spite of the existence of an approved final EIS, in order to accommodate city concerns. It appears now that a solution satisfactory to all parties is possible, thus allowing at last the construction of this essential Interstate segment.

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Abridgment

Interstate Highway System and Development in Nonmetropolitan Areas

RONALD BRIGGS

The current revival of development in small urban and rural communities is one of the more dramatic changes in socioeconomic trends in this century. Since other writers have suggested that the Interstate Highway System played a key role, this paper empirically examines the relationship between the location of freeways and migration and employment change between 1950 and 1975 in all nonmetropolitan counties in the United States by using both descriptive statistics and regression models. The results show that, while counties with freeways as a group have higher average growth rates, even after confounding factors such as proximity to metropolitan areas and presence of urban population concentrations are controlled, the presence of a limited access highway is far from an assurance of development for an individual county. Tourist services are the industry most closely associated with Interstates but, contrary to common conceptions, manufacturing and wholesaling are not clearly associated. The Interstate system was less able to explain the spatial pattern of development than nontransportation factors. Its role appears to have been to raise accessibility levels throughout the nonmetropolitan United States, which has benefited many communities, not just those adjacent to Interstates.

In the 1970s, nonmetropolitan areas--i.e., small towns and rural communities beyond the sphere of influence of major metropolitan centers--experienced a major revival in demographic and economic development (1). Several writers (2-4) suggest that changes in transportation, particularly the development of the Interstate Highway System, played a key role in this reversal of trends in existence for much of this century. Unfortunately, most highway impact studies examine urban rather than rural highways, single projects rather than complete systems, and short- as opposed to long-term impacts (5). Apart from Bohm and Patterson (6) and Lichter and Fuguitt (7), the few studies that address the impacts of the Interstate Highway System on nonmetropolitan development (8-13) are limited in scope, contradictory in their findings, or have methodological inadequacies. They do not permit a definite answer regarding the role of the Interstate in nonmetropolitan development, which was the purpose of the research reported on here (14).

DATA AND METHODOLOGY

The study encompassed all nonmetropolitan counties in the coterminous 48 states, that is, counties outside standard metropolitan statistical areas (SMSAs). An Interstate coding, derived from a computerized administrative data file maintained by the Interstate Reports Branch of the Federal Highway Administration, classified counties as (a) with an Interstate, if 50 percent or more of the planned official Interstate mileage was open to traffic by a given date (1960, 1970, 1975); (b) on System without Interstate, if less than 50 percent of the planned mileage was open; or (c) off System, if the county had no open or planned Interstate mileage. An essentially similar freeway coding included all limited access highways and required that a link be complete to a metropolitan center before a county was considered to have an open freeway.

Annualized county net migration rates, based on U.S. Bureau of the Census data, were calculated for 1950 to 1960, 1960 to 1970, and 1970 to 1975. Rates of employment change were similarly calculated by using U.S. Census of Population data for 1950-1960 and 1960-1970 and Bureau of Economic Analysis (BEA) data for change from 1970 to 1975. (Note that the census data are place-of-residence based and count people, whereas the BEA data are place-of-work based and count jobs.) In addition, the industries examined were those that theory or previous empirical study suggested were associated with freeways, and included (a) retailing, (b) tourist-related industry (defined as eating and drinking establishments, lodging places, and amusement and recreation services), (c) manufacturing, (d) trucking, and (e) wholesaling.

The study then proceeded in four main stages. First, a descriptive analysis was undertaken of the effect of Interstates on net migration, controlling for a series of factors that could produce a spurious relationship between demographic change and the presence of Interstates. Second, a similar analysis for employment change was conducted. Third, a simple model of the interrelationship among Interstates, employment change, and net migration was tested by using path-analytic procedures. Fourth, the importance of the Interstate system relative to other factors influencing migration was assessed.

RESULTS

Demographic Change

In every decade counties with an Interstate highway experienced higher average rates of net migration than those without Interstates (Figure 1). The same is true when other migration measures are used, such as aggregate migration rates, proportion of counties gaining by net inmigration, and proportion experiencing turnaround from net outmigration to net inmigration (14). Although this demonstrates a clear association, it is far from proving a causal link proceeding from highways to migration. For instance, Interstates may have been planned or constructed through counties already experiencing higher migration rates. Counties adjacent to SMSAs receive population spillover from these centers and are more likely than nonadjacent counties to have an Interstate since these highways link metropolitan centers. Nonmetropolitan counties with urban population concentrations have generally experienced higher migration rates and again are more likely to have an Interstate because of their larger size. However, there is evidence to suggest a causal effect of freeways on migration that is independent of these possible confounding factors.

If counties on the Interstate system are classified according to date of highway opening (Table 1), migration rates for any one time period are (a) highest for the counties where the Interstate opened in the previous decade and (b) highest for the counties where an Interstate opened during the migration period being considered. In other words, the opening of an Interstate during one decade is associated with above average rates of net migration during the following decade. This temporal sequencing, in which the cause precedes the hypothesized effect in time, provides solid evidence for the existence of a causal impact of Interstates on migration, which cannot be explained by prior growth rates. Similarly, when adjacency to metropolitan centers and size of urban population concentrations are controlled (Figure 2), an effect of Interstates still emerges.

Employment Change

Generally, employment change is also associated with the Interstate System (Table 2), even after adjacency to SMSAs and size of urban population concentrations are controlled (14). The major exception is the lack of association for manufacturing and wholesaling, which is a surprise, given the many statements in the literature that both are accessibility dependent.

Interrelationship of Demographic and Employment Change

Interstates may affect migration directly as well as indirectly through changes in employment opportunities that, in turn, affect migration. In order to assess this interrelationship, as well as identify the types of industries most affected by limited access highways, path-analytic procedures were applied to the simple causal model in Figure 3 (7).

In contrast to the earlier findings, the results suggest a weak relationship at best between freeways and demographic and employment change (Table 3). The partial correlation coefficients (controlled for adjacency to metropolitan areas and size of largest city in county) are very low, as are the standardized regression coefficients (beta weights). Apart from this, the most notable feature is the minor role of manufacturing and wholesaling and, comparatively, the overwhelming effect of tourism employment. (The initially striking differences between the 1960s and 1970s results primarily reflect the way employment is measured.)

Other Factors Affecting Migration

From the literature, five categories of factors influencing nonmetropolitan change were identified: urbanization, industrial base, social base, government activities, and environmental amenities. With net migration for each of the the three time periods as the dependent variable, regressions were run for variables within each of these categories as well as for all variables together. Figure 4 plots the multiple coefficients of determination (R^2) for re-

Figure 1. Annual net migration rates 1950-1960, 1960-1970, and 1970-1975 by presence of Interstate highway at end of migration period.

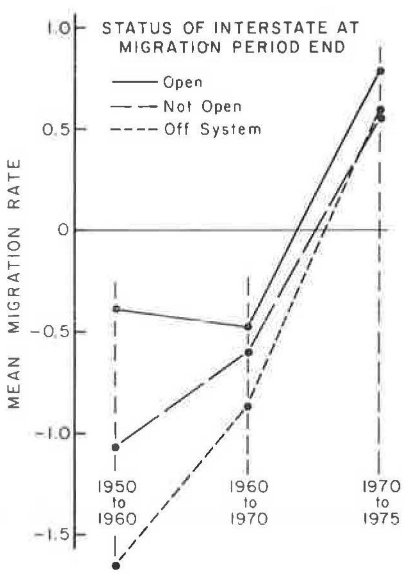


Table 1. Migration rates by date of opening of Interstate highway.

	Interstate System Counties Date of Opening			
	Before 1960	1960-1969	1970-1974	After 1974
Migration Period	4	5	6	7
Mean annual rate of net migration				
1950-1960	-0.393	-1.209	-0.884	-0.874
1960-1970	-0.434	-0.505	-0.585	-0.648
1970-1975	0.370	0.864	0.765	0.538
Number of counties	73	466	160	97

Figure 2. Annual net migration rates for counties with an open freeway compared with counties off the Interstate Highway System and without a freeway, controlled for size of largest place and proximity to metropolitan areas.

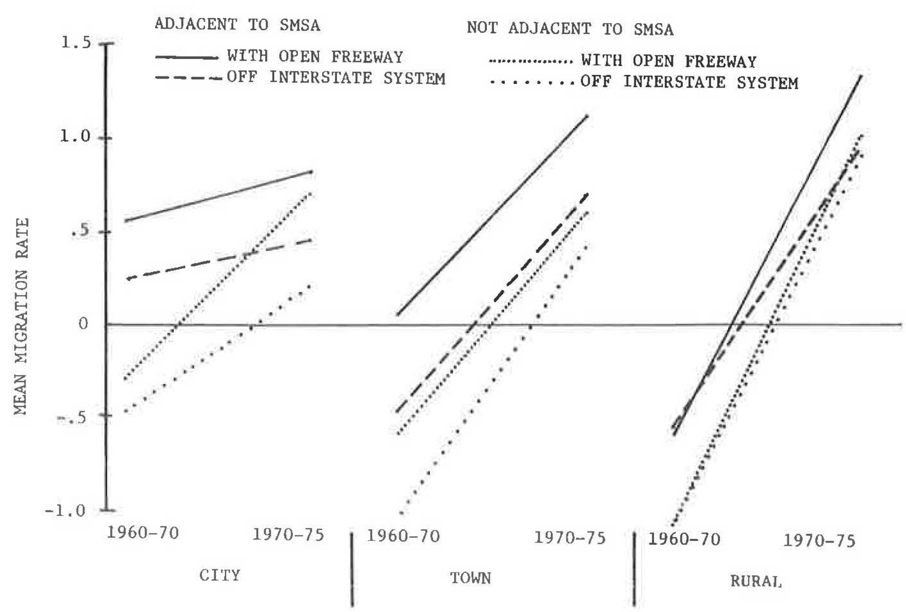


Table 2. Aggregate annual employment growth rates for counties with and without freeways.

	1960 to 1970[a]			1969 to 1975[b]		
		Without a Freeway			Without a Freeway	
Industry	With a Freeway	On System	Off System	With a Freeway	On System	Off System
Total	1.95	1.59	1.09	1.50	1.76	1.36
Retail	2.49	2.07	1.62	2.90	2.17	1.83
Manufacturing	2.48	2.63	2.82	-0.50	1.25	-0.04
Tourist	2.76	2.23	1.71	4.07	3.04	3.19
Trucking	2.14	1.92	1.05	2.92	3.66	2.37
Wholesaling	3.45	3.15	2.44	8.99	7.60	11.60

[a]1960 SMSA definition.
[b]1970 SMSA definition.

Figure 3. Model of the impact of limited access highways on employment and demographic change in nonmetropolitan areas.

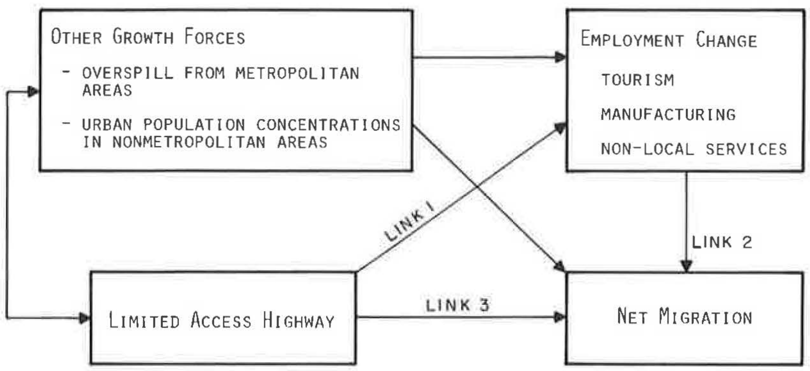
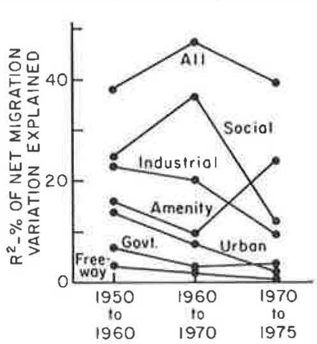


Table 3. Effects of freeways on employment growth and net migration: path-analysis results.

Employment Areas	Partial Correlation Coefficient[a]	Direct Effect of Freeway on Endogenous Variable (Beta Weight)	Indirect Effect of Freeway on Endogenous Variable (Beta Weight)	Indirect Effect as a Percentage of Total Effect
1960-1970				
Migration	0.07	0.020	-	-
Manufacturing	0.04	0.051	0.005	6.6
Tourism	0.07	0.090	0.042	57.1
Trucking	0.04	0.044	0.004	4.9
Wholesaling	0.02	0.028	0.003	4.8
1970-1975				
Migration	0.08	0.053	-	-
Manufacturing	0.005	0.005	0.0001	0.2
Tourism	0.03	0.030	0.0178	25.3
Trucking	0.03	0.029	0.0001	0.2
Wholesaling	-0.02	-0.016	-0.0005	-

Note: All regression equations include three dummy variables as exogenous controls indexing adjacency to metropolitan areas, counties with cities of more than 10 000 population, and counties with cities between 2500 and 10 000 population. The total effect of freeways is the regression coefficient in a model regressing net migration against the three exogenous control variables and the freeway variable. The results were 1960-1970, beta = 0.074 and 1970-1975, beta = 0.071.
[a]Between freeway and endogenous variable controlled for adjacency and size of largest place.

Figure 4. Relative ability of different factors to explain nonmetropolitan county net migration rates, 1950-1975.



gressions within each category, and Table 4 gives the beta weights and R^2s for all variables together. The break-in-slope in Figure 4 between the 1960s and 1970s indicates a change in the processes underlying migration in the 1970s. However, the consistently small R^2s for the Interstate variables and the small beta weights and negligible increments to R^2 suggest that the Interstate Highway System is less able to explain variation in county migration rates than any other factor examined.

CONCLUSION

Two primary questions are raised by this research. First, why did the first two parts of the study suggest an impact of Interstates on nonmetropolitan development, whereas the last two parts suggest little influence? The resolution of this apparent

Table 4. Standardized regression coefficients for variables hypothesized to influence net migration rates in nonmetropolitan counties: 1950-1960, 1960-1970, and 1970-1975.

Factor	1950s	1960s	1970s
Urbanization			
Adjacent to SMSA	0.056	0.105	0.087
City present	0.125	-0.075	-0.162
Town present	0.053	-0.043	-0.105
Industrial base			
Agriculture (%)	-0.146	-0.239	-0.413
Mining (%)	-0.145	-0.248	-0.200
Manufacturing (%)	-0.134	-0.068	-0.239
Social base			
Median income	0.351	0.240	-0.061
Black (%)	-0.069	-0.087	-0.227
Retired population	0.053	0.438	0.195
Government			
Administration (%)	0.013	0.017	-0.026
College present	-0.048	0.093	-0.037
Military (%)	0.043	-0.054	-0.182
Amenity			
Warm winter	0.096	0.015	0.109
Mountain	0.070	0.091	0.109
Coast	0.216	0.022	0.074
Lakes	-0.002	0.019	0.011
2nd homes	-0.009	0.079	0.227
Recreation	0.055	0.031	0.170
Other transportation			
Rail present	-0.062	-0.011	-0.018
Air present	0.050	-0.028	0.046
Freeways			
Open	-0.003	0.015	0.073
New	-	0.026	-0.230
Not yet open	0.061	0.003	-0.006
Coefficients of determination			
All variables	0.383	0.471	0.389
Freeways excluded	0.380	0.469	0.385

contradiction is that, on average, counties with an Interstate have indeed experienced higher rates of migration and employment change. However, the experience of individual counties has been extremely varied with much overlap in growth rates between counties with and without Interstates. The policy planning implication is that the presence of an Interstate is no guarantee of community development, but neither is its absence a precursor of community demise as might have been the case in an earlier era with the railroad. Second, why is there a generally weak relationship between the Interstate system and development, especially in manufacturing, for example? The major effect of the Interstate may have been to raise accessibility levels throughout the nonmetropolitan United States. Consequently, their effect has not been as locationally specific to areas in close proximity to freeways as is commonly expected.

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Abridgment

Improving Minority Participation in Regional Planning

PETER M. LIMA

This paper describes the steps taken by one regional advisory group, the Citizen's Advisory Board to the Omaha-Council Bluffs Metropolitan Area Planning Agency, to improve participation by blacks in the regional planning process. The Omaha-Council Bluffs metropolitan area, the characteristics of Omaha's black population, and the current citizen participation process in the metropolitan area are described and the impacts of regional planning decisions on minorities are discussed. Several actions are then recommended to improve minority participation including (a) recruitment, (b) education, (c) involvement, and (d) evaluation and feedback.

This paper describes how minorities currently become involved in the regional planning of the Omaha-Council Bluffs metropolitan area and presents recommendations for improving minority participation at the regional planning level. The suggested recommendations herein are based on some initial steps taken by the Citizen's Advisory Board (CAB) to the Omaha-Council Bluffs Metropolitan Area Planning Agency (MAPA) to improve participation by black individuals and groups. Although it is much too early to fully assess the long-range impact of these steps on increasing participation by blacks in the regional planning of the Omaha area, I have chosen to present the approach taken by the CAB before it has been fully assessed in order to stimulate discussion among planning professionals.

The remainder of the paper is organized into five sections: (a) characteristics of Omaha's black population, (b) the impact of regional planning on minorities, (c) current citizen participation in regional planning, (d) improving participation, and (e) concluding remarks.

CHARACTERISTICS OF OMAHA'S BLACK POPULATION

The Omaha-Council Bluffs metropolitan area is a major midwestern region centrally located within the United States. The standard metropolitan statistical area (SMSA) is comprised of Douglas and Sarpy Counties, Nebraska, and Pottawattamie County, Iowa, and includes more than 20 incorporated cities, towns, and villages (1, p. 5). Among these municipalities, the three most important are the Cities of Omaha and Bellevue, Nebraska, and the City of Council Bluffs, Iowa. In general, urban development within the region has "...sprawled outward in a low-density pattern being serviced by lineal commercial development" (1, p. 9). This sprawling urban development has clearly impacted inner-city neighborhoods, many of which are inhabited by black residents. A later section of this paper discusses in more detail how these neighborhoods have been impacted by regional planning decisions that encourage sprawl.

In general, the residents of the Omaha-Council Bluffs metropolitan region enjoy a high quality of life. In 1978, Omaha ranked 12th in family income among the nation's 50 largest cities and the unemployment rate was 4 percent, approximately 2 percent lower than the national rate. Nonetheless, these favorable statistics for the residents as a whole do not apply to the black population, which comprises 7-8 percent of the 600 000 people within the SMSA. Compared with an unemployment rate of 4 percent among all SMSA residents, 17 percent of the black labor force is officially unemployed. One report even estimates that the true unemployment rate among blacks is between 35 and 40 percent (2, p. 12). This high unemployment rate among blacks obviously causes low income--the median yearly income for a black family of four is $7500 compared with $15 000 for a white family of the same size. Moreover, approximately 42 percent of the black population is considered economically disadvantaged compared with 9 percent of the white population (2, pp. 11-13).

The living conditions for the black residents within Omaha are bleak. More than 90 percent of the black people in Omaha are located within an 8-mile² ghetto in the northeast sector of the city; compared with a density of 0.60 persons/acre² for the SMSA as a whole, the density within this black sector is 16 persons/acre². The average 1978 housing value in the black sector of $7000, which contrasts sharply with the $28 000 for a housing unit in the white sector, reflects the high-density condition. The fact that more than 30 percent of the housing is deteriorated and more than 2500 lots are vacant is another indication of the poor living conditions within this sector (2, p. 16).

Low educational levels significantly contribute toward the high unemployment and low income among Omaha's black citizens. Only 29 percent of the black population 25 years and older have completed high school, while 60 percent of the white population in the same age group have high school diplomas. Moreover, 50 percent of the eligible black school children drop out whereas 28 percent of the white children drop out. Although 13 percent of the white population has completed four or more years of college, only 3 percent of the black population reached this same level of education (2, pp. 9-11).

Black citizens in Omaha apparently lack faith in the economic and political system since only 11 percent of the eligible black voters in Omaha vote in major elections (2, p. 21). This voting gap among black residents has resulted in a limited number of black elected representatives, which include one state representative and a few members on the school board and other minor boards and commissions. Since blacks do not vote, they apparently believe their votes mean nothing. The irony, though, of the situation is that if blacks do not begin to exercise political influence, their economic condition may worsen. As the next section illustrates, regional planning decisions that do not reflect the needs of the black population may even worsen existing conditions within black residential areas.

IMPACT OF REGIONAL PLANNING ON MINORITIES

This section focuses on the direct and indirect impacts that transportation facilities have on black residential areas, two important issues to black residents.

The proposed North Freeway within Omaha, which cuts through the heart of the black residential sector, is an integral part of the 1995 transportation plan and is on the 6-year element of the transportation improvement program. The facility has gone through corridor planning and preliminary design stages, and a large portion of the land acquisition for the project has been completed. The North Freeway, as originally planned, would have been a north-south connection between east-west Interstates 80 and 680, and its completion would have completed an expressway loop within the city (3). In addition, the proposed east-west airport connector will connect the North Freeway to the Eppley Airport, which lies to the east of the proposed freeway. The present plan calls for the North Freeway to extend only to the airport connector and not to I-680 as originally planned. Interestingly, the cut-off at the airport connector is the approximate division between white and black North Omaha. Most of the North Freeway will then lie within the black residential sector. This decision to cut off the freeway at the connector was apparently due to political maneuvering. Due to the large proportion of the total right-of-way for the proposed North Freeway that has been acquired, the project already has had a significant impact on the black sector. Neighborhood groups are now very active in working out the details of the design in order to minimize neighborhood disruption, noise pollution, air pollution, and so forth.

Regional planning can also have more subtle indirect impacts on these residential areas that may be of greater consequence to blacks than are the direct physical impacts. Earlier this paper noted that development within the Omaha-Council Bluffs region has sprawled out from the central cities. The generally well-developed radial and circumferential expressway system has significantly increased the accessibility to outlying portions of the region; thus, the outward expansion has been encouraged by the increase in transportation capacity. An analysis of preliminary 1980 census data verifies that significant numbers of people have migrated westward from the central city to the suburbs and, according to the data, the growth rate for Omaha as a whole decreased between 1970 and 1980 (4). Public investment in the highway system made through regional planning decisions has certainly contributed to this outmigration; but other types of policies made outside the regional planning process have also put pressure on western growth including utility expansion, mortgage, and busing policies. The net result of all these policies has been a deterioration of the commercial, industrial, and residential base within the black sector.

Regional planning decisions clearly have widespread implications for the viability of black residential areas. Blacks need to become involved early in the process and they need to participate consistently on a day-to-day basis in order to influence decisions.

CURRENT CITIZEN PARTICIPATION

The Omaha-Council Bluffs MAPA was formed in 1967 under an Inter-Local Cooperation Agreement for the purpose of coordinating local planning and development activities. A board of directors implements policy and directs the planning staff, which carries out the day-to-day planning activities. The board of directors receives advice from several technical committees and from a Citizen's Advisory Board (CAB).

The CAB, which was formed to involve private citizens from all socioeconomic segments in the planning for the five-county region, can make recommendations to the staff, technical committees, and board of directors. The overall policy for the CAB's participation activities is set by an executive committee, but all substantive participation is carried out by the five working committees: (a) community involvement, (b) human resources, (c) regional growth and development, (d) natural resources, and (e) transportation.

At present, representatives of various minority groups serve on the MAPA technical committees of comprehensive planning, urban affairs, and regional economic development advisory committee, which have been formed as part of a special economic development demonstration project. The groups represented on these committees include the Greater Omaha Community Action, Comprehensive Employment Training Agency, Chicano Awareness, and the American Indian Center. Minority participation on the regional economic development committee is much stronger than participation on the other MAPA committees because it is a special committee that deals directly with economic problems that impact minorities. But, in general, minority participation on MAPA technical committees is at a low level.

Participation by minorities on the CAB is also at a low level. Of the approximately 80 CAB members, more than 20 represent various community organizations, but only three individuals represent minority groups. One black person is on the executive committee and very active on the CAB and other civic organizations, but the overall participation by blacks and other minorities is very low.

IMPROVING PARTICIPATION

The CAB has taken initial steps to improve participation by blacks that are based on the current approach taken by the CAB to improve participation in general. The CAB annually identifies potential members, recruits new members by letter, presents an orientation session for new members, and immediately involves each new member in one of the five working committees. The same general approach with some important modifications is recommended here for improving participation by blacks and other minorities in regional planning. Of course, some types of actions are beyond the immediate control of a regional planning agency. For example, in my opinion, the level of minority involvement in the political and technical decision-making process depends on the general level of education and employment of minority individuals. However, regional policies impact education and employment levels only over the long run, not the short run. Regional decision makers cannot instantly create jobs, housing, and transportation; they can only influence gradual change in these things. In order to ensure that minority concerns are reflected by long-range regional policies, minorities must participate in the process now. In this regard, a regional planning agency can take immediate steps to encourage effective minority participation by considering the following actions: (a) All individuals within the area must be given an equal opportunity to participate in the planning process, (b) the participants must understand the planning process, (c) the participants must understand all the issues of choice, and (d) the planning agency must give due consideration to the participants' contributions.

Recruitment

Initial recruitment efforts should focus on key persons within the most vital minority organizations in order to recruit individuals who represent minority viewpoints and who will participate on an ongoing basis. An initial phone contact should be made with a minority representative, followed up by written material and followed up again by a personal contact. The planning agency representative making the contact should emphasize (a) the potential impact of regional planning on minority residential areas, (b) the existing citizen participation process within the region, (c) the role that citizens play in the planning process, and (d) the effectiveness of the participation process. It is suggested that during the initial contact the regional planning representative provide only general information and avoid detailed information that can be provided later.

Education

Once an individual is recruited into the citizen participation program, the next step is to educate him or her in the regional planning process. Of course, a clear understanding of the process can only be gained after spending many hours in participation activities. An initial orientation session is a valuable way to brief individuals on the functions of the planning agency and to explain what roles each person can play in the participation program. It is important that the person or persons in charge of the orientation session do not provide too much information to the new participants. Most people will quickly narrow down their field of interest. Therefore, it is not necessary that they be given a detailed breakdown on each activity; it is more important that they now become involved in their primary area of interest.

Involvement

One criterion for an effective citizen-participation program is that each participant understand the issues of choice in selecting various planning options, and active involvement is the key to a clear understanding of regional planning issues. One must dig in and sort out the issues with some guidance from planning professionals. Above all else, citizen participation must mean something; it must be important. No one wants to spend hours and hours of work on frivolous tasks signifying nothing. Thus, participation roles must be directed toward specific issues and specific projects. In another paper (5), I presented a detailed discussion of four types of participatory roles that a citizen can play: (a) review and comment, (b) advocacy, (c) advisory, and (d) participatory planning. I suggested that the review and comment and the advocacy roles have the highest potential among the four roles to encourage participation because they are usually oriented toward the specific project issues. Thus, a new participant should be quickly placed in either the review and comment or advocacy role. Both roles should whet the individual's appetite for planning while minimizing any personal confusion or frustration. As the participant gains experience in the planning process, he or she can then become involved in the advisory and participatory roles.

One additional comment on involvement is needed. Regional planning agencies must begin to emphasize minority issues in their citizen-participation process. All too often, participation activities are centered around majority issues such as environmental impacts, resource recovery, and recreational facilities. Minority issues such as direct and indirect transportation impacts, transit facilities, and housing impacts need to be stressed more often. Placing emphasis on such issues will provide an opportunity for the individual to impact regional planning decisions while helping to maintain the individual's interest in planning at the same time.

Evaluation and Feedback

It is important that the planning agency periodically evaluate the effectiveness of each participation role in resolving planning issues by addressing each one of the four effectiveness criteria: (a) Do all people within the region have an equal opportunity to participate, (b) do the participants understand the planning process, (c) have the participants understood the issues of choice, and (d) has the planning agency given due consideration to the participants' contributions?

Individuals must know whether or not their input to the process has impacted regional decisions. In some situations this will be easy to measure. For example, the acceptance of a citizen's comment on an A-95 case is immediate feedback to the citizen. But other situations will not be as easy to measure. The impact of a citizen's work on establishing goals and objectives, for instance, is not an easy thing to measure. The fact that the agency accepts or rejects the list of goals and objectives is easy to measure, but it is not easy to measure whether or not regional growth is in fact shaped by these goals and objectives. Of course, regional decision makers and citizen participants are going to disagree on many occasions and both parties will probably compromise before a final decision is reached. Thus, it is important that the participants be given feedback as to how their input has influenced the final decision. In this regard, a participant should ask the question: Did the decision makers openly receive citizen comments and did they adequately weigh the consequences of the comments in reaching a final decision? Given evaluation and feedback to their involvement, participants can then change the manner in which they carry out their roles in order to improve their effectiveness in the planning process.

CONCLUSION

This paper recommended several actions to improve minority participation in regional planning based on my experience on the Citizen's Advisory Board to the Omaha-Council Bluffs Metropolitan Area Planning Agency. Although the best citizen-participation program is one that contains a mix of mechanisms, such as a citizen's advisory committee, community workshops, public meetings, attitude surveys, and mailouts, the recommended actions of recruitment, education, involvement, evaluation, and feedback would probably apply best to either technical or citizen advisory committees, but they could also apply to special community workshops or meetings. Minority participation in these committees must be improved and can be improved by contacting key persons within minority groups, showing them that regional planning can impact minority areas hard, convincing them that they can make a difference in reaching final decisions, getting them involved in meaningful activities, and then letting them know if they really did make a difference.

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Highways and Property Values: The Washington Beltway Revisited

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This study is a continuation of an investigation of the impacts of the Washington Capital Beltway (I-495) on residential property values in the adjacent community of North Springfield, Virginia. A 17-year (1962-1978) time series of property values represents the longest continuous longitudinal data base used in any analysis of highway impacts on residential communities. The results show conclusively that properties near the highway increase in value at a rate less than those more distant. It was found that properties in proximity to I-495 sell for approximately $3000-$3500 less than the others.

Today's society has placed an extremely high priority on the development of transportation systems that will facilitate the movement of both goods and people in a swift and reliable fashion and with the greatest convenience, comfort, and privacy. Although conflicts of interest are inevitable on the design and modification of alternative systems, transportation planners attempt to select those projects that will provide the greatest net benefit to society. As a result, there are a number of tools and techniques available for facilitating the integration of social impacts into the transportation planning process (1). Although efforts to gain a more meaningful understanding of the benefits and costs of transportation improvements have considered a number of modal scenarios, a predominant share of attention has been directed toward the case of highways.

Specific benefits and costs that are likely to be associated with the construction or improvement of a limited-access highway are noted below. Benefits have been divided into two classes--those for which highway users are the principal beneficiaries and those that represent a gain accruing primarily to nonusers; alternatively, because a dichotomy of costs by user status would represent a more narrow, less-meaningful perspective, costs have been considered as being either direct or indirect:

1. Benefits: (a) for the user--accessibility (speed and reliability), fuel cost savings, maintenance cost savings (vehicular), safety, comfort and convenience, and aesthetics of travel; and (b) for the nonuser--reduced congestion in general area, economic efficiency, property value changes, economic development, and income and employment; and
2. Costs: (a) direct--right-of-way acquisition, construction, improvement, maintenance, operation, and relocation; and (b) indirect--loss of tax base, provision of additional community services, degradation of community qualities, property value changes, environmental degradation, and loss of income and employment.

In order to achieve a greater understanding of the extent to which the net of highway benefits and costs is reflected in the values of nearby residential properties, I conducted and reported the results of a time-series analysis of residential property values along a portion of Interstate 495 (the Washington beltway) (2). The research methodology included an analysis of sale-resale data during the period 1962 through 1972 exhibited by 1676 residential properties. A principal finding of that study was that those properties in North Springfield, Virginia, located in proximity to I-495, exhibited a tendency (particularly during the last 3 years of the time series) to increase in value at a rate significantly less than that for properties more distant from the highway. The study results suggested that highway-related environmental externalities were responsible for a lowering of values of nearby properties compared with those of properties more distant from the highway. Aside from the specific findings of the study, the effort was notable in that it represented the first attempt to analyze the impacts of a highway on residential property values through the construction of a time series of property value index numbers.

The study reported in this paper is a revision and update of the findings of the earlier study, based on the addition of several more years of data to the already-existing time series. As a result, 17 years of data (1962 through 1978) were made available for analysis. This study incorporates a longer time series of residential property sales data than has been used previously in any investigation of the effects of highways on property values. Following a brief review of the recent literature and a profile of the highway-community interface that exists in North Springfield, a summary of the methodological approach and the results achieved is presented.

RECENT LITERATURE

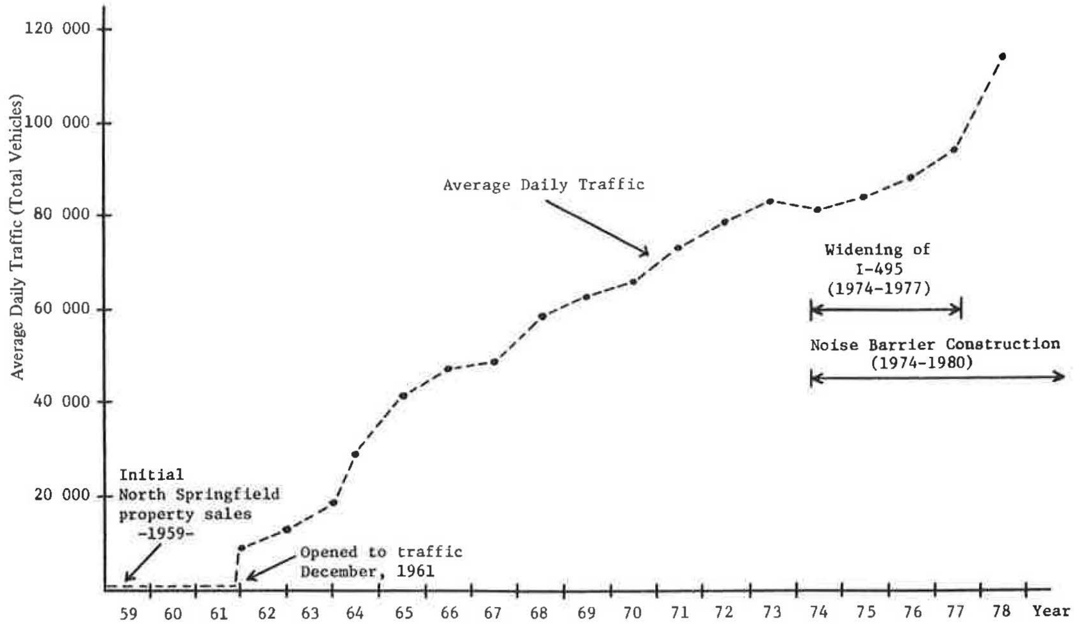
An examination of the published literature indicates that a continuing high level of importance is attached to achieving a greater understanding of the determinants of relative house and land prices. In addition, recent research efforts have placed added emphasis on how neighborhood amenities are valued by people and how such values are translated into prices of land and/or improvements.

Although it preceded publication of the earlier Washington beltway study, a number of empirical efforts into the determinants of relative house prices were surveyed (3). Emphasis was placed on the inclusion of studies that served to isolate and quantify a variety of attributes associated with housing, particularly those that were related to environmental quality in both a physical and a social context. Each of the studies selected for discussion was limited somewhat in that its respective methodological approach incorporated the use of regression analysis (and factor analysis in some cases) as applied to cross-section data. None of those surveyed were based on time series of data.

A recent study analyzed the impact of railway externalities on residential prices (4). Another research effort (5) measured the extent to which variations in levels of local property taxes and public expenditures affect residential property values. Alternatively, the technique of using a time series of property value data was employed in a study on the effects of airports on land values (6). The procedure followed was to measure changes in mean selling prices for various study areas at differing distances from the airport.

Contemporary interest has shifted somewhat from attempting to explain variation in house or land prices, to estimating the implicit valuation of the specific locational features or amenities that have

Figure 1. Traffic profile of I-495, North Springfield, Virginia: 1959-1978.



a major impact on the selling prices of properties (7-10). The major research questions raised collectively focus attention on topics such as the relative usefulness of land only versus the selling prices of land plus improvements; the extent to which hedonic prices (assumed to be equilibrium prices paid by informed, willing buyers) are representative of the more theoretically acceptable willingness-to-pay prices (11); and the development and refinement of models and techniques for estimating price gradients for a number of amenities simultaneously. Finally, a cross section of residential property values was used to determine a set of implicit marginal prices for air quality (12). In combination with income and other variables, the prices are incorporated into a two-equation demand-and-supply model (13). Results are expressed in terms of both price and income elasticity of demand.

STUDY AREA DESCRIPTION

The predominantly residential community of North Springfield is located in Fairfax County, Virginia, along the southwest portion of the Washington beltway. The study site is bisected by the highway, and residential structures are limited to single-family dwellings, of which there are nearly 1700. As computed from Fairfax County courthouse records, property sales prices averaged $22 456 in 1962, $33 440 in 1970, and $65 182 for the first quarter of 1978. Numbers of property turnovers per year were typically between 125 and 200. Additional descriptive information regarding the study site may be found in Langley (2).

As indicated in Figure 1, a variety of highway-related changes has taken place in the time period of interest, with the most notable occurring in recent years. The first is that data from the Commonwealth of Virginia (14) indicate that average daily traffic (ADT) volumes have risen from 8845 vehicles/day in 1961-1962 to 113 790/day in 1978. Second, a widening of the relevant section of I-495 from two lanes in each direction to four lanes, begun in 1974, was completed in 1977. Third, noise barriers were constructed beginning in 1974 in a continuous pattern on both the north and south sides of the highway right-of-way, and minor alterations to the existing walls were being made as recently as 1980. Technically, the barrier type is metal wall on earth berm, and the height of the barrier above the road is 7.6 m. Federal Highway Administration (FHWA) tests have concluded that noise levels in proximity to the highway have been reduced by approximately 15 dB(A), thereby reducing loudness at least by half (15). In addition to measuring the effectiveness of various types of noise barriers, the study evaluated the accuracy of the FHWA Highway Traffic-Noise-Prediction Model. It is interesting to note that the same section of the Washington beltway investigated in the study reported in this paper was also included among the sites selected by FHWA for noise barrier analysis. As a result of personal visits to the study site before, during, and after such construction, it was evident to me not only that noise levels had been lowered as a result, but also that the highway itself was much less obtrusive, and generally less noticeable.

In an overall sense, therefore, North Springfield continues to be the type of community that lends itself appropriately to a study of highway impacts on residential property values. While an inherent stability in the area under study is certainly an attribute from the perspective of research methodology, the general absence of non-highway-related externalities is responsible for a high degree of homogeneity among properties in the area.

METHODOLOGY

For purposes of analysis, the 1676 study-area properties were segmented into three groups. The impact zone (consisting of 1056 properties) was defined to include all properties in such proximity to the highway that it could be documented that residents were subjected to a continuing existence of highway-oriented disturbances. The results of the earlier study suggested that a distance of 1125 ft (343 m) represented an appropriate delimiter, and this measure was used once again in this study. Second, the subset of impact zone properties that were located immediately adjacent to the highway were classified as abutting properties (99 in number). Finally, those properties beyond the boundary of the impact zone were referred to as being located in the nonimpact zone (610 in number).

The research plan included these two major objectives: (a) to construct for each distance-related category a time series of property value index numbers that could be used to describe the behavior of aggregate property values over time and (b) to compare statistically the yearly index numbers among the various property classifications to determine whether any significant differences exist. To the extent that discrepancies are noted, it is accurate to claim that highway-related environmental externalities are the primary contributing factors.

In order to accurately interpret the study results, it is necessary to recognize an important distinction that must be drawn between rate of price appreciation and total or gross impact on property values. The former places no restriction on the actual years to be included in a highway impact study, while the latter would certainly require the measurement of effects on values beginning before construction or even anticipation of the highway. The approach taken in this study emphasizes the rate of price appreciation.

The methodology for price index construction used in this study incorporates only sale-resale pairs of property transaction values, and employs regression analysis to estimate the index numbers (2,16). Courthouse records from Fairfax County indicated that a total of 1322 valid pairs of study area property transactions were recorded for the years 1962 through 1978. Prior to the regression analysis, all property sales values were deflated by using the implicit price deflators for gross national product (17). Although the time series of interest began in the year 1962 (the first full year in which the highway was opened to traffic), the base year for applying the price deflators was selected to be 1959 (the year in which the first property sales were recorded for the study area).

Finally, it is important to understand that the general approach of this study is valid, even when one considers some of the recent findings regarding the appropriateness of methodologies for studying the impact of location dependent amenities on property values. For example, one study suggests that regression studies cannot be used for predictive purposes except to the extent that the city is small, and there is mobility among cities (18). This means that property values at a particular location depend only on amenities (and other relevant variables) at that location (19). Aside from the fact that the approach of this study is not regression-oriented in the same sense as referred to by those authors, the nature of size and mobility characteristics has no direct bearing on an interpretation of the results. This is because the study findings are expressed in terms of differences in rates of price appreciation among the various North Springfield property groups, and no attempt is made to derive an implicit, generalizable valuation for the existing externalities.

FINDINGS

Table 1 summarizes a variety of residential property sales data for North Springfield during the years 1962 through 1978. All valid property transfers are included and, in addition to being presented for all properties, yearly information is subdivided by property category. Two principal observations are notable: (a) the mean selling price of abutting properties tended to be lower on a year-to-year basis than for the other property types in the study area and (b) yearly increases in the mean selling prices of impact zone properties approximated those of the nonimpact zone. The former is explained largely by the fact that abutting properties were priced lower than other properties during the early years of the time series, and the discrepancy has continued throughout the period under consideration. The latter observation could be construed to imply that the existence of highway-associated externalities is not reflected in property values since the averages remain approximately the same throughout the 17 years. As will be indicated subsequently, such a conclusion is not only premature but inaccurate.

The results of residential property price index construction are exhibited in Table 2 by distance category. In addition to the yearly index numbers, the logarithms and standard errors of the logarithms of the index numbers are shown, as well as the total number of initial plus final sales in each year. The three time series of index numbers are depicted in Figure 2. Major observations of interest include

Table 1. North Springfield, Virginia, property sales data: 1962-1978.

Year	All Properties[a] N	All Properties[a] $\bar{x}$ ($)	All Properties[a] Deflated[e] $\bar{x}$ ($)	Abutting[b] N	Abutting[b] $\bar{x}$ ($)	Abutting[b] Deflated $\bar{x}$ ($)	Impact[c] N	Impact[c] $\bar{x}$ ($)	Impact[c] Deflated $\bar{x}$ ($)	Nonimpact[d] N	Nonimpact[d] $\bar{x}$ ($)	Nonimpact[d] Deflated $\bar{x}$ ($)
1962	226	22 456	21 489	10	20 719	19 827	87	22 584	21 611	139	22 375	21 411
1963	238	22 774	21 485	21	22 857	21 563	94	23 432	22 106	144	22 345	21 080
1964	214	23 222	21 562	16	24 544	22 789	84	24 396	22 652	130	22 464	20 858
1965	162	24 224	22 002	11	24 733	22 464	69	24 914	22 629	93	23 712	21 537
1966	162	25 319	22 268	13	24 557	21 598	62	25 534	22 457	100	25 186	22 151
1967	147	26 189	22 384	11	25 441	21 744	52	26 460	22 615	95	26 041	22 257
1968	143	28 730	23 491	6	31 633	25 865	58	29 625	24 223	85	28 120	22 993
1969	129	31 257	24 343	5	28 683	22 339	51	31 324	24 396	78	31 213	24 309
1970	127	33 440	24 715	8	30 521	22 558	42	33 329	24 633	85	33 495	24 756
1971	161	35 517	24 977	16	34 985	24 603	57	36 247	25 490	104	35 117	24 695
1972	157	39 290	26 529	9	40 272	27 192	56	39 808	26 879	101	39 003	26 336
1973	133	46 897	29 928	12	47 216	30 131	44	47 919	30 580	89	46 393	29 606
1974	135	52 009	30 273	6	49 658	28 905	43	51 245	29 828	92	52 366	30 481
1975	121	56 449	29 978	9	55 416	29 430	45	56 688	30 105	76	56 307	29 903
1976	112	58 905	29 735	5	57 667	29 110	35	58 075	29 316	77	59 282	29 925
1977	159	62 817	29 956	9	57 800	27 562	52	62 541	29 824	107	62 952	30 020
1978	33	65 182	29 914	1	65 000	29 830	13	67 446	30 953	20	63 711	29 239
Total	2559			168			944			1615		

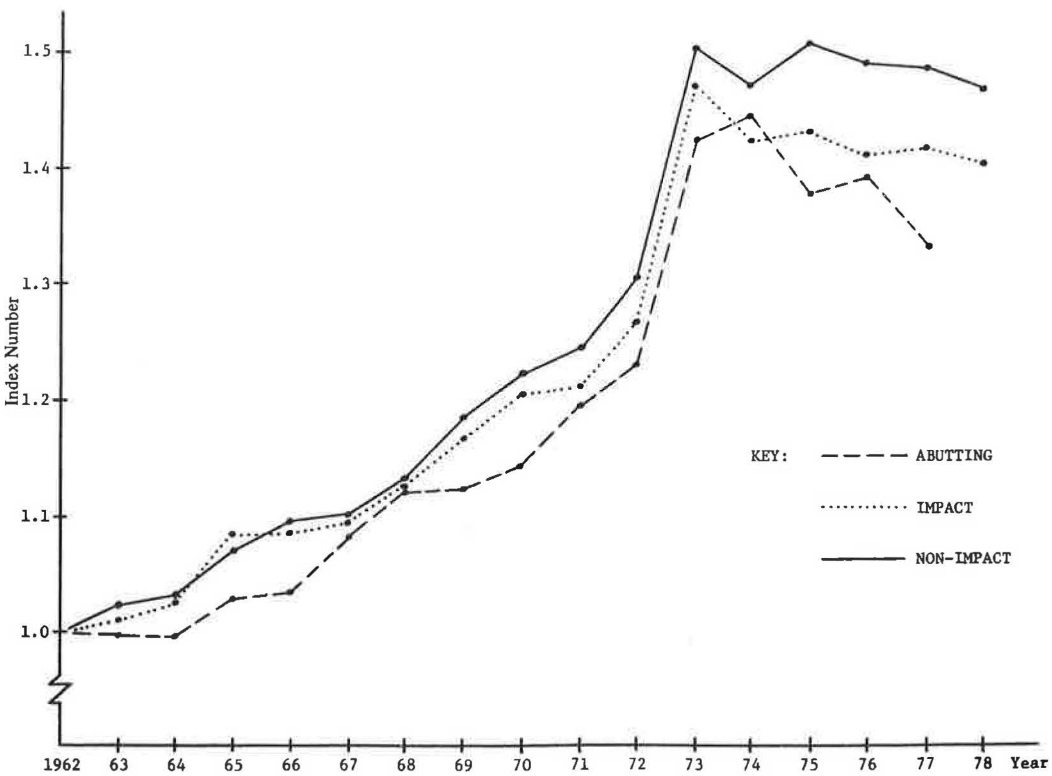
[a]Within 1676 ft.
[b]Within 99 ft.
[c]Within 620 ft.
[d]Within 1056 ft.
[e]Mean sales values were deflated to base year = 1959 by using the implicit price deflator for gross national product (17).

Table 2. Real estate price indexes, North Springfield, Virginia: 1962-1978.

Abutting Properties[a]					Properties in Impact Zone[b] (within 1125 ft from highway)					Properties in Nonimpact Zone[c] (>1125 ft from highway)				
Year	Index	Log of Index	S_e Log	N	Year	Index	Log of Index	S_e Log	N	Year	Index	Log of Index	S_e Log	N
1962	1.000	0.000 00	0.000 00	8	1962	1.000	0.000 00	0.000 00	62	1962	1.000	0.000 00	0.000 00	96
1963	0.987	-0.005 83	0.015 78	12	1963	1.011	0.004 81	0.006 32	68	1963	1.024	0.010 42	0.005 31	107
1964	0.990	-0.004 33	0.014 19	18	1964	1.031	0.013 10	0.006 14	70	1964	1.033	0.014 14	0.005 03	108
1965	1.030	0.012 66	0.015 52	10	1965	1.084	0.035 08	0.005 48	78	1965	1.071	0.029 71	0.005 49	83
1966	1.037	0.015 82	0.015 75	13	1966	1.088	0.036 51	0.006 23	71	1966	1.097	0.040 10	0.004 97	107
1967	1.082	0.034 08	0.013 90	15	1967	1.096	0.039 93	0.006 38	57	1967	1.101	0.041 87	0.005 08	118
1968	1.122	0.049 83	0.017 49	8	1968	1.124	0.050 69	0.006 40	66	1968	1.132	0.053 90	0.005 16	112
1969	1.122	0.050 06	0.018 77	6	1969	1.167	0.067 19	0.006 37	65	1969	1.185	0.073 76	0.005 19	107
1970	1.142	0.057 82	0.017 09	9	1970	1.207	0.081 56	0.006 70	56	1970	1.222	0.087 20	0.005 25	113
1971	1.197	0.077 93	0.014 09	24	1971	1.213	0.083 71	0.006 13	74	1971	1.245	0.095 33	0.005 09	123
1972	1.233	0.090 99	0.016 13	11	1972	1.268	0.103 09	0.006 49	67	1972	1.307	0.116 44	0.005 03	131
1973	1.427	0.154 56	0.014 21	13	1973	1.471	0.167 65	0.006 98	47	1973	1.504	0.177 20	0.005 27	114
1974	1.444	0.159 67	0.019 20	6	1974	1.422	0.152 86	0.007 05	46	1974	1.472	0.167 90	0.005 42	98
1975	1.378	0.139 32	0.015 13	12	1975	1.434	0.156 60	0.006 90	51	1975	1.507	0.178 21	0.005 82	79
1976	1.392	0.143 79	0.020 03	5	1976	1.411	0.149 58	0.007 80	31	1976	1.491	0.173 47	0.006 07	69
1977	1.333	0.124 88	0.018 88	6	1977	1.419	0.152 06	0.007 34	44	1977	1.487	0.172 33	0.005 43	96
1978[d]					1978	1.403	0.146 92	0.011 06	13	1978	1.466	0.166 13	0.010 08	17

[a]R^2 = 0.8278. [b]R^2 = 0.7824. [c]R^2 = 0.8085. [d]Insufficient sales of abutting properties.

Figure 2. Property value price indexes: 1962-1978.



the following: (a) the time series of index numbers for abutting properties consistently shows less-than-comparable figures for impact and nonimpact zone properties (aside from the slight aberration of data in the year 1974), (b) with the exception of one year early in the time series, index numbers for impact zone properties are less in magnitude than those for nonimpact zone properties, and (c) the apparent divergences among index numbers of various property types are the greatest in years subsequent to 1973. It is evident, therefore, that properties nearer the highway exhibit a very definite tendency to increase in value at a rate less than those more distant from the highway.

One-tailed student-t tests were used to test for statistical significance among the various index number differences noted above. Table 3 notes those pairs of index numbers for which the differences were found to be significantly different at the 10 percent level, or better. While 12 of the 17 years in the time series are represented in Table 3, a preponderance of attention is focused obviously on the years from 1970 to 1978. These findings lend conclusive support to the contention that highway-related environmental externalities from I-495 are responsible for an adverse impact on nearby residential property values in North Springfield. It is quite likely, however, that the widening construc-

Table 3. Significant differences among index numbers and conversion to value differences in dollars.

Year	Price Deflator	Index Numbers: Abutters	Impact	Nonimpact	Difference Among Indexes	Difference Expressed in Dollars[a]
1965	1.101	1.030	1.084		-0.054[b]	1278
1966	1.137	1.037	1.088		-0.051[b]	1246
1970	1.353	1.142	1.207		-0.065[b]	1890
1977	2.097	1.333	1.419		-0.086[b]	3875
1964	1.077	0.990		1.033	-0.043[b]	995
1966	1.137	1.037		1.097	-0.060[b]	1466
1970	1.353	1.142		1.222	-0.080[b]	2326
1971	1.422	1.197		1.245	-0.048[b]	1467
1972	1.481	1.233		1.307	-0.074[b]	2355
1973	1.567	1.427		1.504	-0.077[b]	2593
1975	1.883	1.378		1.507	-0.129[d]	5220
1976	1.981	1.392		1.491	-0.099[b]	4214
1977	2.097	1.333		1.487	-0.154[c]	6940
1971	1.422		1.213	1.245	-0.032[b]	978
1972	1.481		1.268	1.307	-0.039[b]	1241
1974	1.718		1.422	1.472	-0.050[b]	1846
1975	1.883		1.434	1.507	-0.073[d]	2954
1976	1.981		1.411	1.491	-0.080[c]	3406
1977	2.097		1.419	1.487	-0.068[c]	3064
1978	2.179		1.403	1.466	-0.063[b]	2950

[a] Dollar differences have been inflated to reflect real value in each respective year. Computation: $22 456 x price deflator x difference among indexes.
[b] Indicates significance at 10 percent level.
[c] Indicates significance at 2.5 percent level.
[d] Indicates significance at 1 percent level.

tion from 1974 through 1977 was responsible for a portion of the differences in recent years that are apparent in Table 3.

An added feature of Table 3 is that the significantly different index numbers are transformed into dollar differences that have been inflated to reflect real dollar values in the respective years. These are shown in column 7 of Table 3. Although the value differences are greatest for abutting versus nonimpact zone properties, the recent differences between impact and nonimpact area properties are more representative of the impact on nearby properties in general. With reference to the dollar differences shown in the bottom portion of column 7 of Table 3, therefore, it can be stated that properties in proximity to the highway (within 1125 ft) sell for approximately $3000-$3500 less than equivalent properties located farther from the highway.

EVALUATION

This study proves conclusively that highway-originated environmental externalities are the major cause of an inverse relationship between yearly increases in North Springfield property resale values and proximity to I-495. Aside from simply revising and updating the results of the earlier study, the current effort found significant differences among distance-related property value index numbers in 12 of the 17 years under study. Although significant differences were found in each of the latest nine years in the time series under study, it is likely that the highway widening construction from 1974 through 1977 had some impact on the magnitude of such differences in those particular years. In general, therefore, the overall results justify a much stronger statement concerning highway impacts on property values than did the findings of the 1962-1972 analysis. An additional contribution of this study is that the length of the time series (17 years) was unprecedented in previous highway impact investigations.

Although the study findings are valid in a statistical sense, caution should be exercised regarding their overall generalizability. It would be misleading to attempt to apply the results of this study directly to the situations of other highway-community interfaces. It would be very useful, however, to employ the methodology and procedures of this study for the purpose of gaining insight into the net economic impact of highways on property values in other areas.

It was interesting to note that noise barriers had been constructed along the right-of-way boundaries of the Washington beltway in North Springfield and that reductions of up to 15 dB(A) in noise levels were estimated. As a result, the loudness of traffic noise has been reduced by at least one-half. Unfortunately, such improvements occurred so recently that any possible impact on property sales values could not have been detected. Perhaps a future study may investigate this. While it is well documented that highway-originated disturbances can have adverse impacts on the values of nearby residential properties, it will be interesting to see if such a trend reverses, given that the level of disturbance has been reduced significantly.

Finally, it is appropriate to mention that the findings of this study are quite consistent with generally accepted theories of capital asset pricing. That is, each yearly deflated housing price actually represents the present value of a stream of anticipated housing services and locational amenities. If such anticipations were to have remained constant over time, no changes in deflated housing prices could have been expected. Property sales prices in North Springfield did change throughout the period under observations, however. This phenomenon can be attributed to two general factors: (a) changes in the level or degree of an externality and (b) changes in consumer attitudes (preference or tastes) toward an externality. Traffic volumes on I-495 (level of externality) have increased quite dramatically and, without any doubt, people have become much more cognizant and concerned about environmental issues, including traffic-generated noise and air pollutants, since the environmental movement began approximately with Earth Day in 1969. Also, the construction that took place in order to widen the highway and the erection of noise barriers must be regarded as having been annoying sources of environmental externalities. These had an adverse impact on those residents in proximity to the highway.

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Highway Noise, Noise Mitigation, and Residential Property Values

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This paper presents the findings of a study of the relationship between different noise levels and market values for a sample of 206 single-family residences abutting Interstate-495 in Northern Virginia and for a sample of 207 residences along two heavily traveled urban streets in the Tidewater area of Virginia. Estimates of the influence of noise on the market price of houses sold in 1978-1979 at these sites, where barriers have since been completed, were then used to estimate economic benefits received by property owners. By using these estimates, it was concluded that recent public expenditures on highway noise abatement per household far exceed reasonable economic benefit levels, even for noise reductions of 10 dB(A).

Part 772 of Title 23 of the Code of Federal Regulations emphasizes that final decisions about highway noise mitigation are not to be made without serious consideration of the costs of abatement. Paraphrasing the law, there may be sections of highways where the costs of abatement are so high in relation to the benefits received that it would be impracticable to apply noise abatement measures.

At least one author has attempted to provide evidence regarding the social impacts of noise (1); yet, economic data are necessary as an aid in decisions about noise mitigation. Early empirical evidence on the effects of highway noise was provided by Gamble and others (2) and Nelson (3); however, the results of these and more recent studies appear to have had only marginal influence on noise mitigation policies.

OBJECTIVES AND SCOPE

The objectives of this study were (a) to empirically estimate the effect of highway-generated noise on residential housing values and (b) to suggest financial criteria for the construction of noise barriers consistent with the estimated benefits that noise walls provide the owners of residential properties within the noise contour of heavily traveled highways. These major objectives were closely related in the sense that estimates of the reduction in property value, if any, that results from high levels of highway noise from mobile sources provide inferences about the potential benefits to be derived from noise abatement. With this estimate of potential benefits in hand, the second objective could be met.

The scope of the research was limited to an analysis of single-family, owner-occupied dwellings within the noise contours of highways to which Part 772 of Title 23 of the Code of Federal Regulations applies. Business, recreation, and multifamily properties were excluded from the analysis.

METHODOLOGY

The methodology used in this study is explained in moderate detail in the subsections that follow. Simply described, the method involved

1. Demonstration of a theoretical relationship between residential property values and noise,
2. Development of a mathematical equation to test the hypothesis that variations in the market price of housing adjacent to heavily traveled suburban highways can be largely explained by differences in the structural attributes of housing and differences in levels of noise,
3. Collection and development of detailed housing and noise data in areas of Virginia where noise levels are sufficiently high to require noise mitigation, and
4. Use of multiple regression analysis to estimate the willingness of housing consumers to pay for quiet as opposed to relatively noisy houses.

Conceptual Framework

The economic literature is replete with examples of the basic notion on which this study is predicated. Simply stated, the notion is that households, in choosing their residential location, are forced to reveal their preferences (willingness to pay) for certain characteristics or attributes of housing, including levels of noise. In other words, if people value quiet, the market will reflect that preference. Given this basic premise, the residential choice problem can be formalized mathematically into an equation by which the relationship between the market price of housing and noise can be tested empirically.

Following Nelson (3) and Allen (4), an economic relationship can be shown to exist between housing services and market price, where housing services refer to the idea that the market value of a dwelling reflects the quantity of services that a house will supply to a user. This relationship implies that for consumer equilibrium in the housing market--that is, for a given consumer to remain at a particular location--there must be price differentials among various house locations that compensate consumers for the differences in the housing services at those locations. Stated another way, consumer equilibrium, which will result because of mobility and the ability to buy and sell in the housing market, requires that for identical housing at locations 1 and 2, where noise at 1 is greater than noise at 2, the price of housing at location 1 must be less than that at location 2 by an amount to compensate buyers for the additional noise (5,6). Otherwise, the consumer will be better off by living at location 2.

Arguments in the housing literature that consider housing as a bundle of diverse items analogous to the description of food as a basket of goods are presented by a number of authors. Among these are Muth (7), King (6), and Nelson (3). This approach allows one to control empirically for differences in housing services when estimating the influence of such factors as noise or public expenditures on the market price of property (8-10). It is known technically as hedonic pricing (11-14). Specifically in the case at hand, the attributes of a house serve as surrogates for the flow of services associated with that house when one attempts to relate housing price to the flow of services. To the extent that observable attributes capture differences in perceivable service flows, they will help explain variations in price (12). Assuming that housing services are a function of housing characteristics, one can say that

$$h = f(w_1, w_2 \dots w_n) \quad (1)$$

where w_1 and w_n are stock components of the housing bundle. Nevertheless, the arguments presented in the previous section concerning locational equilibrium still hold. It follows that household locational equilibrium requires, if other significant factors are controlled, that differences in housing attributes must be compensated for by differences in housing prices, since differences in observable attributes account for different service flows.

Now, based on the development in Allen (4), one can say that

$$P_{ij} = k(W_i, A_{ij}, d_i) \quad (2)$$

where

P_{ij} = market price of house i at location j;
W_i = attributes of house i;
A_{ij} = supply of local public goods;
d_i = distance of house i to the central city, a measure of accessibility; and
k = some mathematical function relating P_{ij} to W_i, and A_{ij} to d_i.

Only recently has the literature addressed the implications of the use of hedonic pricing on choice of functional forms for empirical testing. However, Muellbauer (15), Pollak and Wachter (16), and Nelson (3) have discussed the assumptions under which Equation 2 is linear. Nevertheless, as is explained elsewhere, the testing of several equation forms is the most appropriate empirical approach (4).

Accordingly, the parameters of Equation 2 will be estimated under three alternative functional specifications. These specifications are as follows:

1. $P_{ij} = \alpha_i W_i + \beta_j A_{ij} - \delta_i d_i \quad (3)$

where the variables are defined as in Equation 2 and α_i, β_j, and δ_i are estimates of the implicit price of the variable in question;

2. Estimation of Equation 3 with the dependent variable as log P_{ij} instead of P_{ij} (this is the log-linear form); and
3. Estimation of Equation 3 with dependent and independent variables in logs (this is the log-log form).

Data

Because noise data were the most difficult to obtain, the study design called for the housing data to be taken from parts of Virginia for which the Department of Highways and Transportation had either taken or developed extensive noise data. Areas that met these requirements were neighborhoods contiguous to Interstate-495 in Northern Virginia, between Interstate-66 and Telegraph Road in Alexandria; to Denbigh Boulevard in Newport News; and to Great Neck Road in Virginia Beach.

Once these sites were selected, an aerial photo of each with the 70-dB(A) noise contour superimposed on it was obtained. Also, site-specific unmitigated noise level estimates for properties both inside and beyond the 70-dB(A) contour were developed for each neighborhood from data collected in an earlier Research Council study (17). Detailed 1977, 1978, and 1979 data on house prices and characteristics were obtained for the Northern Virginia sites from the multiple listing files of the Washington Metropolitan Council of Governments. Similar data were obtained for the Tidewater area sites from the housing data file maintained by Market Data Center, Incorporated, for the savings and loan companies in that area.

EMPIRICAL RESULTS

The results of multiple regression estimations of the extent to which the market price of residential housing is influenced by noise are discussed below on the basis of two study sites. Simplification of Equation 3 is required for the analysis. Equation 3 argues that, in general, the price of a particular house equals the sum of the implicit price of its characteristics times the quantity of each and the value of local public services minus the cost associated with accessibility to the central business district. The accessibility variable and the local public service variable, however, can be dropped from the analysis in this study because (a) within the neighborhoods studied neither varies enough to be expected to influence the price of houses and (b) separate treatment of the Northern Virginia and Tidewater samples renders the across-sample differences in accessibility and local public goods empirically unimportant (18-21).

Equation 3 has now been revised to argue that the market price of house A at location B within a neighborhood that abuts a highway that has traffic generating relatively high levels of noise can be explained largely by the characteristics of house A and the level of noise at its location. Neighborhood amenities, such as the neatness of lawns, cleanliness of streets, and friendliness of neighbors, can be assumed to be the same for houses within the samples.

The measures of housing characteristics and noise used to test the relationship between noise and property values are listed in Table 1. Table 2 presents the means and standard deviations of these measures.

Table 1. Variables used to test influence of noise on market price of housing.

Variable	Type of Variable	Characteristic Measured
VAL[a]	Dependent	Sale price
SPA	Explanatory	Square feet of floorspace
AGE	Explanatory	Age of house in years
LOT	Explanatory	Lot size in square feet
BTH	Explanatory	Number of baths less 1
FIRE	Explanatory	Number of fireplaces
STYLE[b]	Explanatory	Style of house
BSMT[c]	Explanatory	Type of basement
CONST[d]	Explanatory	Type of construction
NOISE	Explanatory	House location: 1 = inside noise contour, 0 = outside noise contour
TN	Explanatory	Noise: $L_{10} - L_{90}$
TNI	Explanatory	Noise: Traffic noise index TNI = 4(TN) + (L_{90} - 30)
LTEN	Explanatory	Noise: L_{10}
LEQ	Explanatory	Noise: L-equivalent

[a] Sales occurring in different years have been adjusted to 1978 constant dollars by Housing Price Indexes for Virginia standard metropolitan statistical areas (21).
[b] Northern Virginia: 1 = ramblers or ranchers, 0 = other styles; Tidewater Virginia: 0 = ranchers, 1 = other styles.
[c] Northern Virginia: 1 = crawl space or slab, 0 = full basement; Tidewater Virginia: Basement not used as variable.
[d] Northern Virginia: 1 = other than full brick, 0 = brick.

Table 2. Sample characteristics: Northern Virginia and Tidewater areas.

	Northern Virginia		Tidewater Virginia	
Variable	Mean	SD	Mean	SD
VAL	68 161.40	10 404.10	47 112.70	10 636.50
SPA	1 714.77	221.42	1 723.07	395.92
AGE	20.45	3.36	9.64	5.01
TNI	49.56	36.01	34.99	24.33
TN	7.45	9.53	3.95	5.61
LEQ	54.31	9.56	50.97	5.59
LTEN	57.16	9.49	54.54	6.24
DAYS	24.88	28.23	-	-
LOT	11 383.00	3 013.34	1.28	1.03
BTH	0.61	0.76	0.83	0.49

Northern Virginia Sample

Linear Equation Results

Estimates of the parameters of the linear equation for the Northern Virginia sample (N=206) are summarized in Table 3. Each equation uses basically the same set of physical house characteristics. The first equation compares the prices of houses lying within the 70-dB(A) noise contour with those of houses outside the contour--that is, those further from the highway. The other equations examine the influence of more location-specific noise measures on the market price of houses close to I-495.

For the statistical technique used in this study to perform adequately, several conditions are ideally required. One of the most important is that the explanatory variables and noise measures used to explain differences in market price should not be linearly related. Among the variables describing the physical aspects of housing, the pairwise correlation coefficients are quite low; many are in the range from 0.01 to 0.30. Those between the noise measures and the structural characteristics variables ranged from 0.06 to 0.22, and more powerful statistical tests for independence showed even weaker relationships between noise and the other explanatory variables. Multiple regression of noise on other variables showed correlations in the range from 0.02 to 0.13. This is a stronger test of linear independence than is an examination of pairwise coefficients. Thus, the multiple regression technique should be able to effectively separate noise from other influences on market price.

Structural Attribute Prices

Although estimates of physical or structural attributes are not the primary concern of the study, their inspection is important as a gauge of the reasonableness of the results. Several observations can be made. The first is that the coefficient estimates are consistent with one another in each of the equations. Second, the large majority of variables is significant and of the expected sign. Third, the coefficient estimates appear reasonable on a priori grounds.

Approximately 70 percent of the variation in the market price of housing was explained by the structural and noise variables tested in Equations 1 through 5 as indicated by the R^2 estimates shown in Table 3. Furthermore, the low standard error of

Table 3. Linear estimates: Northern Virginia sample (N=206).

	Equation									
Variable	1	t-Statistic	2	t-Statistic	3[a]	t-Statistic	4[a]	t-Statistic	5[a]	t-Statistic
Constant term	71 172.00	14.63	71 577.00	14.64						
SPA	16.07	6.97	15.90	6.85						
AGE	-873.95	5.43	-884.18	5.47						
LOT	0.19	1.21	0.19	1.21						
BTH	2393.72	3.32	2480.00	3.40						
FIRE	2752.58	4.24	2688.47	4.08						
STYLE	-3955.00	3.97	-3864.90	3.87						
BSMT	-1073.51	1.00	-1012.51	0.94						
NOISE	-379.48	0.41								
TN			-32.49	0.71						
TNI					-8.94	0.74				
LTEN							-94.37	2.10		
LEQ									-44.96	1.00
R^2	0.70		0.70		0.70		0.71		0.70	
Standard error ($)	5809		5804		5803		5747		5796	
f-statistic	57.6		57.7		57.7		59.3		57.9	

Note: For a one-tail test, 2.33 is significant at 0.99; 1.97 is significant at 0.975; 1.65 at 0.95; and 1.29 at 0.90.
[a]Blank cells indicate coefficients and significance levels approximate to those in Equation 1.

$5800 is indicative of the ability of the model to explain housing prices. The reader may at first glance surmise that explaining 70 percent of the variation in market price leaves a great deal unexplained. However, two rebuttals of such a concern are offered:

1. Cross-section studies that use disaggregate data bases and many more variables rarely explain more than 50-60 percent of housing market variation; therefore, by comparison the model tested here performs quite well; and
2. More importantly, the objective of the study is to examine the influence noise has on market price rather than to forecast market price (as noted earlier, the independence of the structural and noise variables used to explain variations in housing prices is sufficient to test for such noise influences).

Noise Influences on Market Price

An obvious test for noise influence is to examine houses inside the 70-dB(A) contour compared with those outside the 70-dB(A) line. (Equation 1 shows a negative but statistically insignificant relationship between houses lying within the noise contour and price.) Such a test, in my opinion, does not adequately reflect potential changes in noise levels for properties located at successively increasing distances from the noise source; therefore, the noise measures in Equations 2 through 5 were tested. The justification for choosing these measures is fairly straightforward. It is reasonable to argue that annoyance might be a key factor regarding how noise might influence consumers' decisions in the market. Further, one can find several suggestions in the literature of noise measures that supposedly correlate well with annoyance (18,23). Among these are the difference between typical ambient or background noise (L_{90}) and that level exceeded 10 percent of the time (L_{10}); L_{eq}, which is the equivalent sound level, usually 2.5-3.5 dB(A) lower than L_{10}; and a traffic noise index that heavily weights variations in noise due to truck stack noise. In addition to these three noise variables, L_{10} was tested as well.

Results in Table 3 show that (L_{10} - L_{90}) = TN, the traffic noise index = TNI, and the equivalent sound level = LEQ are statistically insignificant influences on price within any reasonable confidence levels. Equation 4, however, shows that for the Northern Virginia sample, house prices do appear to be influenced somewhat by the L_{10} noise levels. The coefficient point estimate of $94/decibel is significant at the 97.5 percent level of confidence and suggests that in the relevant range of noise, where the average L_{10} for houses sampled along I-495 is approximately 63, a house that experiences an L_{10} = 69 dB(A) will have a market price of about $565 less [6 dB(A) x $94] than a house with otherwise identical characteristics and an L_{10} noise level = 63. For a house experiencing 80 dB(A) the estimated reduction in price would on average be 17 x $94 = $1598 at 1978 prices.

Log-Linear and Log-Log Equation Results

Because the log-linear functional form is less restrictive as an estimator (see section, Developing an Empirical Test), a summary of results is presented in Table 4. Although they are not shown, estimates for the structural variables (when converted to antilogs) are comparable to the estimates by using the linear equation. The R^2, standard error of the estimate, and the f-statistics are also comparable.

The appropriate interpretation of the parameter estimates on the noise variables is that they are constant elasticity coefficients; more simply, for LTEN the coefficient in Table 4 = -0.0015 means that a 1-dB(A) increase in noise brings about a 0.15 percent reduction in the market price of the property in question. Evaluated at the mean house price for the Northern Virginia sample, this implies that 1 dB(A) is worth $67 360 x 0.0015 = $101.04 at the 97.5 percent level of confidence. As was the case for the linear equation, none of the other noise measures was statistically significant. Table 4 also presents the log-log estimates.

Tidewater Virginia Sample

Results of regression analysis on a sample of 207 house sales in two neighborhoods abutting Denbigh Boulevard and Great Neck Road in the Tidewater area are shown in Table 5. The interpretation of this table is identical to that of the table used to present the results for the Northern Virginia sample.

The results show that, for reasonable levels of confidence (95 percent and above), none of the noise measures used has a statistically significant influ-

Table 4. Estimates summary: Northern Virginia sample (N=206).

Variable	Parameter Estimates			
	Log-Linear[a]	t-Statistic	Log-Log[b]	t-Statistic
NOISE	-0.006	0.44	-	-
TN	-0.0006	0.97	-0.000 1	0.21
TNI	-0.0002	1.02	-0.000 05	0.27
LTEN	-0.0015	2.23	-0.001 0	1.48
LEQ	-0.0008	1.19	-0.000 3	0.45

[a] R^2 = 0.69. [b] R^2 = 0.71.

Table 5. Estimates summary: Tidewater Virginia sample (N=207).

Variable	Parameter Estimates					
	Linear[a]	t-Statistic	Log-Linear[b]	t-Statistic	Log-Log[c]	t-Statistic
NOISE	-531.75	0.58	-0.013	0.78	-	
TN	-102.07	1.33	-0.002	1.27	-0.0013	0.95
TNI	-22.55	1.27	-0.0004	1.18	-0.0003	0.94
LTEN	-88.26	1.27	-0.0015	1.18	-0.0012	0.96
LEQ	-100.98	1.29	-0.0018	1.18	-0.0014	0.98

[a] R^2 = 0.69. [b] R^2 = 0.70. [c] R^2 = 0.71.

ence on the market price of properties sold in the Tidewater area sample. (The sample was also stratified by high and low property prices and according to neighborhood, but the results still showed an insignificant relationship between price and noise.) However, for confidence levels as low as 85 percent (which policymakers may prefer to accept), noise was significant. Interestingly, at the 85 percent level of confidence the estimated influence per dB(A) was similar to that for the Northern Virginia sample for L_{10}: \$88 ± \$72. These estimates show that, even when one arranges the statistical tests to allow every possible chance for noise to be judged as an important influence on the market price of property, the parameter estimates will not equal large amounts of money. More specifically, these estimates for the Tidewater area show a willingness to pay between \$16 and \$160 per dB(A) with the mean estimate being equal to \$88 to avoid noise.

Results are similar for the log-log equation estimates, which also are shown in Table 5.

IMPLICATIONS OF RESULTS FOR NOISE MITIGATION POLICY

The examination of the results presented earlier, along with financial data on noise barriers previously constructed at the Northern Virginia and Tidewater Virginia sites, suggests three conclusions relevant to future policy on noise mitigation.

First, the regression results presented for the 413 houses at the study sites strongly suggest that the influence of highway noise on the market price of housing is relatively minor. In particular, the reader will recall that only one of the five variables used to test noise sensitivity proved significant for levels of confidence as high as 97.5 percent. For LTEN, the elasticity estimates showed that a 1-dB(A) increase in the L_{10} noise level would reduce the market price for the Northern Virginia houses by approximately 0.15 percent. For a 5-dB(A) difference, the reduction would be about 0.75 percent, or for a \$65 000 house about \$500. For the Tidewater study sites, noise was not a statistically significant influence on price, except for low levels of confidence. A comparison of the results from this study and those of earlier studies of Northern Virginia strengthens the conclusion that noise is a weak influence on housing price. In a 1974 study of properties in Springfield, Virginia, a 5-dB(A) difference was estimated to result in a \$380 reduction in market price (2); in a 1975 study of the same area, the estimates for noise influence were comparable. Given the increase in general housing prices in the period from 1975 to 1979, the estimate obtained in this study of \$94 ± \$88 for 1-dB(A) change is certainly reasonable. Furthermore, in my opinion, the results of these studies offer important evidence about the order of magnitude of the influence of noise on property values. One can strongly argue that empirical evidence supports only small monetary relationships between noise and the market price of housing.

A second conclusion that is important to the establishment of future noise mitigation policy is that past expenditures on noise mitigation have not been reasonably aligned with economic benefits as estimated in this study. The relevance of the estimates developed here is that the market reflects willingness to pay, which is a good monitor of the value of something to consumers--i.e., the benefits received. Thus, the figures presented earlier for the Northern Virginia sample that show a change of 1 dB(A) in the L_{10} noise level at the 97.5 percent level of confidence would be reflected by a change in the market price equal to \$94 ± \$88 [or a maximum change of \$182/dB(A)] give an estimate of what consumers, as they perceive noise nuisance, believe reductions in noise are worth to them as reflected by their decisions in the market. Given this interval estimate, one can compare public expenditures on noise mitigation per house with what the market indicates people are willing to pay to avoid higher levels of noise. In Northern Virginia, for example, one noise barrier was built to protect 60 houses at a total cost of \$436 375 (\$7273/dwelling). Assuming the barrier achieved typical attenuation levels and reduced the L_{10} noise level by 10 dB(A)/house, the maximum estimated benefits are \$182 [10 dB(A)] = \$1820/dwelling. Even with a large margin for error, benefits (as estimated by willingness to pay) are well below \$7300/dwelling.

The third conclusion that relates to noise mitigation policy is that expenditures per dwelling protected have been extremely variable. In the example given previously, the expenditure was about \$7300/dwelling. At two other sites in Northern Virginia differences in design and dwellings protected yielded costs of \$14 919 and \$24 800/household. If economic benefits as reflected by differences in market price between relatively noisy and quiet houses were to have served as technical input to the decision process in these cases, one may have reasonably expected the range of expenditures per dwelling protected to have been smaller.

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Effects of Beltways on the Location of Residences and Selected Workplaces

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Beltways have been cited as factors that encourage the decentralization of people and jobs from central cities and thereby contribute to inefficient patterns of urban development. This study compares changes in total population, manufacturing employment, retail employment, and commuting in 24 standard metropolitan statistical areas, half of which had a beltway constructed during the study period. When the data are divided into a prebeltway and either a beltway construction or a postbeltway period, no statistically significant effects on the central cities are found. The study period is 1950-1970 for population and 1958-1977 for employment; the population data represent an advance on prior research because they have been corrected for annexations by the central cities between 1950 and 1970. Comparison with another statistical study by using regression analysis and eight case studies suggests that other forces such as land use regulation or local opportunities for annexation outweigh the beltway's influence on decentralization.

Energy, environmental, and economic factors have recently created new demands for downtown development. This demand in many cities, however, is felt to be fragile and susceptible to erosion if governmental actions favor suburban areas (1,2). Beltways--high-speed, limited-access highways encircling central cities--have been specifically criticized as factors that may disrupt emerging downtown development markets. In one instance, a research institute concluded on the basis of trends in three beltway and three nonbeltway cities that construction of the Richmond, Virginia, beltway would accelerate the departure of both people and jobs from Richmond and its central business district (CBD) (3). In late 1979, then Secretary of Transportation Neil Goldschmidt refused to authorize completion of the Dayton, Ohio, beltway because of concern that the facility would further weaken the central city by encouraging an exodus of businesses from Dayton (4). This was a particularly difficult and controversial decision, both because of the magnitude of its implications and the dearth of information available on the potential impacts of various courses of action. Little research on the effects of beltways on either suburbanization or central-city vitality has been done. As discussed in the literature review, previous research has either not clearly focused on this area or has suffered from methodological weaknesses.

This paper reports research that examines changes in residential population and two sectors of employment, manufacturing and retail trade, in a sample of 12 beltway and 12 nonbeltway metropolitan areas. The study scope restricted data sources to readily available secondary sources, especially the economic censuses and the Census of Population. The objective of this study was to determine if there is any systematic association between urban decentralization and the presence of a beltway in metropolitan areas. The research also provides some evidence about the use of beltways to influence urban development in efforts to realize societal goals such as revitalization of central cities.

BACKGROUND

Recent economic and demographic trends in U.S. metropolitan areas both explain the concern for the welfare of central cities and assist in interpreting the data in the 24 sample cities. Between 1950 and 1970 the population of central cities of the standard metropolitan statistical areas (SMSAs) as defined in 1970 rose slowly from 54 million to 64 million. At the same time, suburban regions of these SMSAs nearly doubled from 40 million to 76 million. However, between 1970 and 1978, the same central cities are estimated to have lost about 4 million persons while their suburban areas grew by an additional 7 million persons. These census figures include the effects of substantial annexations by the central cities between 1950 and 1970. Correction for annexation would probably result in absolute population losses for the entire period. Such a correction for annexations by the 24 sample cities included in this research had exactly that result. These population changes reflect high suburban birth and in-migration rates compared with the central cities' heavy out-migration rates combined with low in-migration rates.

Central-city jobs also declined while suburban employment rose. Between 1947 and 1963, central-city employment in 90 SMSAs dropped from 7.4 million to 6.7 million. These figures have been corrected for annexations. The corresponding suburban employment rose in the same period from 3.6 million to 6.6 million. Central-city employment has also shifted away from manufacturing and toward services and white-collar jobs. Between 1947 and 1963, manufacturing jobs located in the central city dropped 13 percent while service employment in the central city increased 23 percent (5). Evidence is mixed as to whether the same downward trends in central-city employment have continued in the 1960s and early 1970s, or if employment trends stabilized to a pattern of relatively slow central-city growth of about 1 pecent annually from 1960 to 1975 compared with about 3 percent annually in the suburbs (6,7). The shift from manufacturing clearly continued in the later period.

These shifts in the relative importance of the various central-city and suburban employment sectors indicate changes in the economic function of the central cities as they become office centers supplying administrative and service functions to their metropolitan regions and beyond. At the same time, manufacturing and retail firms are moving to the suburbs where more space and more customers are located. The decline in central-city population and jobs appears related to the size of the metropolitan area and to geographic region. The central-city population losses are most severe in the metropolitan areas with more than 1 million people, and the jobs and people are shifting from the North and Northeast to the South and West (7,8).

Previous Research

Previous studies of beltways comprise four case studies of individual beltways and three largely descriptive statistical studies of groups of beltway and nonbeltway cities. The four case studies analyze Boston's Route 128 (9), the Maryland and Virginia portions of the Capital Beltway in separate studies (10,11), and the Raleigh, North Carolina, Beltway (12). All of these studies found that intensive development sprang up about these roads just as is the case with radial highways. In addition, there was a noticeable increase in multifamily residences in the vicinity of the Capital and Raleigh Beltways. Route 128 quickly attracted industrial development: Several years after its opening, there was a net of $80 million in additional industrial development and 12 000 additional employees in the corridor.

The beltway studies have often noted that many of the businesses and industries locating along these highways are relocating from the CBD; however, a sustained analysis of CBD changes in relationship to the beltway lay outside the scope of these case studies. The Virginia portion of the Capital Beltway was found to promote a more compact, less star-like urban form as residential uses filled in the entire peripheral area instead of following radial routes outward from the center. The distribution of commercial areas was unaffected. Industrial plants also began to appear in peripheral areas associated with the Capital Beltway. However, these areas were previously not easily accessible and it is not clear whether the same development would have occurred if a radial had passed through. Knowledgeable local observers have stated their conclusion that the Raleigh Beltway is a cause of the decline of the commercial core of the city, which is assuming the doughnut form with a comparatively unused center. Based on a review of the highway impact literature down to late 1963, Racster (13) hypothesized that the attractiveness of a beltway location lies in the access it offers to the entire region as contrasted to the more limited access along a radial corridor.

The three descriptive statistical studies were the Urban Institute team's six-city analysis prepared for Richmond, Virginia; an unpublished Federal Highway Administration (FHWA) staff study of seven cities with and seven cities without beltways (14); and a study of office suburbanization along freeway corridors in seven cities (15). Although the study of office sites found that radial routes had a lower percentage increase in office sites than did beltways, this reflects the large, undeveloped areas

Table 1. Regions and SMSA size classes.

Factor	Beltway City	Nonbeltway City
Region		
Northeast/North Central	Washington Minneapolis-St. Paul Indianapolis Columbus Toledo Quad cities	Philadelphia Dayton Grand Rapids Springfield
South/West	Houston Atlanta San Antonio Omaha Sioux Falls	Phoenix Portland Sacramento Birmingham Oklahoma City Knoxville Spokane
Size Class[a]		
<750 000	Omaha Quad cities Sioux Falls	Oklahoma City Grand Rapids Springfield Knoxville Spokane
750 000-2 million	Atlanta Indianapolis Columbus San Antonio Toledo	Portland Sacramento Phoenix Dayton Birmingham
>2 million	Washington Baltimore Houston Minneapolis-St. Paul	Philadelphia Pittsburgh

[a]1970 SMSA population.

crossed by the beltways rather than network configuration. The beltway routes had lower absolute numbers of sites, and thus the base numbers of sites for the percentages were very small. The Urban Institute's study has already been described. The unpublished FHWA study found that beltway central cities lost population less rapidly than nonbeltway central cities during the 1960s.

Because revitalization was not a major issue when these studies were prepared, the focus was on suburbanization. The case studies, in particular, do not give systematic attention to what happened in the central city. The statistical studies are based on very small numbers of cases and their findings may be of limited general application.

Research Approach

The evidence summarized in this paper is principally from a nationwide study. The findings of this study have been supplemented by a recent statistical study, The Land Use and Urban Development Impacts of Beltways, prepared for the U.S. Department of Transportation, the Department of Housing and Urban Development, and FHWA by the firm of Blayney-Dyett under subcontract to Payne-Maxie. The latter study included eight case studies based on local interviews with officials, developers, and businessmen.

The specific research questions addressed in this study are

1. Do beltway cities show different rates of population change in their central cities, suburban rings, or both, than nonbeltway cities?
2. Do beltways affect patterns of population density? and
3. Do beltway cities now show different rates of average percentage change in manufacturing or retail employment in their central cities, suburban rings, or both, than nonbeltway cities?

The first step in determining if beltways are associated with decentralization is to show whether any growth rates within a metropolitan area with a beltway differ from those in metropolitan areas without beltways. The first and third research questions focus on differing growth rates. Beltways, by increasing accessibility of suburban areas, may lead to a more tightly clustered suburban development pattern as suggested by study of the Capital Beltway. As a result, a metropolitan area may continue to be centralized but around a new feature--the beltway itself. The second research question investigates this possibility.

DATA

Data on total population, manufacturing employment, and retail employment for the central city and the remainder of the metropolitan area or suburban ring were collected from secondary sources (16-18). The sample is composed of 24 SMSAs divided evenly between beltway and nonbeltway areas.

The sample SMSAs ordered by size are as follows:

Beltway	Nonbeltway
Washington, DC	Philadelphia, PA
Baltimore, MD	Pittsburgh, PA
Houston, TX	Portland, OR
Minneapolis-St. Paul, MN	Sacramento, CA
Atlanta, GA	Phoenix, AZ
Indianapolis, IN	Dayton, OH
Columbus, OH	Birmingham, AL
San Antonio, TX	Oklahoma City, OK
Toledo, OH	Grand Rapids, MI
Omaha, NE	Springfield, MA
Quad cities (Davenport-Bettendorf, IA, and Rock Island, IL)	Knoxville, TN
Sioux Falls, SD	Spokane, WA

The 12 beltway SMSAs comprise most of the SMSAs with beltways essentially completed by 1973. Each beltway forms a continuous loop around at least three-quarters of its SMSA and is no closer than 2 miles to the CBD. The nonbeltway SMSAs have well-developed radial networks but relatively few lateral freeway connectors between suburbs. These SMSAs were selected to match, as closely as possible, the size and geographic distribution of the beltway group. Thus, when comparisons are made in the study between the beltway and nonbeltway groups, the comparison is between two network configurations--radial and beltway or concentric.

The general approach of this study was to compare percentage changes in selected economic and demographic variables for beltway and nonbeltway metropolitan areas between 1950 and 1977. The metropolitan areas were divided into central cities and suburban rings or remainders of SMSAs. Differences between average percentage changes were tested for significance by using the difference-of-means test (19). The SMSAs were disaggregated by geographic region and by SMSA size in 1970, as shown in Table 1, in an effort to make the samples more homogeneous.

Since the estimates of population after 1970 could not be made entirely consistent with the earlier data from the Census of Population, the population data cover the period 1950-1970. The before-beltway period is 1950-1960, while 1960-1970 is the period when the beltways were under construction and opening to traffic. All but three of the beltways were nearly completed by 1973, and all had substantial mileage open by 1970. Employment and commuting data were available for the 1970s; the Census of Retail Trade was available for 1972 and 1977, the Annual Survey of Manufacturing for 1973 and 1976, and the Annual Housing Survey for 1975. Thus, the 1970s are the after-beltway period for the employment and commuting analyses. The Census of Retail

Table 2. Percentage changes in central-city population in 24 beltway and nonbeltway SMSAs excluding annexation.

	Change (%)			Population		
City Group	1950-1960	1960-1970	1950-1970	1950	1960	1970
Beltway	2.9	-8.8	-6.0	5 492 031	5 568 266	5 213 080
Nonbeltway	-0.7	-9.2	-10.5	4 805 446	4 668 455	4 315 315
Total	1.1	-9.0	-8.8	10 297 477	10 236 721	9 528 395

Note: Data based on unweighted averages.

Table 3. Central-city population in beltway and nonbeltway SMSAs by region, 1950-1970.

	Population			Change (%)		
City Group	1950	1960	1970	1950-1960	1960-1970	1950-1970
Northeast-North Central Region						
Beltway	3 852 299	3 799 562	3 528 880	0.6	-9.2	-8.9
Nonbeltway	3 331 197	3 187 525	2 982 163	-2.4	-10.3	-12.5
Total	7 183 496	6 987 087	6 511 043	-0.7	-9.7	-10.4
South-West Region						
Beltway	1 639 732	1 768 704	1 684 200	6.2	-8.2	-2.1
Nonbeltway	1 474 049	1 480 930	1 333 152	0.5	-8.5	-9.0
Total	3 113 781	3 249 634	3 017 352	2.8	-8.4	-6.1

Note: Data based on constant 1950 central-city boundaries and unweighted averages.

Trade was the only economic census available for 1977 at the time that the research was conducted.

For groups of central cities or rings, the percentage changes used were the average of the individual items in each group, not the percentage change of the aggregate population of the group. Use of these unweighted averages focused on changes of individual cities or rings within the beltway or nonbeltway groups rather than on changes in the group populations as a whole. There was a large range in the population size of the individual members of each group, and small percentage changes in the larger ones resulted in large numerical changes. Aggregate percentage changes for each group would be overly responsive to these extreme numerical values.

The data have been corrected for boundary changes during the study period in two ways. Both the employment and population data reflect the SMSAs as defined in 1970 regardless of the date the data themselves refer to. Thus, counties have been added to the SMSA definitions of the 1950s and 1960s. The effects of annexations by the central cities have been corrected only in the population data through comparison of the tract maps of 1950, 1960, and 1970. All population data reflect the central-city boundaries of 1950. It was not possible to make the same correction to the employment data to produce standardized areas for the central cities.

In contrast, the Blayney-Dyett sample is larger (54 SMSAs). It was chosen by using different criteria for the beltway completion date and includes beltways very close to the CBD and beltways around coastal cities where a loop around three-quarters of the city is not possible. Annexations are not corrected in this study, which attempted to isolate the effects of beltways on population and employment through regression analysis.

Population Changes

In all three censuses, the total population (adjusted to exclude annexation) of the beltway central cities as a group was greater than that in the nonbeltway central cities, and the gap has widened as the nonbeltway central cities sustained a greater population loss within their 1950 boundaries than the beltway cities. (See Table 2, which is derived from FHWA and Census of Population data.) When the 20-year period is divided into a prebeltway era (1950-1960) and a beltway construction era (1960-1970), the beltway central cities, on the average, lost fewer persons in the 1960s when their beltways were being constructed and opening than did the nonbeltway central cities. This was also true in the prebeltway decade. Tests of the difference between means show that the differences between the average percentage changes for the beltway versus nonbeltway cities are statistically not significant. It is difficult to relate these changes in levels and rates of changes to the appearance of the beltways in the 1960s, since the trends in population levels and percentage changes favor the beltway cities both before and after the beltways were built.

Since the nationwide sample showed no effects, the analysis was refined by analyzing the data by region and size of SMSA. Many areas of the South and West have been found to be rapidly increasing in population in the 1970s. In contrast to these sunbelt areas, the Northeast or frostbelt has been stagnant or losing population. Such regional trends may obscure trends associated with the presence of a beltway. Also, the Northeast/North Central cities are, in general, older cities that developed before the automobile. Different historical circumstances may have produced different patterns of land and automobile uses that result in different responses to the presence of a beltway. Therefore, the 24 sample cities have been divided into two regions: Northeast/North Central region and the South/West region. The SMSAs by region were noted earlier. The population of the beltway and nonbeltway central cities in the two regions and their average percentage changes appear in Table 3.

These grouped data reveal some influence of overall regional population trends. In both periods, the Northeast/North Central beltway and nonbeltway cities do not fare as well as their South/West counterparts. However, the pattern is most pronounced in the 1950s. During the 1960s, central cities in the fast-growing South/West region lost population nearly as heavily as the Northeast/North Central cities and regional differences appear to fade. Within their respective regions, the beltway central cities continue to gain more or lose less population than nonbeltway central cities in both periods. As in the overall comparison between the regions, differences become very small in the

1960s. This convergence is particularly notable in the South/West region. Statistical tests of these very small samples show no significant differences between the means of the beltway and nonbeltway for either region. It should be noted, however, that there were significant individual variations within each group. Individual cities are discussed below.

Of the seven individual Northeast/North Central beltway cities, only Columbus and Quad cities grew appreciably in the period 1950-1960, and all lost population between 1960 and 1970 at rates ranging from 1 to 17 percent. This information is presented graphically in Figures 1 and 2. Similarly, the individual nonbeltway cities in this region have two growing cities in the 1950s and none in the 1960s. Percentage changes in the population of the South/West central cities vary more than those in the Northeast/North Central cities for both decades (Table 4). The South/West region has the extreme gainer (Houston) and loser (Atlanta) for 1960-1970,

Figure 1. Percentage change in population in beltway and nonbeltway central cities in North Central-Northeast region, 1950-1970.

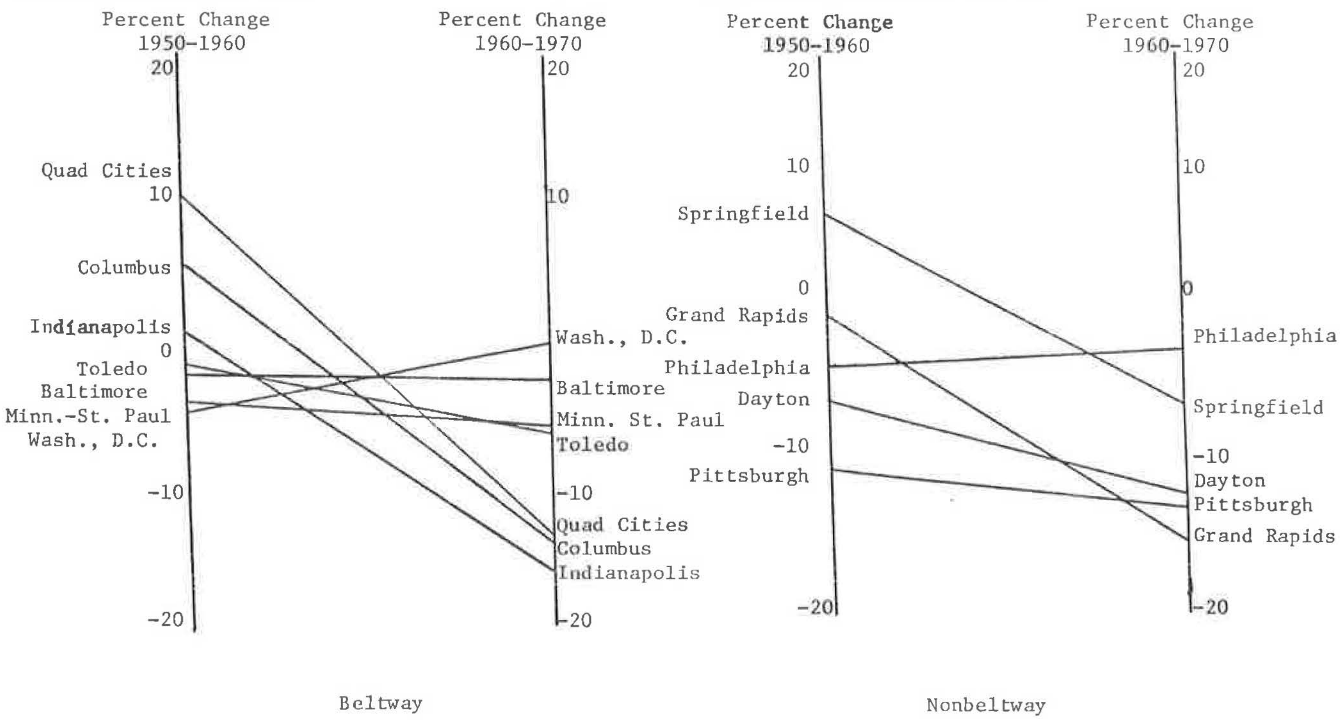
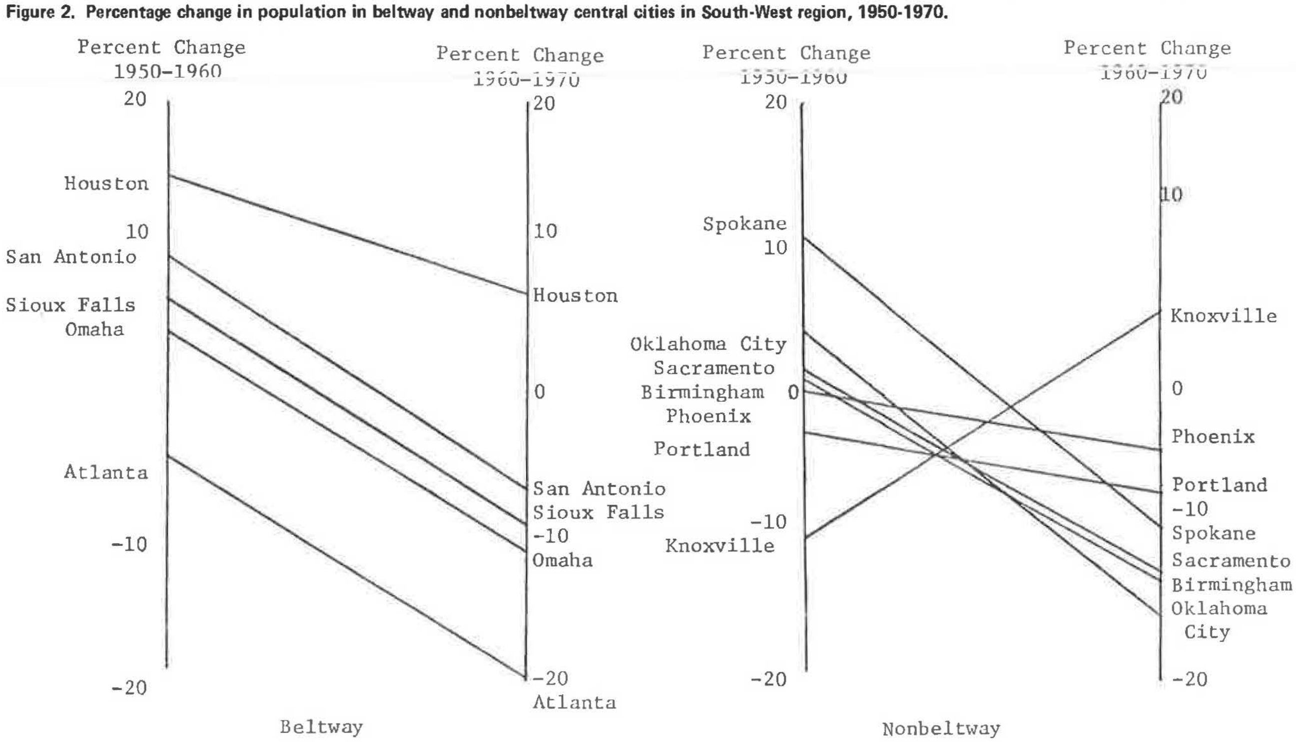


Figure 2. Percentage change in population in beltway and nonbeltway central cities in South-West region, 1950-1970.



and the extreme gainer (Houston) and second most extreme loser (Knoxville) for 1950-1960. There is a group of cities--Washington, D.C., Baltimore, Minneapolis-St. Paul, Toledo, Philadelphia, Phoenix, and Portland--whose population decline has been relatively stable and less than 10 percent since 1950. The larger number of such cities found in the Northeast/North Central region probably is not significant. All of these cities are in the larger SMSAs and the majority are found in SMSAs larger than 2 million in population in 1970. The Northeast/North Central region contains more sample central cities in the larger SMSAs than the South/West region.

Surveys of city dwellers have found that the suburban amenity of low density and large lot sizes are valued (20). This finding suggests that pressures for and against decentralization may be different in central cities of different population densities. Controlling the effect of density may reveal more clearly the role of beltways in decentralization. Density of the 24 sample cities was computed for 1950, 1960, and 1970 by using the 1950 areas and population figures corrected for the 1950 areas.

When the four most-dense beltway and most-dense nonbeltway central cities are compared with the four least-dense beltway and nonbeltway cities, density in the low-density cities fell only 2 percent and the high-density cities fell 13 percent (see Table 5). Within the density classes, beltway cities fell less than nonbeltway cities. However, this cannot be ascribed to the influence of the beltways because the beltway cities resisted decentralization in the 1950s before construction of their beltways as well as in the 1960s.

Trends in the 24 sample cities reflect national demographic trends and indicate that beltways play a minor (if any) role in the growth and distribution of population in metropolitan areas. Analysis of beltway and nonbeltway cities reveals either no statistically significant differences or differences that can be explained just as easily by other factors. Similar conclusions are reached in the Blayney-Dyett comparative statistical study, which finds only the distribution of higher-density residential development to be apparently sensitive to the presence of a beltway.

The findings do not necessarily preclude the possibility that a beltway would help or harm the central city that it circumscribes. The measured effects may be overwhelmed by

1. The inadequate time between the beltway's completion and the last census (1970) for impacts to be fully consummated;
2. The size of each geographic unit of analysis and boundary distortions, which may wash out localized impacts; and
3. The concurrent existence of other public policies, especially in land use regulation and home finance, which have stronger and more pervasive influences on population distribution.

The last point is emphasized by the Blayney-Dyett case studies in which many competing public actions and market forces are documented. Most importantly, beltways are only one component of the urban transportation network, and their effects cannot be segregated from the presence of other, noncircumferential arteries and transit facilities.

Employment

Since the average distance between workers' homes and their jobs is approximately 10 miles, the population characteristics of a city do not necessarily reflect the economic activities within its boundaries, as is clear from the discussion of national trends. Suburbanization of employment, changes in economic activity in central cities, and suburban congestion coupled with long commuting trips by automobile are widespread phenomena of the 1950s and afterwards. They are not caused by beltways; however, it is not clear if beltways have influenced these trends.

Sample trends for manufacturing employment show no significant differences between beltway and nonbeltway cities in either their central cities or their suburban rings (see Table 6). This is due at least in part to the small sample sizes and high variability. Central cities as a group lost manufacturing employment more heavily than suburban areas. Analysis by region and class size failed to reveal any significant differences.

Results for percentage changes in retail trade employment also do not show significant differences between beltway and nonbeltway cities either for all beltway and nonbeltway cities or for the regional and size class groups. The tendency for retail trade employment to be expanding in suburban areas, in the South and West, and in smaller SMSAs is apparent, but generally the differences are not significant.

Examination of manufacturing and retail trade em-

Table 4. Population change in central cities of beltway and nonbeltway SMSAs by 1975 class size of SMSA, 1950, 1960, 1970.

	Change (%)		
SMSA Size	1950-1960	1960-1970	1950-1970
<750 000	4.1	-9.7	-6.2
Beltway	6.9	-11.6	-5.5
Nonbeltway	2.4	-8.6	-6.7
750 000-2 million	0.2	-11.8	-12.0
Beltway	1.8	-13.2	-11.5
Nonbeltway	-1.4	-10.2	-12.5
>2 million	-1.5	-3.4	-4.5
Beltway	1.2	-1.0	0.4
Nonbeltway	-7.0	-8.2	-14.5

Note: Data derived from FHWA and Census of Population and based on unweighted averages.

Table 5. Average density and average percentage change in density for high and low density central cities, 1950-1970.

	Density (persons/mile^2)			Change (%)		
Density and City Group	1950	1960	1970	1950-1960	1960-1970	1950-1970
High density (N=8)						
Beltway (N=4)	10 928	10 759	9814	-1.3	-9.9	-11.2
Nonbeltway (N=4)	11 569	10 985	9940	-4.7	-10.6	-14.8
Total	11 249	10 872	9877	-3.0	-10.3	-13.0
Low density (N=8)						
Beltway (N=4)	4 493	4 953	4642	10.4	-6.0	4.2
Nonbeltway (N=4)	4 649	4 688	4266	1.4	-8.6	-7.8
Total	4 571	4 820	4454	5.9	-7.3	-1.8

Note: Data based on 1970 central-city boundaries and unweighted averages.

Table 6. Mean percentage changes with standard deviations for manufacturing and retail trade employment for beltway and nonbeltway SMSAs by size of SMSA and region, 1972-1977.

	Manufacturing (1973-1976)				Retail Trade (1972-1977)			
Factor	Beltway	SD	Non-beltway	SD	Beltway	SD	Non-beltway	SD
Area								
24 SMSAs	N=10[a]		N=9[b]		N=12		N=12	
Central city	-9.57	8.81	-13.67	6.27	21.77[b]	25.51	8.81	33.32
Ring	1.83	8.48	-3.94	6.54	35.51	19.51	33.32	15.12
North East/North Central	N=6		N=4		N=7		N=5	
Central city	-12.30	3.35	-13.70	5.98	2.70	17.41	-4.14	14.52
Ring	0.25	10.62	-9.08	5.01	27.14	10.27	19.34	6.24
South/West	N=4		N=5		N=5		N=7	
Central city	-5.45	13.68	-13.64	7.20	18.06	26.01	13.74	9.02
Ring	4.20	3.88	0.16	4.41	47.22	24.02	43.14	10.84
Size								
>2 million	N=4		N=2		N=4		N=2	
Central city	-6.58	11.58	-16.30	5.52	1.25	25.49	-0.87	20.14
Ring	6.10	7.93	9.40	1.27	32.03	9.61	26.98	10.80
2 million-750 000					N=5		N=5	
Central city					4.90	18.20	4.52	18.89
Ring					29.20	17.29	44.42	11.70
<750 000					N=3		N=5	
Central city					26.57	18.55	9.14	13.36
Ring					50.67	29.21	28.56	13.20
Classes combined for mfg. only (2 million-750 000 and <750 000)	N=6		N=6					
Central city	-11.57	6.88	-11.73	6.45				
Ring	-1.02	8.20	-3.45	6.59				

Note: Data based on Annual Survey of Manufacturing, 1973 and 1976; Geographic Area Services, Census of Retail Trade, 1972 and 1977.
[a]Data unavailable for Sioux Falls and Quad cities. [b]Data unavailable for Sacramento, Springfield, and Spokane.

Table 7. Percent distribution of workers by place of residence and place of work, 1970-1975.

	Place of Work					
	Central City		Outside Central City		Outside SMSA	
Place of Residence	1970	1975	1970	1975	1970	1975
Beltway SMSA						
Central city	82	78	17	21	1	1
Outside central city	51	45	46	53	3	3
Nonbeltway SMSA						
Central city	81	81	15	17	4	2
Outside central city	31	30	60	64	9	7

Note: Data based on U.S. Bureau of Census, Census of Population: 1970 Detailed Characteristics; Current Population Reports, Series P-23, Special Studies 86, 89, 98, and unpublished data.

ployment growth in the past for the 24 sample cities reveals that the central city and suburbs of the beltway and nonbeltway cities have not differed significantly in employment growth either as a group or by region or size class for the periods 1958-1963, 1963-1967, and 1967-1972. Employment in both sectors shows a pattern of stagnation in central cities and brisk expansion in the suburban rings. This decentralization appears as early as 1959-1963 and predates all 12 beltways. The pattern is particularly striking in the Northeast/North Central region's SMSAs whose overall loss of manufacturing employment was actually confined to the central cities while their suburbs gained.

Blayney-Dyett, relying on census data, analyzed the suburbanization of manufacturing employment for 1967-1972 and the suburbanization of retail trade for a partial sample for 1972-1977. They did not find any significant relationships between beltways and the other variables that could not be ascribed to other causes.

Commuting

Rather limited data are available on commuting in the 1970s. Data from the 1970 Census of Population reflect patterns during construction of the beltways. However, the Annual Housing Survey for 1975 includes 6 of the 24 sample SMSAs divided evenly between beltway and nonbeltway SMSAs. The cities are Philadelphia; Portland, Oregon; Springfield-Holyoke-Chicopee, Massachusetts; Atlanta; Columbus; and San Antonio. Table 7 suggests that longer commuting may be more common in beltway SMSAs where higher percentages of people live in one jurisdiction and work in another than in the nonbeltway SMSAs. However, significant conclusions cannot be drawn on the basis of such a small sample size and small numerical changes. Blayney-Dyett also found no significant relationships between commuting patterns and beltways that could not more easily be ascribed to other causes.

The sample cities show the decentralization of employment and increase in long-distance commuting across jurisdictional lines characteristic of U.S. cities since at least the late 1940s. This national trend predates the beltways. There is no evidence from either the 24 sample cities examined in this study or from Blayney-Dyett's larger sample that links beltways with a different degree of decentralization or a different commuting pattern than is characteristic of nonbeltway cities. Most U.S. cities suffer to some degree from the fiscal and equity consequences of decentralization; there is no evidence from this study that beltways are a specific cause of decentralization leading to these consequences.

In part, the finding of no significant beltway impact may be due to problems with the research design and availability of data, similar to the problems documented in the population section. The 1972-1977 period used as the "after" period of expected beltway impacts is short and contains a recession. The beltways were actually completed throughout the 1960s and early 1970s. Thus there is no clear-cut "before" or "after" period. The unavailability of major portions of the economic censuses of 1977 limited the analysis for this and the Blayney-Dyett study.

Another problem arising in the research design was the small sample size and high variability within the sample as measured by standard deviations. This problem is not easily corrected since both studies include all beltways that met study criteria. However, examination of the average percentage changes in employment in Table 6 suggests that in many instances the percentages are sufficiently similar between the beltway and nonbeltway cities that a larger sample would not result in significant differences.

CONCLUSIONS

Subject to the caveats raised in the concluding paragraphs of each subject discussion, beltways appear to have no significant effects on overall central-city vitality or on overall suburbanization of people and jobs. Blayney-Dyett's case studies suggest that land use regulation, tax and mortgage policies, and other factors generally outweigh the influences of beltways. These findings based on aggregate data cannot take the place of detailed, project-level analyses that explicitly take into consideration the types of local factors that the case studies found to be important.

The findings of this research, in combination with the case studies, suggest that beltways and probably transportation facilities in general are, at most, one of many influences on the pattern of urban development and that policies to support revitalization of central cities might be better implemented by using beltways or other transportation facilities to support measures such as land use controls that bear more directly on urban development.

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Monitoring Traffic Management on Retailing Activities: Problems and Possible Solutions

A.D. MAY AND P.M. WEAVER

A method for objectively measuring the effect of traffic management on retailers' receipts is discussed. It identifies the need for information on these effects and, by considering the impact of traffic management on retailing activities in general terms, highlights the problems in obtaining such information. A checklist of criteria for studies designed to measure effects on trading performance is presented and used as a basis for developing a new method designed

to be both objective and generally applicable. The method involves collection of indexed monthly receipts for a stratified sample of individual shops and the use of national control data to project expected levels of trade. These are then used to identify changes in trading performances. The method is tested by using a traffic management scheme in York, England. Results indicate that effects, while significant, were smaller than those claimed by traders and were short lived. Outstanding methodological issues are identified.

Traffic management measures have been developed largely to help the car or bus user, pedestrian, cyclist, and resident; the business community is rarely identified as a group to be assisted. Instead, the traffic engineer all too often sees business people as inevitable opponents of traffic management, whose fears are ill-founded and who need to be pacified if possible. Not surprisingly, business people tend, therefore, to view traffic management as a threat and react against schemes that are proposed rather than suggesting ways in which schemes can be devised to help them. There has been a need for some time to reduce the delays in implementation that such differences of view cause; one obvious approach to solving this problem is to provide a clearer understanding of the ways in which traffic management can affect or assist business activity. Recently, the need to resolve these differences has become more acute since there has been a growing interest in the use of traffic management schemes as land use planning tools to help revitalize business activity. Many pedestrian streets have been introduced with this in mind (1, 2) as have the Urban Mass Transportation Administration's recent experimental automobile-restricted zones (3), and traffic cell schemes such as that in Gothenburg (4). Clearly, it is important not just to convince business interests of the merits of such schemes, but also to be sure that their beneficial effects on business are sufficient to justify the restrictions imposed.

An understanding of the mechanisms by which traffic management affects business activity and of the magnitude of the effects produced is therefore of value to transport planners and engineers and to the business community. Others who might benefit include public transport and car-park operators, customers, and clients and other professional groups such as Chartered Surveyors (5).

This paper looks briefly at the general form of such a mechanism and its application specifically to retailing activity. It discusses some of the problems of working in this field, reviews some other studies on the topic, and then describes a study conducted recently in York, England, which has been used to test some possible survey and analysis procedures.

RELATION BETWEEN TRAFFIC MANAGEMENT AND RETAILING ACTIVITY

The ways in which traffic management can affect retailing activity are best seen by considering the general relation between transport and land use (Figure 1) (6). Transport policies can affect land use in three distinct ways:

1. By consuming or releasing land,
2. By improving or reducing accessibility, and
3. By improving or worsening the environment.

Traffic management schemes rarely consume land except for minor junction improvements. However, schemes may release road space for other uses such as pedestrian streets, meeting areas, and markets. All traffic management schemes affect accessibility (in terms of journey time, distance, cost, and reliability) and most will improve or worsen the environment by adding to or reducing the traffic in individual streets.

The ways in which these changes might affect retailing activities are depicted in Figure 2 and are briefly described below.

1. Improvements in environment and in accessibility may encourage additional custom. Conversely, a deterioration in these factors could discourage custom. In practice it is often the case that traffic management improves the environment while worsening accessibility (or vice versa) and the net effect on custom is thus uncertain.
2. It is worth noting that changes in accessibility and the quality of the environment do not have to occur for effects on custom to be felt; adverse publicity about an otherwise successful scheme may discourage customers (7).
3. Changes in consumer behavior may affect shop receipts; however, it is possible for receipts to stay constant despite changes in consumer behavior, if customers compensate by buying more on each visit (8).
4. A shop's operating costs can be affected both by changes in consumer behavior and, directly, by changes in accessibility that may add to servicing and staffing costs.
5. The combined effect on receipts and operating costs may affect the profitability of shops in the short term and may in the longer term lead to changes in the mix, intensity, and quality of activities in the shopping center.
6. Both consumer behavior in the short term and land use changes in the long term can be influenced

Figure 1. Transport-land use relation.

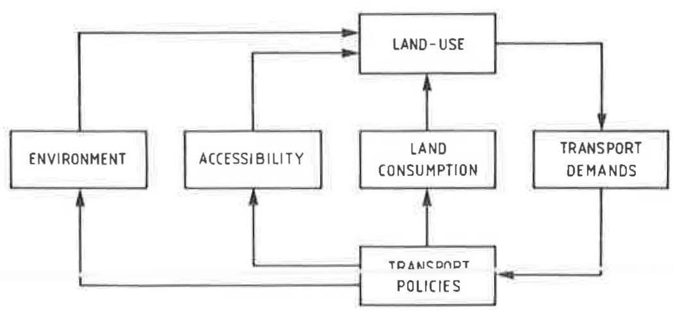


Figure 2. Traffic management-retailing relation.

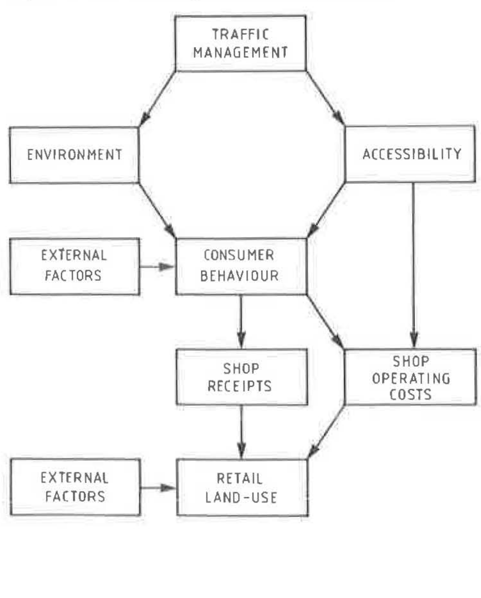
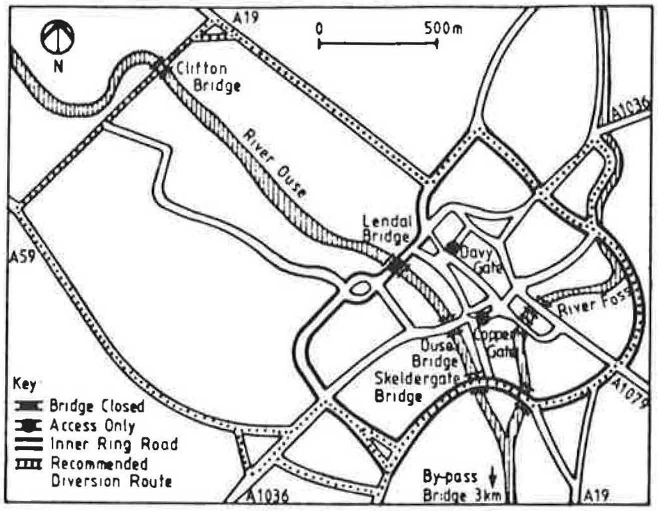


Figure 3. Temporary traffic management measures for York's road network, October 1978.



by a wide range of external factors such as seasonal factors, inflation, fiscal policy, and competition from other centers. In particular, it is worth noting that improved accessibility to one center may reduce receipts in a competing one, even if its accessibility is unchanged (7).

The work reported on in this paper limits itself to assessing the effects of traffic management on shop receipts. It excludes both the short-term effects on operating costs and the long-term ones on land use patterns.

STUDY REQUIREMENTS

Even with this limitation, the requirements of a study of the effects of traffic management on retail activity are complex. As indicated by Figure 2, four interrelated strands of inquiry are needed. The first must attempt to assess the impact of traffic management on the accessibility and environmental quality of the shopping center as a whole and, ideally, the specific effects of individual elements of the traffic management scheme and on individual locations within the center. The second will need to identify changes in the number and nature of shopping journeys to the center. The third must attempt to establish whether these changes in consumer behavior are caused by environmental or accessibility changes or by external factors. The fourth must identify specific changes in shop receipts and relate these to identified changes in consumer behavior. Only when all four of these strands are available will it be possible to draw tentative conclusions about the short-term influence of a traffic management scheme (and, ideally, of its individual elements) on retailing activity.

PROBLEMS FACED IN MEASURING RETAIL IMPACTS

Many difficulties will have to be overcome in order to satisfy these study requirements. First, a decision is needed on the extent of the area to be studied, since the effects of traffic management measures need not necessarily be confined to their immediate vicinity (9). Second, environmental and accessibility changes need to be measured for different locations in the center and, in the case of accessibility, for journeys from different origins and by different modes. Third, changes in numbers of customers may be difficult to assess and may need to be estimated from proxy measures such as pedestrian and parking counts. Fourth, it is often difficult to obtain adequate and valid data on receipts since firms are usually reluctant to release commercial information. Fifth, even if it is possible to measure changes in consumer behavior and in receipts, causality remains to be established. Comparative data from a panel of control shops or from shops in a control location will be needed to ensure that external factors are not influencing results. Finally, even if changes can be attributed to traffic management, the complexity of the effects will make isolation of the specific cause extremely difficult.

The study of which this report forms part has attempted to tackle all these problems. However, this paper concentrates on methodology developed to deal specifically with the problems of measuring changes in receipts and establishing suitable controls.

CRITERIA FOR MEASUREMENT OF CHANGES IN RECEIPTS

The first stage in this process was to establish a checklist of criteria for measuring changes in receipts. The method should

1. Be based on objective data, since experience suggests that assessment based on surrogate measures or on traders' subjective opinions is liable to be inaccurate;
2. Take account of past trading performances to isolate the effects of seasonal and secular trends in individual shops' performances;
3. Isolate the effects of external economic and social factors by using a control that should ideally be specific to the types of shops and center being studied;
4. Enable any statistically significant deviations in trading performance to be identified and quantified; and
5. Be able to assess whether changes in trading performance had varied with time, by shop type, or by location within the shopping center, as a basis for identifying short-lived and longer-term effects, activities particularly at risk, and specific causes of changes.

THE YORK STUDY

Based on these criteria, our own work seeks, not so much to make a case study of a particular scheme, but rather to establish and test a method for measuring effects on retail activity that might be seen to be objective and generally applicable. The traffic management scheme on which this method was tested and the other surveys of which the study of retail trade formed a part are described below.

The Scheme

The scheme under study, which has been fully described elsewhere (10), was associated with the temporary closure of Lendal Bridge for repair. The scheme operated from October 4, 1978, to April 8, 1979. During this period, Lendal Bridge remained open for buses, taxis, and cyclists, but all other traffic had to find alternative routes. Since Lendal Bridge is one of only four river crossings in the city center, providing more than 25 percent of cross-river capacity, serious congestion was feared, particularly in the narrow, medieval streets in the heart of the center. Therefore, to control through movement, two important thoroughfares, Davygate and Coppergate, were closed except for buses and for access. (See Figure 3.)

Related Surveys

This scheme was particularly well suited for a study attempting to devise and test methods of assessing the effects of such measures on retail trade. The general background to York's traffic problems was already well documented (11). The U.K. Department of Transport was measuring the direct effects on accessibility and environment and the specific changes in numbers of shopping journeys, pedestrians, and parked cars (8). Early analysis of these results indicated a significant shortfall in the number of trips to York during the first stage of the scheme. Over the midafternoon period a fall of 19 percent was recorded in the number of vehicle movements crossing the river for personal business or shopping trips. Of this shortfall, 75 percent was caused by a drop in the number of personal business or shopping trips originating from south of the river. However, while giving grounds for further enquiry, the mere spatial and temporal coincidence of these events do not, of themselves, imply causality. Moreover, as already noted, a reduction in shopping trips, however caused, need not necessarily imply a loss of trade in monetary terms.

York traders did, in fact, claim that receipts had fallen by as much as 25 percent as a direct result of the scheme but, as noted earlier, such estimates are not necessarily reliable. Investigation, both into the causes of changes in consumer behavior and into actual changes in trading performance, were still required, but the Department of Transport was unsuccessful in seeking the agreement of the York Chamber of Trade and Commerce to such surveys. The Chamber was, however, prepared to accept the involvement of the Institute for Transport Studies, acting as an impartial and objective third party. The techniques used by the Institute to identify causes of changes in consumer behavior and the findings of that inquiry are documented elsewhere (12). The following sections describe the techniques adopted to measure trading effects and outline the results obtained.

TRADERS' SURVEY

The survey and analysis method was designed to meet the criteria set out above by

1. Collecting objective data in the form of traders' receipts;
2. Obtaining information for a sufficient period to identify seasonal and secular trends for individual shops;
3. Using national data to provide a control and, with data from number 2 above, to project expected levels of trade for individual shops over the period of the traffic management scheme;
4. Analyzing statistically the differences between projected and achieved receipts for individual shops; and
5. Aggregating these differences to permit comparisons by time period, type of shop, and location.

Methods Used to Collect Trading Data

A questionnaire was drafted that sought information from individual stores on the shop's characteristics (e.g., type of business, number of employees, and whether a chain store) and trading trends since January 1976. The decision to ask for trends in receipts from 1976 was a compromise between the desire to have information going back as far as possible for analytical reasons and the risk of low response if shopkeepers were asked for too much information. Turnover trend information was obtained by asking retailers to plot receipts graphically for successive months. A monthly time interval was chosen to maintain compatibility with national data (13) and to enable short-lived and longer-term effects to be isolated. Traders were asked to choose their own scale for the axis indicating receipts. The only constraint was that they should choose an equal interval scale starting from a zero origin. Having constructed the graphs, traders wishing to preserve confidentiality were invited to cut the receipts scale away. This left only a pattern of points that, by depicting the relative magnitude of successive trade figures, could be converted into a numerical time series based on index linking.

Before distributing the questionnaire, the University, in cooperation with the York Chamber of Trade and Commerce, convened a meeting of local traders. This gave the opportunity to publicize the survey, explain the approach adopted, and assess trading opinion. By the close of the meeting a show of hands indicated almost complete support for the survey. It was on this basis that, for the pilot survey, it was decided that further personal contact would not be necessary. However, a postal survey proved very disappointing with response rates of below 20 percent. Discussion with shopkeepers later showed that, in almost all cases, failure to respond was due, not to a reluctance to supply information, but rather to the time and effort involved in completing the questionnaire. Evidently, for the full survey, the survey procedure had to be revised.

First, a new questionnaire was designed. Many of the background questions asking about the store and its business and most of the more complicated explanations were omitted. It was decided that the revised questionnaire should be distributed and collected personally. The intention was to give most of the explanations and instructions for completing the forms verbally, while also building some degree of rapport with individual traders to boost response rates. Throughout the distribution phase, an official from the York Chamber of Trade and Commerce was at hand both to demonstrate the authenticity of the survey and to encourage traders to complete their forms.

Questionnaires were distributed to all department stores and to a 20 percent stratified random sample of all other shops in the city center. Stratification was both by store type and location within the city center. Four categories of store were recognized: foodshops, clothing and footwear stores, household durables (furniture, carpeting, and decorating) shops, and specialty hard-goods stores (e.g., jewellers and electrical goods). In addition the city center was divided into an inner and an outer zone (Figure 4) to test whether the core of the center, which included the main traffic restrictions, was more seriously affected. Of the 92 questionnaires distributed, 58 usable returns were obtained. This represented a 100 percent return from the department stores (7 questionnaires) and a 60 percent return from the other shops (51 questionnaires). This meant that a usable return was obtained from approximately one in every eight shops in York's city center.

No statistically significant differences were found between the composition of the achieved sample (classified both by store type and location) and the population distribution. However, it should be noted that while this revised procedure achieved a much more satisfactory response rate, the effort involved in distributing and collecting the questionnaires was considerable at up to 2 h/shop.

Projecting Expected Levels of Trade

In order to counter the effect of external economic factors, the time series data for each shop was compared with the national pattern of sales for shops of a similar type. The comparison was made by dividing successive monthly trade figures for each shop in York by the corresponding national index. This left a series of trading ratios for each store that described the trading performance of that store over time relative to national levels. An example is given in Table 1.

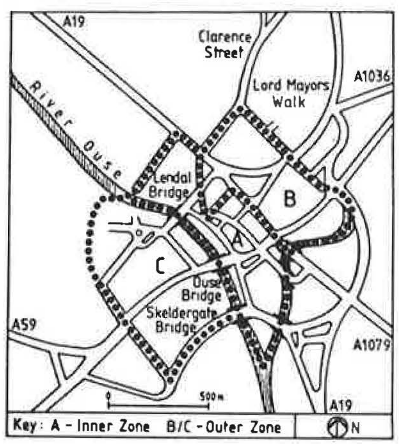
A time series analysis was then performed on the trading ratios for each shop. The secular trend was obtained in each case by a least-squares, line-fitting procedure and the seasonal component was isolated by using a conventional additive model.

Thus calibrated, the time series models could be projected forward under the assumption of stable, but not static, conditions to predict trading ratios for each shop in the absence of the traffic scheme. Expected levels of trade were then set for each shop by multiplying the projected ratios by the corresponding national index for each month that the traffic management scheme was in operation. An example is given in Table 2.

Comparing Achieved with Projected Levels of Trade

This put the projected figures, calculated to take account both of past trading performances and national trends, into a form enabling direct comparison with the achieved figures for individual shops reported by traders. The percentage difference between actual and expected trading levels was then calculated for each shop on a monthly basis. Table 2 illustrates how these comparisons were made. By weighting these monthly figures according to the relative importance of each month's receipts, comparisons were then made for the entire six-month closure period of Lendal Bridge. Only at this stage was aggregation across groups of shops by type or location possible, because the measure of trading performance used--the percentage deviation of achieved from expected trading levels--was common to all shops and was independent of the type of scale used by individual shopkeepers to supply the initial trading data.

Figure 4. Division of city center into an inner and an outer zone.



Limitations of the Method

Obviously even such a complex procedure has its limitations. It relies on shopkeepers to provide valid information and to have constructed their graphs correctly. While the latter point was checked when collecting the information, it was not considered possible to include questions to check on the validity of the information. Ideally, the information should have covered a before period of more than 2.5 years to identify seasonal trends with greater accuracy; however, as noted above, it was felt that requests for further data would have reduced the response rate. The use of a national control is subject to criticism on the grounds that it contains shops from a variety of urban, suburban, and rural locations that may not be suitable for identifying the external influences occurring in towns similar to York. This problem was imposed on the study by the aggregate form in which national data were then available (13); the only alternative would have been to identify a suitable control center. Finally, the analysis gives equal weight to all shops, irrespective of their importance to the center's economic health or overall trade. This limitation is imposed on the analysis by the reluctance of traders to release absolute receipt data. It is worth noting in this respect that only 5 percent of the respondents elected not to remove their receipt sales.

Results of Trading Analysis

In the analysis, department stores were considered separately from other shops. As has been mentioned, information was obtained from all seven of York's department stores and, in consequence, analysis of the data was not concerned with the estimation, but rather with the derivation, of population parameters.

Over the full period of closure of Lendal Bridge, the mean percentage deviation of achieved from ex-

Table 1. Hypothetical example to show derivation of trading ratios.

Ratio	Trading Factor	Jan. 1976	Feb. 1976	March 1976	April 1976	May 1976	June 1976[a]	Sept. 1978
a	Trading index (York shop)	100	120	160	180	220	230	300
b	Trading index (national)	100	132	164	180	200	200	250
a/b	Trading ratio	1.00	0.91	0.97	1.00	1.10	1.15	1.20

[a]This analysis was continued for 33 months.

Table 2. Hypothetical example to show derivation of expected trading levels and comparison with achieved figures.

Ratio	Trading Factor	Oct. 1978	Nov. 1978	Dec. 1978	Jan. 1979	Feb. 1979	March 1979
a′/b	Projected trading ratio	1.1	1.0	0.9	0.8	0.9	1.2
b	Trading index (national)	150	160	200	125	130	140
a′	Expected trading index (York shop)	165	160	180	100	117	168
a	Achieved trading index (York shop)	160	152	171	105	117	170
a - a′/a′	Deviation from expected (%)	-3.0	-5.0	-5.0	+5.0	0.0	+1.2

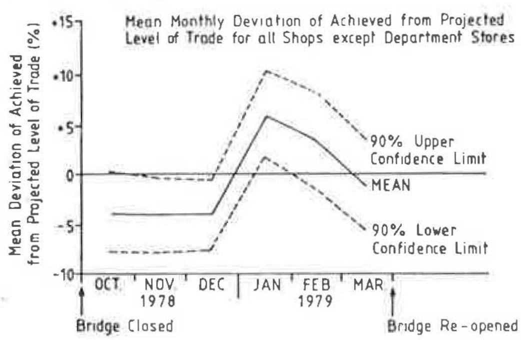
Table 3. Mean percentage deviation of achieved sales from expected sales by shop type.

Type	Mean	Standard Error	n	95 Percent Confidence Bands
Foodstores	-6.0	2.0	8	±5.6
Clothing, footwear stores	+1.4	2.3	14	±5.1
Household durables	+3.2	2.3	8	±5.4
Specialty hard-goods stores	-5.6	2.6	21	±5.4

Table 4. Mean percentage deviation of achieved sales from expected sales by zone.

Zone	Mean	Standard Error	n	95 Percent Confidence Bands
Inner	-4.2	1.9	31	±3.9
Outer	+0.3	1.8	20	±4.4

Figure 5. Mean monthly deviation of achieved from projected level of trade for all shops except department stores.



pected sales was -2.4 percent (±2.9 percent) for all shops except department stores. The mean deviation for department stores was +1.1 percent.

Table 3 gives the mean deviation of achieved from expected sales for different types of shops. It can be seen that two categories of shops, foodstores and specialty hard-goods stores, experienced levels of sales that were significantly better than those of foodstores and specialty hard-goods stores (at least at the 90 percent level and, in most cases, at the 95 percent level).

Trading performances were also found to differ according to location within the shopping center. Table 4 shows that the performance of shops in the middle of the center was significantly below that expected (at the 95 percent level) and was significantly worse than the performance of shops in the outer fringes (at the 90 percent level). The extent of the shortfall in the case of shops in the inner zone was 4.2 percent (±3.9 percent).

Finally, trading performances varied throughout the six-month period during which Lendal Bridge was closed. Figure 5 shows how the mean trading performance of all stores except department stores varied by month. Over the first three months, the mean trading performance was below expected levels. The shortfall was significant at the 90 percent level. Trade was significantly above that expected in January 1979; it then returned to projected levels in February and March.

These results suggest that York's shopkeepers, and particularly those selling food and hard goods and those in the inner part of the center, did experience a pattern of trade different from the pattern that they might have expected during the period that Lendal Bridge was closed. This effect was most marked in the initial period of closure.

These results, as indicated earlier, provide one input to an assessment of the effects of the closure of Lendal Bridge on retailing activity. It is not possible from these results alone to identify the closure of the bridge as the specific cause of the changes in trading performance, since other factors peculiar to York may have been responsible. Indeed, York experienced a serious flood in late December that had some effect on trade. The results of the study of consumer behavior (12) are being used to isolate specific causes.

Preliminary results indicate that closure of the bridge was the most important cause of any changes in behavior and, hence, receipts, although its significance varied with origin and mode of the shopping journey. They also suggest that problems of route finding and parking as a result of the closure were the major factors causing changes in shopping patterns. This may explain the greater impact in the inner zone. It appears likely that differences between retail sectors in the number and location of alternative shopping opportunities account for the variation in trading performance by type of shop.

However, the most important point to note is that the aggregate effects were not only small, but also short lived, and significantly less pronounced than traders or changes in shopping journeys had suggested.

CONCLUSIONS

Although it has been possible to draw some conclusions specific to York above, this paper has been concerned mainly with the problems of measuring the effects of traffic management measures on retailing. The following conclusions can be drawn on this issue.

1. A measure of trading performance based on receipts does not necessarily lead to the same conclusions as an assessment based on traders' opinions or the interpretation of surrogate variables. Although it is not possible to say that any of these methods provides wholly reliable answers, the method based on receipts is certainly the most objective.
2. It is possible to obtain details on receipts from shopkeepers. However, it is a time-consuming task and may well need to be done by an independent and impartial agency.
3. From the work in York and work in the Netherlands, reviewed elsewhere (14), it seems possible to achieve a response rate of at least 50 percent; however, it would be worth trying to find ways of increasing this rate.
4. Given the kinds of changes in economic conditions that were experienced over the course of this study, a control to separate external influences on receipts is essential. Asking shopkeepers to specify the cause of any change in receipts is probably not a sufficiently reliable approach.
5. Obtaining such a control is difficult. In the United Kingdom, national data can be used (although their format has recently been changed), but this does not necessarily represent expected patterns of trade in a particular town. The use of a control town is an alternative approach, and it may be worth devoting more effort to identifying suitable control towns.
6. However, it appears that effects of traffic management schemes on receipts, even for the most

severely affected groups of shops, may well be relatively small. It will be important, therefore, to devote as much effort as possible to studying the more-direct costs imposed on retailers' operations.

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Nonlocal Traffic in a Residential Neighborhood: The Problem and Its Management as Seen by Residents

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This study examines the problem of nonlocal traffic in a relatively lightly traveled residential neighborhood adjacent to the Pennsylvania State University campus at State College, Pennsylvania. The purpose of this research is, first, to assess what constitutes a traffic problem for the area residents and, second, to evaluate their preferences among alternative traffic control measures. The data were collected through field observation and a home-interview survey on a sample of streets in the neighborhood. An analysis of variance shows significant overall differences between medium- and light-traveled streets in the residents' perception of the problem and willingness to accept traffic restraint measures; however, the residents' location relative to a particular control device and how it affects their mobility, as well as other socioeconomic factors, account for a great deal of the difference. Controlling speeding in the neighborhood is the residents' most important concern and four-way stop signs are the preferred solution to that problem. The research findings point out some of the inadequacies of traffic engineering practices, such as traffic counts, accident records, and solicitation of citizen complaints when viewed in isolation to be used as a basis for traffic management decisions.

Management of nonlocal traffic in residential neighborhoods has been a complex and controversial issue among transportation planners and the public. According to standard planning principles, streets in residential areas that are designed for local traffic should not be used by nonresidents to minimize travel times, to avoid traffic signals, or for parking (1). Environmental research has shown that high traffic volume and speed directly increase traffic accidents, as well as noise and air pollution; they have also been associated with decline in neighborhood quality and property values (2). Although traffic management strategies have been shown to alleviate some of the above problems, they have met with opposition from area residents and outsiders because they inhibit mobility and are an inconvenience, especially to those who do not benefit directly from the reduction of traffic (3).

IMPACT OF THROUGH TRAFFIC ON RESIDENTIAL ENVIRONMENTS

Studies of the quality of residential environments, as perceived by residents, have identified noise; accessibility; social compatibility with neighbors; maintenance of lawns, buildings, and streets; and safety of both self and property as important dimensions of neighborhood satisfaction (4,5). Through traffic in a residential neighborhood disturbs many of these qualities and threatens that environment. Traffic noise causes the greatest disturbance (2). Noise is related to volume of traffic and the speed and type of vehicle. Perception of noise correlates strongly with objective noise levels (6). However, personality, past experience, and situational variables such as time of sound are important in determining how a sound is perceived (7,8).

The volume and speed of traffic threaten the safety of residents. Families with young children and the elderly are especially fearful. For instance, in one study 74 percent of child and automobile accidents were found to have occurred within 1 km of the child's home and, in more than 70 percent of these, the child is the cause of the accident, presumably because he or she has not yet developed skills to react to traffic movement (9). Property owners are concerned with the effect that increased traffic may have on the value of their property.

A question of interest to environmental researchers has been how people adapt to various environmental stress conditions. Appleyard, for example, found that high traffic volumes lowered social interaction that, in turn, led to a reduction of neighborhood cohesion and, ultimately, to a decline in homeowners' incentives to maintain their residences (2). A high level of traffic has also been associated with rapid population turnovers and with changes of land use from residential to commercial activities (10).

Effects of the volume of traffic form a vexing question. What matters is the perception of traffic and the willingness of residents to do something about its negative impact. The perception is determined by personal characteristics, such as one's frame of reference; by the status of the perceiver (homeowner versus renter, or permanent resident versus student); and, finally, by how the traffic affects the individual (location of home relative to traffic control device).

RESIDENTIAL TRAFFIC CONTROLS

Several types of traffic control have been implemented in the United States to manage nonlocal traffic in residential neighborhoods. Such controls can be categorized according to three types of strategies. Each is briefly described here.

Peripheral Strategies

Peripheral strategies are intended to reduce or stop nonlocal traffic from entering secondary residential streets along the periphery of the neighborhood. Such controls include traffic signs such as "Do Not Enter" or "No Left Turn" or they involve actual construction of physical devices, such as median barriers along arterials to prevent left turns and to increase the traffic capacity of the arterial. Outward flowing one-way streets and cul-de-sacs appear to be the most effective controls. The advantage of this approach is that controls are placed at the very site where the problem begins to occur. The strategy is effective because fewer motorists violate rules on busy streets where the perceived likelihood of enforcement is great (3).

Internal Strategies

Internal controls include stop signs (two-way or four-way) at key intersections, speed bumps and undulations with the intention of slowing down traffic, diverters of various designs, redesign of local streets, and limited-access pedestrian ways. The common version of speed bumps has a bad reputation among residents and local governments alike. The issue of the liability of local governments for injury due to speed bumps has come up in the courts (1). Research is currently being conducted to evaluate a new type of undulation design, and it is expected that the problems will be overcome (2).

The redesign of streets to a limited-access local automobile-pedestrian way can be accomplished by widening certain sections of the tree bank, planting shrubs in appropriate locations, allowing street parking for visitors, and even providing play areas. This approach allows local vehicles to pass through but makes it inconvenient enough so that nonlocal traffic would avoid the area. Such designs have been successfully implemented for years in many European cities and are currently being tried in Cambridge and Boston (11). Various parking strategies can also be used as means to discourage and regulate through traffic and speeding.

The advantage of most of the controls included in this approach is that measures can be implemented on a street-by-street basis depending on the traffic situation and the needs of the adjacent residents. The problems stem from the fact that such controls are not obvious to the outsider, can be very frustrating, may encourage violations, and are difficult to enforce.

External Strategies

Through traffic problems are usually associated with congestion on nearby arterial roads and intersections. The conventional approach is to relieve congestion by either increasing the capacity of the existing network or by expanding that network. The advantage of this approach is that it tries to solve the problem at its origin. The disadvantage is that such solutions are usually too expensive to implement and do not guarantee that motorists will stop going through the neighborhood.

Impacts of Controls

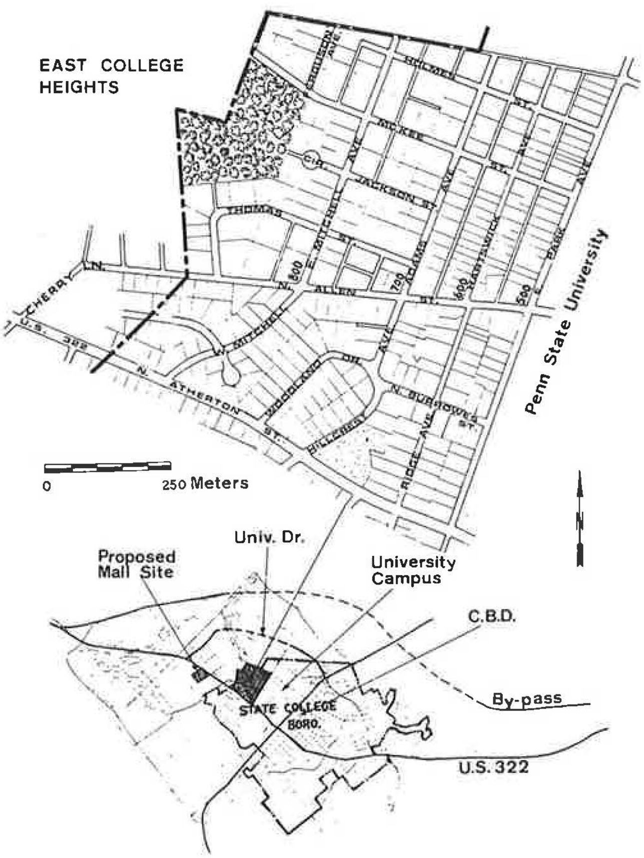
Research findings suggest that a residential neighborhood experiences a significant increase in property values and a reduction in accident rates as a consequence of a program involving street diverters and street closings (12); however, such strategies have been found to create side effects and to be potentially in conflict with a number of community interest groups (13). For instance, residents of the neighborhood in question may have to sacrifice their mobility in order to achieve the increased safety and tranquility that the traffic controls aim to accomplish. Motorists from the rest of the city are denied their right of access to portions of the urban street network, or they are diverted to other more congested streets, thus contributing to further deterioration of the traffic situation on those streets. The conflicts created by some of these strategies end up being contested in the courts, where challenges are made regarding the reasonable exercise of municipal powers (3). Emergency and other public service vehicles may be inconvenienced in their operations. Traffic engineers, who have the responsibility to facilitate the safe flow of traffic, are usually not experienced in handling the problems brought up here. Their engineering handbooks were developed to solve traffic problems on large roadways and have not been adequately adapted for use in medium- and light-traffic residential areas (1).

The problem of through traffic cannot be solved simply through reliance on technical application of solutions. The minimization of adverse side effects requires that the solution be responsive to the problem as it is perceived by local residents. In addition, the solution must anticipate residents' reactions. The present study focuses on these two aspects of the larger issue. It does so through measurement of both residents' perception of the through traffic problem and their responses to several alternative solutions.

EAST COLLEGE HEIGHTS NEIGHBORHOOD CASE

East College Heights is a low-density, single-family residential neighborhood of approximately 0.5 km^2 in the northeast end of the Borough of State Col-

Figure 1. Borough of State College and the East College Heights neighborhood.



lege, Pennsylvania (see Figure 1). State College is a university community of 35 000 that has experienced problems of rapid growth due to increases in student enrollment. The neighborhood is one of the oldest and most stable in the Borough. Its mature landscaping, attractive and well-maintained housing stock, serenity, and walking proximity to the campus make it a highly desirable place to live. Its residents have a long history of taking action to protect the character of their environment from outside threats such as transient parking, through traffic, and conversion of single-family units into rental apartments for students.

The neighborhood is bounded on the west by Atherton Street, a major four-lane arterial that is the only north-south corridor to carry a very heavy traffic load of 22 000 average daily traffic (ADT). Its southern boundary is Park Avenue, another heavy traffic arterial (10 000 ADT) that separates the neighborhood from the university campus. On the north and east sides it is surrounded by open space and park land. The intersection of Atherton and Park is one of the busiest in town, characterized by an F-level of service, where the greatest number of collisions and injuries occurs. Other intersections with high rates of traffic collision involving rear-end or left-turn accidents are at Atherton with Cherry Lane, Mitchell, and Hillcrest.

The traffic problem is created by southbound traffic heading toward the central business district (CBD) and the university on Atherton from suburban communities. In order to avoid the heavy traffic on Atherton and delays at traffic lights at Hillcrest and Park, many motorists cut through the study area (see Figure 1). A motorist can save time if he or she goes through the area during morning rush hours. The reverse movement takes place during evening rush hours. One recent study documented that there were more vehicles cutting through the neighborhood during rush hours than were turning at the intersection of Park Avenue and North Atherton Street (13).

Several direct and indirect solutions have been entertained in the past but have not come to fruition, including completion of the State College bypass, extension of University Drive, and the addition of a third lane on Park Avenue. Six years ago, a no-parking policy was adopted for the whole neighborhood in an effort to solve the problem caused by nonresidents who parked on these streets. The idea of imposing controls to restrict nonlocal traffic is not a new one. In the past, proposals were presented by the planning staff to close streets at one end of the neighborhood but failed due to the residents' opposition. Neighborhood action was triggered recently to control through traffic because of the prospective development of a major shopping mall less than 1 km north of the area along Atherton Street. The mall, according to Pennsylvania Department of Transportation studies, would generate 16 900 additional trips per day, many of which were expected to cut through College Heights (13). In April 1980, the mall developers withdrew their plans after considerable community opposition.

The planning commission staff, at the request of the State College Borough Council, conducted an opinion survey of area residents in January 1980. A questionnaire was mailed to all 365 area households in order to assess the residents' attitudes about through traffic and to evaluate alternative measures to correct the situation. Of the 142, or 39 percent, of the households that responded, 72 percent felt that there was a through traffic problem and 84 percent felt the Borough should take action to control through traffic.

The survey presented five alternatives that consisted of a combination of three basic techniques: post-type bollards to create dead-end turnarounds, intersection barrier diverters, and traffic signs. Residents were asked to rank them according to their preferences. The use of only a system of diverters was the most popular one (13). There was not much consistency in the recorded preferences. It appears that the more complex alternatives were the least popular among the respondents, while the most simple alternatives were the most popular. The main finding from the respondents' comments was that many felt too many restrictions were placed on their mobility. The community service and emergency vehicle personnel, whose opinions were also solicited on the alternatives, complained that they would be required to use roundabout routes that would conceivably cause delays and waste energy.

Study Objectives

Because of the difficulty in interpreting the results, limitations in the design and implementation of the above mail survey, and more recent developments, the planning department, in cooperation with university staff, decided to undertake a new survey in order to provide the necessary detailed and up-to-date information on which a decision could be made to proceed with controls or not. A new instrument was designed with the following objectives in mind:

1. To define more precisely the meaning of a traffic problem as perceived by neighborhood residents;
2. To determine a relation between actual traffic volume and the impact on residents' attitudes and actions;

3. To discover how the relative location of residents' homes to proposed control devices affects attitudes toward particular traffic control devices;
4. To get a better understanding of how factors such as size of household, length of residence, length of intended future residence, ownership, occupation, mode of transportation used to go to work, as well as values toward residential environment influence respondent's opinions;
5. To acquire a more representative sample of the whole area population;
6. To obtain evaluations of additional alternatives that had been suggested on the basis of a review of the relevant literature; and
7. To acquire opinions since the defeat of the proposed mall.

Methodology

A field observation survey was used to record physical characteristics of streets. Objective measures of activity patterns such as traffic counts were taken on each street block at five separate 15-min time intervals each day over a four-day period.

Attitudinal data were gathered by in-home personal interviews conducted during the first two weeks of July 1980. Twelve street segments were selected to represent different parts of the neighborhood defined in terms of volume of traffic and proximity to campus and to arterials. The sample population included all 186 households on those street segments. At 68 households on the selected street blocks, residents could not be found at home and 10 households refused to cooperate. Some 108 interviews were completed, or 58 percent of the study area population. This response rate is considered high for this type of survey and compares favorably with the 39 percent response in the previous mail survey.

The questionnaire is divided into three parts. The first part includes questions about personal and family characteristics of the respondents such as age, sex, length of time residing at present address, ownership of dwelling, size and composition of household, size of hometown, number of years in dwelling, number of years intending to stay, and a five-point scale on appreciation of factors that contribute to the quality of residential environment. The second part of the questionnaire consists of attitudes on traffic perception in general, as well as perception of traffic speed and noise specifically. Impacts of the ways in which traffic interferes with household activities and the actions that respondents take to prevent a worsening of the situation are also included in this part. In the third part of the questionnaire opinions about the effectiveness of 11 alternative measures of controlling traffic are solicited and the popularity of the alternatives under two future scenarios is assessed (see section on Attitudes Toward Alternative Traffic Control Measures later in this paper). The first scenario serves as a baseline situation in which no major changes in traffic patterns are assumed, while the second one assumes a substantial increase of through traffic due to a major commercial development similar to the proposed mall along the Atherton Street corridor. A twelfth alternative labeled "Do nothing" was also included. The attitudes of respondents toward potential impacts of the traffic measures were also assessed.

ANALYSIS AND RESULTS

The analysis is divided into two parts. In the first part the relation is examined among the objective traffic volume and reported impacts of traffic on the personal life of residents, attitudes toward volume of traffic, noise and speed of traffic, and, finally, actions that individuals have taken or are willing to take in order to alleviate traffic problems. In the second part, the relation between traffic volume and the attitudes and preferences toward each of several alternative traffic control measures and the anticipated impacts of those measures are examined. In both parts of the analysis, responses are grouped by street. The 600-700 north blocks of McKee Street are reported together with East Mitchell Avenue, and the 500 north block of Holmes Street is reported together with the same block of McKee Street.

Traffic flows range from 20 vehicles/h to 300 vehicles/h during morning and evening peak hours. This is an otherwise quiet, homogeneous community. Of the respondents, 89 percent are homeowners. The majority of respondents are associated with the university: 36 percent are university professors, and most of the 27 percent who were retired have worked at the university. Some students tend to occupy rental apartments on streets near the university where the percentage of rental dwelling units reaches 40 percent. With the exception of the students, who comprise a small percentage of the total population, the neighborhood seems very stable. Some 60 percent have been living in the same unit for more than 10 years. Due to the proximity of the neighborhood to the university the majority walk or bike to work. There is a consensus of values regarding factors that contribute to residential quality. Traffic safety, ability to get around by walking, and quiet and tranquil environment to walk, ride a bike, and play ranked highest. Accessiblity by car to work and facilities ranked lowest.

Analysis of variance and Pearson's correlation coefficient were used to study the relations among traffic volume, attitudes, and action. The volume of traffic by street forms the categorical independent variable and the attitudes or opinion scores are used as dependent variables. The five-point scale perception of the problem and popularity of solutions were assumed to have interval properties.

Attitudes and Impacts

To the question--how do you feel about the traffic problem in the East College Heights area--73 percent responded that there is a problem, but only 25 percent felt that the problem is serious. Those 60 percent of the respondents who indicated that they had participated in the previous mail survey felt that traffic was a more serious problem than those who had not participated, suggesting that the previous results were biased. They suffered from a selection bias. Some 52 percent said that it was only morning and/or evening rush-hour traffic on their block that bothered them; 66 percent felt that traffic on their street is speeding. According to police reports speeding is an occasional phenomenon; but, from discussions with residents, it is evident that whenever speeding occurs, it bothers the residents because they feel it should never happen.

Noise was not found to be a problem in general: 60 percent felt the traffic noise to be acceptable. However, residents of properties located close to intersections with arterials--especially Atherton Street--felt that noise from traffic on the arterial is a very serious problem. Noise complaints correlate highly with traffic volume, while perception of the traffic problem correlates highly with speed complaints. According to respondents, traffic has been an increasing problem in this neighborhood.

When asked--which of the following everyday ac-

Table 1. Reported attitudes, impacts, and actions as they relate to through traffic.

	Light-Traffic Street				Medium-Traffic Street						
	Far from Campus	Close to Campus			Far from Campus			Close to Campus			
Survey Categories	E. Mitchell (and 600-700 N. Mckee)	Hartswick	500 N. Mckee (and 500 N. Holmes)	Ridge	Woodland	Hillcrest	W. Mitchell	800 N. Allen	600-700 N. Allen	500 N. Allen	All Streets
Traffic volume[a]	29/26	21/30	45/153	75/87	99/150	99/165	258/138	84/141	276/234	318/306	
Attitudes[b]											
Overall traffic problem	2.40	2.45	2.63	2.42	2.78	2.11	2.00	1.83	0.175	2.33	2.32
Speed	2.27	2.27	2.54	2.28	2.28	2.00	1.85	1.50	1.50	2.16	2.12
Noise	2.77	3.00	2.54	2.57	2.85	2.33	2.42	1.83	2.00	1.83	2.52
Impacts											
Backing from driveway (%)	36	36	10	42	50	77	100	50	100	83	56
Interference with indoor activities (%)	40	27	36	42	42	44	42	66	62	66	44
Accidents (%)	22	9	27	0	35	33	50	50	37	0	28
Actions											
Talk to neighbors (%)	54	36	27	42	50	55	85	83	50	0	55
Sign petition (%)	31	27	36	57	7	22	78	33	25	0	33
No. of observations	22	11	11	7	14	10	14	6	8	6	108

[a]Estimated number of vehicles per morning/evening peak-hour derived through extrapolation of 15-min counts obtained from field observations (13).
[b]Computed mean from five-point scale (1, very serious problem; 5, no problem at all).

tivities does traffic interfere with--backing the car out of driveway was the most frequently cited, followed by crossing the street on foot and working, sleeping, or having a conversation in the house. Backing the car out was found to be highly correlated with the volume of traffic and with the perception of the problem, while the interference with indoor activities was particularly associated with noise complaints. To the question--have you or any other member of your household had any traffic accident or incident, such as a near miss, in this neighborhood--28 percent responded yes. The police have reports only on a very limited number of accidents. The reason for this discrepancy may be that many accidents reported in the interview were not felt to be worth reporting or were near misses.

In terms of actions exercised by residents to prevent a worsening of the situation, a majority of respondents had already talked to their neighbors about the traffic problem. Many had already or had considered attending meetings and had signed petitions. It was interesting to find out that the actions had very low correlations with the objective traffic counts. The problem is not considered to be severe enough to warrant massive behavior change such as planting shrubs, fencing yards, spending less time outdoors, or even relocating.

A significant difference exists overall in the perception of traffic between residents of light-traffic streets and those who live on medium-traffic streets. However, resident's perception of the traffic problem is not always directly related to the actual volume of traffic on the street. For example, it is worth noting that residents of the 500 block of North Allen Street, which is the most heavily traveled in the neighborhood, do not differ much in their perception of the traffic problem from residents of the quiet blocks of McKee Street. Residents on busy Woodland Drive are the least concerned about the problem. A look at the composition of residents of these streets offers a possible interpretation for some of these differences. We are dealing here with the most transient and most stable blocks in the area. Most residents on Allen Street are students who have the shortest duration of stay. Only 33 percent plan to live there indefinitely. Other findings suggest that the Allen Street residents do not care as much about what happens to their street. It is the only block on which residents reported that they do not discuss the problem with neighbors, nor have they participated in any meetings or sent any letter of complaint to Borough authorities. On the other hand, 85 percent of the residents on Woodland plan to stay indefinitely in their present residences and 78 percent of them have been living in the same dwelling for more than 10 years. It is probable that, during this period, Woodland Drive residents have adapted to the traffic situation on their street. They seem to prefer to live with what they are used to rather than to take a chance on measures that may prove to be an inconvenience. Finally, on quieter streets like McKee Street and East Mitchell Avenue, a few speeding cars can draw attention and provoke residents. Table 1 provides estimates of traffic volume in number of vehicles per peak hour, the computed means of answers to the problem perception questions, and the traffic impacts and action taken by residents categorized by street.

Attitudes Toward Alternative Traffic Control Measures

A total of 12 alternative measures, including a do-nothing approach, was presented and residents were asked to indicate for which alternatives they would be willing to allocate local tax money for construction and enforcement. A brief description of these measures follows.

Peripheral Strategies

1. No turn signs and traffic light. Install signs to prohibit left turns at the intersections of Atherton with Mitchell, Woodland, and Ridge as well as Park Avenue with Holmes and Burrows. In addition, install a traffic light at Cherry Lane and Atherton that allows only a few cars to turn at a time.

2. Median on Atherton. Construct a center barrier along Atherton from Park to Cherry Lane, with a break at the Hillcrest intersection.

3. Cul-de-sac. Close off end of local streets that intersect with arterials (e.g., Mitchell, Woodland, Ridge, Holmes, and Burrows).

Internal Strategies

4. Parking. Remove parking restriction on one side of streets with heavy traffic problem to reduce

the speed of traffic (e.g., Allen, Mitchell, and Woodland).

5. Four-way stop signs. Add four-way stop signs at key intersections (e.g., Mitchell and Allen and Allen and Ridge).

6. Enforce speed limit. Improve enforcement of legal speed limit in whole neighborhood.

7. Diverters. Install physical barrier diagonally across the road at the intersection of Allen and Hillcrest to prevent straight-through traffic while allowing passage for emergency and service vehicles.

8. Limited-access pedestrian street. Alter design of streets, give priority to pedestrians, and allow residents and emergency service vehicles to have complete slow access.

9. Speed bumps. Install undulations in streets with speeding traffic.

External Strategies

10. Third lane on Park Avenue. Add a third lane on Park Avenue between Atherton and Allen Streets.

11. University Drive Extension. Build the proposed University Drive Extension as an alternate north-south connection.

The only three measures that were received positively were the extension of University Drive, the enforcement of speed limits, and the installation of four-way stop signs at key intersections. The most unpopular choice was the restoration of on-street parking. Four additional measures were popular among those who consider traffic to be a serious problem; these include diverters, cul-de-sacs, speed bumps, and no-turn signs on Atherton Street. A five-point scale, ranging from strongly in favor to strongly against measured the popularity, while another five-point scale ranging from definitely would improve to definitely would not improve measured the effectiveness of each alternative in terms of improving the through-traffic problem in the neighborhood.

The peripheral strategies, including the no-turn sign, median on Atherton, and cul-de-sac measures, are clustered together. Residents who favored this group of measures assigned the highest priority to their implementation. The internal strategies are broken down into three subcategories that are highly intercorrelated. The most popular group includes four-way stop signs and enforcement of speed limits. Both of these measures are soft--that is, they still allow traffic to pass through the neighborhood though traffic is expected to be slowed. The second category includes more novel, drastic, and difficult-to-accept measures such as diverters, limited-access pedestrian street, and speed bumps. On-street parking was considered a category by itself. The only other measure whose popularity correlates highly with it is the limited-access street in which parking is both an integral part of the street and one of the tools for discouraging speeding traffic. The two external strategies--the addition of a third lane on Park Avenue and the extension of University Drive--are also found to be highly correlated. Finally, the do-nothing approach is the least popular and is negatively correlated to most other suggested measures.

In order to examine the relation between perceived effectiveness of measures and their popularity, the popularity rank and the effectiveness rank for each street on each measure were compared. Diverters ranked high in effectiveness (4) but low in popularity (9). Residents who are against diverters seem to be expressing a real concern regarding their ability to move around freely by car. The limited-access street alternative ranked low in effectiveness but high in popularity. The measures of extending University Drive and controlling speed limits were considered to be the most effective and popular alternatives, although there are some doubts about the effectiveness of the latter. The on-street parking and do-nothing approaches were considered the least popular and least effective. Table 2 presents the Pearson's correlation coefficients between the popularity scores of the alternative measures. The diagonal cells in the matrix provide the coefficients that relate effectiveness with popularity for each measure.

Another important question to be examined was the influence of traffic volume and location of household on the preference of the measures. For the examination of a street-by-street breakdown of opinions, an analysis of variance was used. The effects of the different impacts are considered both overall, by using an F-test to test the hypothesis that the population means are equal and in pairwise comparisons among means of opinion by using the multiple t-ratio to detect statistically significant differences between pairs of streets (14). Table 3 presents the mean popularity index of the measures for all respondents on each street.

Three measures proved significantly different overall between medium- and light-traffic streets, the enforcement of speed limits, speed bumps, and the do-nothing approach. Three other measures were found to be significantly different among individual streets. For example, the no-turn signs on Atherton were favored by residents of West Mitchell Avenue, while they were opposed by residents of the 800 block of North Allen because this measure would result in channeling through traffic to Cherry Lane and Allen Street. Residents of Allen Street are strongly in favor of internal strategies, especially those that aim at reducing speed.

The socioeconomic characteristics of respondents did not prove to have great influence on their responses. The number of years that the household intends to stay in their present dwelling appears to be one of the variables that proves significant but is contrary to what was expected. If volume of future traffic is assumed constant, residents who plan to stay indefinitely do not consider traffic to be a serious problem and their preference of control measures differs from those of the rest of the population.

The mode of travel used to go to work by the primary income earner was found to be significant in influencing a household's attitudes toward traffic. Those who bike or walk to work consistently think traffic is more of a problem and are more willing to accept solutions that inhibit the free use of the car, such as limited-access pedestrian streets, diverters, speed bumps, and cul-de-sacs. Occupation seems to influence responses. The retired residents seem more conservative than university professors in their preferences of alternatives; they do not consider traffic to be such a serious problem. There were very few households with young children (ages of less than 10 years), and they are too dispersed throughout the neighborhood to be able to make any generalizations. However, larger households (four or more) tend to be more concerned about the traffic problem.

The size of the city where the respondent has spent most of his or her life was expected to influence responses in that big-city folks were expected to perceive the traffic problem of State College as minimal; however, the opposite result was found. An interpretation of this attitude might be that former residents of big cities expect near perfection from a small college town such as State College.

Table 2. Correlation of popularity scores for traffic control measures (Pearson's coefficient).

Traffic Control Measure	No Turn	Median	Cul-de-Sac	Parking	Four-Way Stop	Enforce Speed	Diverters	Limited Access	Speed Bumps	Third Lane on Park	University Drive Extension	Do Nothing
No-turn signs	0.77[a]	0.45[a]	0.42[a]	0.07	-0.00	-0.00	0.09	0.15	0.04	0.00	0.07	-0.36[a]
Median on Atherton		0.69[a]	0.31[a]	0.05	0.14	0.01	0.14	0.30[a]	0.16	0.12	0.07	-0.15
Cul-de-sac			0.64[a]	0.05	0.12	0.13	0.52[a]	0.29[a]	0.16	-0.04	0.04	-0.34[a]
Parking				0.74[a]	0.13	0.04	0.07	0.24[a]	0.04	0.00	0.03	0.04
Four-way stop signs					0.75[a]	0.54[a]	0.09	0.16	0.10	0.02	0.08	-0.26
Enforce speed limit						0.56[a]	0.02	0.18	0.13	-0.00	-0.11	-0.20[a]
Diverter							0.66[a]	0.26[a]	0.37[a]	0.05	0.08	-0.18
Limited-access street								0.60[a]	0.35[a]	0.25[a]	0.32[a]	-0.19[a]
Speed bumps									0.77[a]	0.08	0.08	-0.23[a]
Third lane on Park Avenue										0.82[a]	0.19[a]	-0.04
University Drive extension											0.73[a]	-0.07
Do nothing												0.58[a]

Note: Coefficients on the diagonal signify the correlations between popularity and effectiveness.
[a]Significant at 0.05 level.

Table 3. Resident attitudes toward traffic control measures by street.

	Light-Traffic Street				Medium-Traffic Street						
	Far from Campus	Close to Campus			Far from Campus				Close to Campus		
Traffic Control Measure	E. Mitchell (and 600-700 N. Mckee)	Hartswick	500 N. Mckee (and 500 N. Holmes)	Ridge	Woodland	Hillcrest	W. Mitchell	800 N. Allen	600-700 N. Allen	500 N. Allen	All Streets
No-turn signs	3.18	2.81	3.27	3.28	3.57	3.11	1.92[a]	4.16[a]	3.50	3.66	3.14
Median on Atherton	3.36	3.45	3.63	3.00	3.50	3.11	2.64	3.66	3.50	3.66	3.32
Cul-de-sac	3.68	3.09	3.63	3.28	3.42	3.55	2.78	3.50	2.87	4.00	3.37
Parking	3.54	4.54[a]	3.09	3.71	4.07	3.66	3.42	3.50	3.25	3.33	3.63
Four-way stop signs	2.68	2.27	2.45	3.14	2.35	2.66	2.78	1.16[a]	1.37[a]	2.66	2.43
Enforce speed limit[a]	2.40	1.63	2.36	2.42	2.42	2.66	2.21	1.16[a]	1.75[a]	1.33[a]	2.14
Diverter	3.63	3.27	3.63	2.71	3.14	3.33	3.35	3.16	3.00	3.66	3.34
Limited-access street	3.40	3.45	3.54	3.42	3.35	2.88	2.50	3.33	3.37	2.83	3.22
Speed bumps[a]	3.27	3.36	3.90	3.28	3.71	3.22	2.92	2.66	3.24	2.83	3.29
Third lane on Park Avenue	3.86	3.45	3.36	3.57	3.14	2.33[a]	2.92	3.00	3.62	2.00	3.24
University Drive extension	1.95	3.00	2.72	2.28	1.71	1.55	2.07	1.66	2.87	1.83	2.15
Do nothing[a]	2.95	4.18	3.18	2.71	2.78	3.22	3.85	4.33[a]	4.00	3.66	3.39
No. of observations	22	11	11	7	14	10	14	6	8	6	108

Note: Computed mean from five-point popularity scale (1, strongly in favor; 5, strongly against).
[a]Statistically significant difference from overall mean (0.05 level).

Finally, those who consider through traffic to be a serious problem were found to be concerned about the effect of traffic on the value of their properties and less concerned about the restrictions on their mobility or the congestion on other streets.

CONCLUSIONS AND IMPLICATIONS

The study makes contributions in three areas:

1. It provides better and more detailed information for State College officials than what was available from the previous mail survey;
2. It confirms findings from the research literature regarding acceptance of traffic control measures in residential areas; and
3. It contributes to existing knowledge of how residents perceive problems in neighborhoods characterized by medium-to-light traffic.

The survey provided a more representative view of residents' attitudes. It defined more precisely what the residents felt to be the extent of the traffic problem, and it offered more alternative traffic control measures to choose from. It is not the volume of traffic or the noise but speed and safety that primarily concern residents.

The most popular internal solution was found to be speed control. The solution of diverters that was found to be the first choice in the original survey was among the least popular alternatives in the present study. Current levels of traffic volume do not warrant any more-severe measures than four-way stop signs, and the majority of residents assigned medium-to-low priority to implementation of even that measure in relation to other Borough projects. However, there were some streets on which more drastic measures were thought to be necessary and all streets would opt for strict controls in the event that through-traffic volume increases in the future.

The majority of respondents are very concerned about preserving their neighborhood and want to be assured that their present level of mobility will be maintained. Many residents see a continuous turnover of the properties on the more heavily traveled streets to students and transient households as a threat that, in the long run, may expand into all areas of the neighborhood. However, residents still have to realize that they have to give up the current level of mobility in order to improve the traffic situation.

Enforcement of speed limits has been a continuing problem in the East College Heights area, especially since there is only occasional speeding and the cost of law enforcement under such conditions is prohibitive. Control of speeding by other means such as stop signs, speed bumps, and altering the design of the street must be explored further. This analysis confirms previous studies about the difference of opinions held by traffic engineers and the public about the appropriate use of four-way stop signs and speed bumps (1).

The survey showed that residents were unfamiliar with the concept of altering the design of the street, but after an explanation they were very much willing to accept it. The East College Heights area has a positive experience involving two streets (Ridge Avenue and Hartswick Avenue) with a much narrower street pavement, 4.8 m wide as opposed to 9 m on other streets. In addition to the benefit of discouraging through traffic, such a design is more environmentally sound, is aesthetically pleasing, and provides energy savings. It provides more open space and land for vegetation and controls run-off. Narrow pavements reduce heat reflection in summer and, finally, it is less expensive to install smaller areas of pavement (15).

Another important conclusion of this study seems to be that objectively measured traffic volume, accident records, and accounts of citizen complaints to authorities are not sufficient to provide a complete picture of the extent of a traffic problem in a neighborhood. This is especially so with respect to relatively light-traffic residential areas. It was found that residents appeared to be bothered more by occasional speeding by unexpected nonresidents or the passage of a truck on lightly traveled streets, than they were by the constant flow of traffic in more heavily traveled areas. The variation in the type of residents on the respective streets was found to contribute to the differences in the perception of the problem. It has been observed that a few influential neighbors can change the opinion of the block. The police record only major accidents, but it was found that it is the number of incidents, near misses, or the fear of an accident that might influence resident's perception. Finally, citizen complaints may be exaggerated or omitted depending on the personality of the resident or the environmental context. This analysis in itself is not sufficient to establish criteria for residential traffic management, but it does provide important empirical findings that can point out the inadequacies of current practices to decision makers.

Because of the novelty of the alternative measures suggested, there are only a few case studies that can be analyzed and evaluated. If a traffic-restraint program is to be implemented, it should start with simple solutions on a street-by-street basis and should then be modified and improved as conditions warrant. We are considering here relatively inexpensive projects, some of which can be implemented as part of the standard street maintenance program. The public should be fully informed about the implications that are known about the alternative control measures and should be made fully aware of how they can participate in the decision-making process. Citizens must realize that they have the power to shape their neighborhood, if they want to. It was surprising to find that, even in a small, sophisticated, and concerned community, about half of the respondents in the survey indicated that they do not feel confident that they can change their street and their environment. It is believed that traffic management should be accomplished in a positive manner and with goals of improving and maintaining the residential environment and making it a good place to live in--not as a reaction to individual complaints or as the aftermath of a serious accident but as an integral component of ongoing neighborhood preservation plans.

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Neighborhood Automobile Restraint: The Chevy Chase Section Four, Maryland, Experience

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The Town of Chevy Chase Section Four, Maryland, is an affluent community of 3000 people lying between two major north-south radial travel corridors in suburban Washington, D.C. Several town streets have become convenient short-cut routes for commuters on their way to downtown Washington and for shoppers and employees in downtown Bethesda, located immediately west of the town. New economic development and the advent of regional rail rapid transit in downtown Bethesda is expected to exacerbate current through-traffic problems. This paper describes a proposed plan to alleviate the town's traffic problems. The focus of this paper is the issues that shaped the development of the plan and citizen reaction to it. These issues include whether or not a community has the right to deny access to nonresidents, the importance of public acceptance of any plan, the need for citizens to understand each other's problems and concerns, citizen reaction to physical barriers and other traffic-control devices, and the limited effectiveness and applicability of some control measures. The Chevy Chase Section Four experience is of interest to transportation engineers, local officials, and neighborhood groups considering the development of neighborhood traffic management plans in their communities.

Few transportation system management strategies arouse more citizen interest or generate more controversy than the automobile-restraint method in residential neighborhoods. Neighborhood traffic management programs have wide-ranging social, economic, and environmental impacts that directly affect the lives of area residents. Neighborhood automobile-restraint measures literally hit close to home.

Over a period of years, the Town of Chevy Chase Section Four, Maryland, has developed a traffic-restraint system that has had limited success in dealing with neighborhood traffic problems, particularly with through-traffic encroachment. This paper describes the problems in Chevy Chase Section Four, the traffic management plan that was recently recommended to solve these problems, and, most importantly, the underlying issues that shaped the development of the plan and citizen response to it. The issues discussed in this paper include whether or not a community has the right to deny access to nonresidents, the importance of public acceptance of any plan, the need for citizens to understand each other's problems and concerns, citizen reaction to physical barriers and other trffic control devices, and the limited effectiveness and applicability of some control measures.

The Chevy Chase Section Four experience is of interest to transportation engineers, local officials, and neighborhood groups because the problems faced there are similar to those of many communities. This experience illustrates the important issues that must be addressed to resolve conflicts and develop a traffic management plan that can be supported by the entire community.

THE PROBLEM

Chevy Chase Section 4 Setting

The Town of Chevy Chase Section Four is a close-in suburban community of 3000 people in the Washington, D.C., metropolitan area. It is bounded on three sides by major, multilane arterial highways and on the fourth side by a two-lane secondary arterial street (see Figure 1). These four arterials carry a total of 110 000 vehicles per average weekday. Another secondary arterial street, Leland-Maple, penetrates the town from the west to the north. This route carries 5000 vehicles on an average weekday and approximately 800 vehicles during the evening peak hour.

The close proximity of these major arterial routes and major traffic generators places significant traffic pressure on the town. This pressure manifests itself in the form of through-traffic encroachment and parking by nonresidents on neighborhood streets. Traffic oriented toward the Bethesda, Maryland, central business district, located along the western town boundary, uses town streets. Commuters also use town streets during the early morning and late afternoon to avoid delays on the congested peripheral arterial street system. With the opening of regional rail rapid transit service in 1983 and greater development of downtown Bethesda in the future, the town's traffic problems will be exacerbated.

Approximately 1100 vehicles/h currently enter and leave the town during the peak commuting hours that begin at 8:00 a.m. and 5:00 p.m. Some streets carry as many as 800 vehicles/h, while others carry as few as 15 or 20 vehicles/h at these times. Based on the total number of vehicles entering and leaving the town and empirical estimates of the number of trips generated by Chevy Chase Section Four households, it was estimated that roughly half of all traffic on town streets during peak commuting hours is nonresident through traffic. Through traffic currently ranges from 460 to 740 vehicles/h between 8:00 a.m. and 9:00 a.m., and from 290 to 670 vehicles/h between 5:00 p.m. and 6:00 p.m. The magnitude of through traffic could double in the future in response to new economic development and kiss-and-ride activity at the new Metrorail station in downtown Bethesda. The major through-traffic movements are shown in Figure 2.

Town Efforts to Control Traffic

The Town Council of Chevy Chase Section Four created a traffic committee in the fall of 1975 to consider the increasing impacts of traffic on the town and to develop a comprehensive traffic plan for coping with these impacts. The automobile-restraint system shown in Figure 1 was subsequently instituted. The first part of the system is a nonresident parking ban that has been successful in reducing nonresident parking encroachment. The second part is a through-traffic-restraint system consisting of commuter peak-period turn and enter prohibitions on most of the entrances to the town. Also, a one-way street "maze" was implemented in one of the neighborhood sectors.

The results of these restraints are mixed. Through traffic continues to encroach because (a) not all entrances to the town could be posted, (b) many motorists chose to ignore the restrictions, and (c) while the one-way maze is generally successful, through-traffic paths still exist and are used by outside traffic. Also, the system imposes significant excess travel on residents of certain areas and none on others. Having concluded that these measures were not adequately deterring through-traffic encroachment, the town, working through its traffic committee and with consultant assistance, undertook

Figure 1. Existing traffic-restraint system in Chevy Chase Section Four.

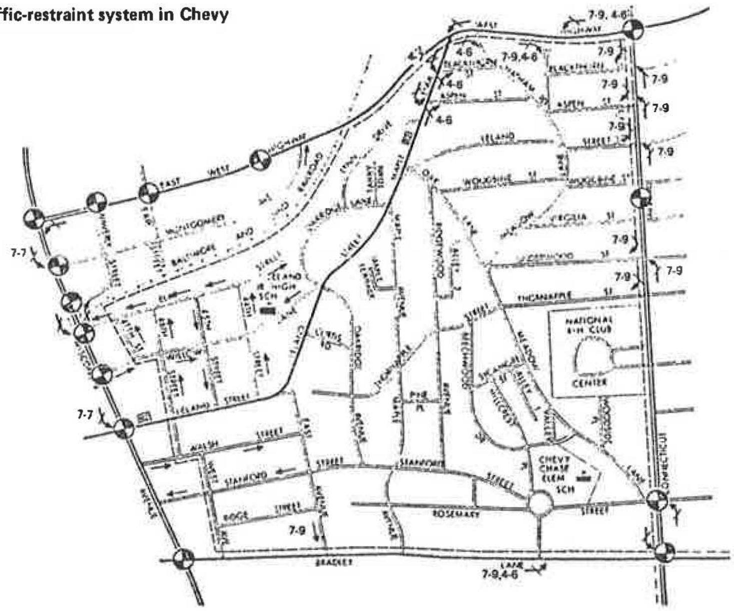
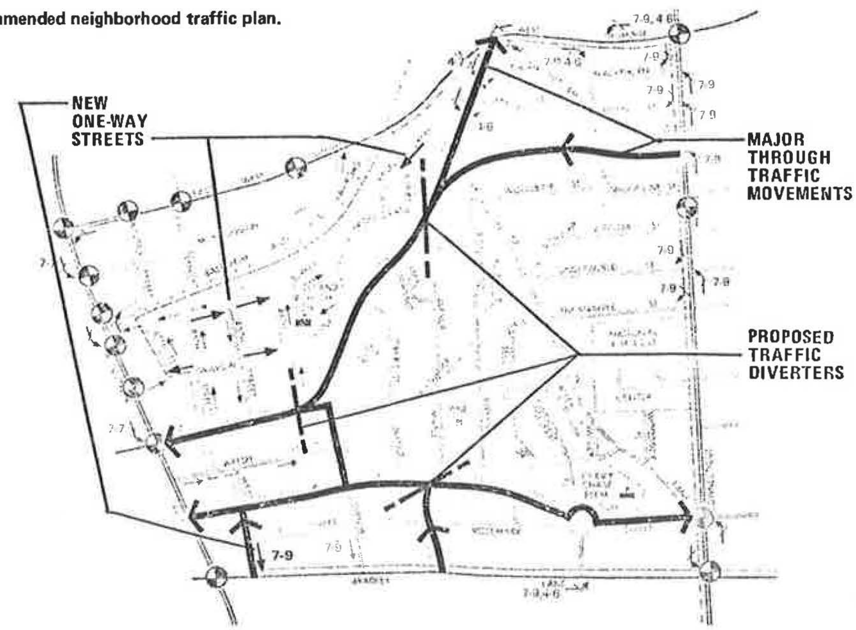


Figure 2. Recommended neighborhood traffic plan.



the development of a comprehensive neighborhood traffic management plan.

PROPOSED SOLUTION

Development of Traffic Management Plan

Preliminary plan alternatives were developed and presented to the town council, town manager, and town traffic committee. Each alternative encompassed a combination of two or more of the following restraint techniques (1):

1. Posted turn prohibitions on peripheral arterials,
2. Physical barriers or diverters within the local street network to eliminate direct through routes,
3. Closure of local streets at the town periphery to reduce the number of entrances to the town,
4. Back-to-back one-way streets, and
5. One-way street maze patterns on local streets.

Some alternatives relied primarily on physical barriers and diverters to divert through traffic; others relied primarily on regulatory measures. The use of stop signs and traffic signals to reduce travel speeds and deter through traffic was not considered a viable control strategy. Flagrant violation of these controls has been observed in other communities (2). Placement of stop signs at intersections where there is visibly little need to control right-of-way can breed driver contempt and hazardous disregard for these devices. Stop controls have been observed to have very limited effect in reducing traffic speed, except in the immediate vicinity of the device itself (3). The exclusive reliance on peak-hour turn prohibitions and on one-way streets also was not considered a viable control strategy. Traffic monitoring during the course of this study indicated that 30 to 50 violations of existing controls of this type occur each day on town streets during peak commuting hours. These controls can be effective only if a high degree of police enforcement is available.

The town traffic committee selected three plan alternatives that were analyzed in greater detail. Each plan was evaluated in terms of the following criteria:

1. Effectiveness in reducing through traffic;
2. Degree of inconvenience to residents entering and leaving the town;
3. Ease of circulation within the town;
4. Impact on public services, such as police and fire protection, emergency vehicle access, snow removal, trash collection, etc.;
5. Impact on school bus routes;
6. Degree of enforcement required; and
7. Approximate capital cost.

Computer network analyses were used to quantify the first three criteria. The remaining criteria were measured qualitatively.

The traffic committee recommended that the traffic management plan shown in Figure 2 be presented to the town residents and adopted by the town council. New diagonal traffic diverters and one-way streets would inhibit the flow of through traffic and divert it to the peripheral arterial street system. The diverters would force approaching traffic to turn right or left; through traffic would not be permitted. The middle 12-ft section of each diverter would be designed to provide enough ground clearance for emergency vehicles such as fire trucks to pass over them safely. According to Anthony Kanz and William Keim, other communities in the region have used this type of diverter successfully for some time and, thus, have established a local precedent for their use. Inexpensive temporary diverters made from stock highway construction items such as wooden barriers would be installed for an initial trial period. Permanent diverters made of bollards, wooden or metal guard rails, or brick or masonry walls would be constructed and attractively landscaped and signed pending a successful demonstration of the temporary diverters. The initial capital cost of each diverter could range from several hundred dollars to $15 000 or more, depending on the design and the extent to which intersection reconstruction is required.

Public Involvement and Reaction to Plan

Local officials and town residents played key roles in developing the recommended neighborhood traffic management plan. Formal working sessions between the consultant, members of the town council and traffic committee, the town manager, and school, county, state, and public service representatives were conducted at each major milestone of the project. Town residents volunteered to conduct traffic counts and a traffic sign inventory. They participated in two public meetings, one at the outset of the study to indicate their perceptions of traffic problems and one near the end of this study to solicit reactions to the plan recommended by the traffic committee. Each household was mailed a short summary report describing the town's traffic problems, the process by which the recommended plan was developed, and the recommended plan itself. Approximately 200 persons attended the first public meeting and 300 persons attended the second public meeting. Members of the traffic committee conducted three additional meetings subsequent to the second public meeting to answer further questions and solicit suggestions for improving the recommended plan.

Strong community support for alleviating neighborhood traffic problems was expressed at both public meetings. However, at the second meeting, there was adamant, vocal opposition to the traffic diverters. Opponents outnumbered proponents four or five to one. The opponents favored a plan that would include more turn prohibitions, one-way streets, stop signs, speed bumps, and/or traffic signals on the streets most frequently used by through traffic. In addition, there was a groundswell of support for establishing the town's first police force (or contracting with a neighboring community for such services) to more strictly enforce existing and any additional traffic control devices. As might be expected, the strongest opposition came from those who do not now experience significant traffic problems but feared that they would if the recommended plan was adopted. They generally supported efforts to solve traffic problems in other areas of the neighborhood but were concerned that the proposed plan would merely divert traffic to their street--and not to the peripheral arterials. They were especially supportive of regulatory measures to control outside traffic and favored the status quo over the traffic diverter solution. Some opponents threatened legal action if the proposed plan was implemented.

Chevy Chase Section Four has subsequently elected to experiment with less drastic measures before further considering a barrier solution. A series of stop signs has recently been installed at three intersections on Leland-Maple Street. The town traffic committee is also investigating the formation of a town police force. The cost to the town for one police officer and equipment has been estimated at approximately $25 000 annually. Other nonbarrier solutions are also being explored by the committee.

ISSUES

The neighborhood traffic problems experienced by Chevy Chase Section Four and the residents' reactions to the proposed installation of physical diverters are similar to those of many other communities. The underlying issues that shaped the development of the Chevy Chase Section Four plan and the citizen response to it are described below.

Each community must resolve for itself the question of whether or not it has the right to deny access to through traffic. Most citizens believe that high through-traffic volumes, excessive speeds, and nonresident parking encroachment are not compatible with life in residential areas. There is typically general support for some type of neighborhood traffic management that will preserve the integrity of the neighborhood, reduce the potential for traffic accidents and property damage, and reduce litter and noise and air pollution. In the context of a functional classification of highways, local neighborhood streets are not intended to carry significant through-traffic volumes but rather to serve as access to residents' homes. Others believe that neighborhood traffic controls will divert through traffic to other adjacent communities, overburden already congested arterial streets, and reduce the efficiency of the overall transportation system. They feel that, since the regional highway network has evolved over a period of decades and residents from all parts of the region have routinely used town streets for some time, the town residents have no right to deny them access. Although the Chevy Chase Section Four residents are clearly in favor of adopting measures to discourage through traffic, they have elected not to barricade themselves from the outside world.

Public acceptance is the key to establishing any kind of neighborhood traffic management program. It is important that the public participate in (a) defining neighborhood traffic problems, (b) identifying and assessing solutions to these problems, and (c) selecting the best plan for implementation. In the case of Chevy Chase Section Four, this involvement extended from local elected officials to ordinary citizens. Members of the town council, the traffic committee, and town manager were actively involved in every step of the planning process. Input from the general citizenry was received during the data-collection effort, through their representatives on the traffic committee, and at two public meetings. Those who are now most affected by neighborhood traffic problems and would benefit most from a successful control strategy attended in greater numbers and were most eager to be heard at the first public meeting. Those who are now least affected by neighborhood traffic problems and feel most threatened by changes in existing traffic patterns dominated the second public meeting. Greater involvement of both groups of citizens during the formulation and assessment of various plan alternatives may have promoted greater understanding and facilitated development of a recommended plan that could be supported by the entire community.

Citizens from all areas of the community must understand each others' problems and concerns. Not everyone is affected equally by neighborhood traffic problems; some residents are greatly affected, and others are not affected at all. Those who are least affected must be made aware of their neighbor's legitimate traffic problems, if they are to be enrolled in the effort to combat these problems. A cooperative problem-solving process must be established so that no single neighborhood group is unduly made worse off for the betterment of others. Otherwise, a situation develops that pits citizens who are most directly affected by neighborhood traffic problems and want something to be done about them against those who are less affected and perceive that they can only be made worse off by anything that disrupts the status quo. The polarization of neighborhood residents into two groups--clear winners versus clear losers--obviously reduced the chances of developing and implementing a successful neighborhood traffic management program.

Consider, for example, the effort to combat through traffic. Through-traffic encroachment is not a new problem in the town; it has existed for many years. Those who purchased homes in recent years presumably did so in full recognition of traffic conditions on their street and with the expectation that these conditions would not change dramatically during the period over which they would own their homes. Those who purchased homes on streets heavily traveled by through traffic would directly benefit from the diversion of this traffic to other streets. Those who purchased homes on streets to which through traffic is diverted would be adversely affected. Thus, some citizens would benefit to the detriment of others. Ultimately, this could be translated into changes in property values and direct income transfers that could be considerable in an affluent community such as Chevy Chase Section Four.

A well-conceived traffic management plan would, of course, divert through traffic from local town streets to the peripheral arterial street system, not from one local street to another. Nonetheless, citizens who perceive, correctly or incorrectly, that a neighbor's problem will be solved by diverting through traffic onto their street will oppose such plans. Citizens who are not convinced (or will not be convinced) that a plan will divert through traffic to peripheral streets will not support the plan. This kind of concern was the greatest source of opposition to a barrier solution in Chevy Chase Section Four.

Strategies that rely on traffic-control devices are generally more acceptable than those involving physical barriers or diverters. Barriers and diverters are viewed by many citizens (and transportation engineers as well) as a source of inconvenience, a nuisance, and potentially hazardous. Turn prohibitions, one-way streets, and stop signs are less onerous. The extent to which they will result in through-traffic reductions depends on the degree to which they are enforced. Some citizens believe that traffic signs must be obeyed by outsiders passing through the town but not by residents traveling to and from their homes. As a result, they think that by selectively enforcing traffic signs, through traffic can be eliminated without inconveniencing them. This may have been why some citizens endorsed the use of more signs and opposed traffic diverters in Chevy Chase Section Four.

Barriers and diverters, even those with mountable center sections, are also opposed by the police, fire departments, and emergency rescue squads. They were concerned that the diverters would reduce emergency response by fire trucks and ambulances, cause equipment damage, and endanger the safety of bicyclists, motorcycle riders, and firefighters who ride on the back of fire trucks.

It is important that all concerned understand the effectiveness and applicability of the various traffic-restraint techniques. Consider the case of speed bumps. Several citizens believe that speed bumps would be an effective measure to reduce vehicle speeds and the amount of through traffic on Maple-Leland Street. The idea has a logical appeal; the best way to slow down a speeding vehicle is to place obstacles in its path (4). After all, speed bumps appear to be successful in many apartment complex and shopping center parking lots. Experiments in other communities, however, have shown that, far from reducing speeds, these bumps could cause drivers to speed up to minimize their shock and discomfort (4). The bumps could cause vehicle damage; endanger the safety of bicyclists, motorcyclists, and firefighters; and possibly involve legal action. Speed bumps have been removed in some communities because of the noise generated by vehicles hitting them (3). Some citizens were skeptical of these arguments and remained convinced that speed bumps were applicable in their community.

Most neighborhood traffic problems are relative. For example, it does not matter that the number of nonresidents using or parking on town streets is less than neighboring communities, if residents perceive that these problems seriously affect their quality of life. What may be considered tolerable in one community may be considered excessive in another.

CONCLUSIONS

The experience in developing a neighborhood traffic management plan for Chevy Chase Section Four illustrates that there are inescapable trade-offs between the benefits that would accrue to some versus the hardships that would be imposed on others. These trade-offs are of two types: (a) reduced traffic problems in the community versus increased travel time and cost to diverted through traffic and others using the peripheral arterial streets and (b) the benefits that accrue to those who would have through traffic diverted from their street versus those who would be made worse off by changing existing neighborhood traffic patterns.

Technical solutions to neighborhood traffic management problems can be found to make the community as a whole better off. In the case of Chevy Chase Section Four, several feasible solutions were identified. However, all of these solutions had something in common. In the jargon of the economist Lester L. Thurow, each solution had a significant zero-sum element (5). That is, someone had to be made worse off so others could benefit. For this reason, the selection of a recommended course of action becomes a matter of political choice.

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Assessing Traffic Management Strategies in Residential Neighborhoods

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This paper describes the development and application of a dense network-type of model, with emphasis on the assessment of traffic management strategies in a residential neighborhood. The MICRO-ASSIGNMENT model was selected for use in this study after extensive literature review and operational experience. The model input and output were modified and fuel computation added. The model was applied to the College Terrace residential neighborhood area of Palo Alto, California. The no-control base condition and five transportation-system-management-type neighborhood strategies were evaluated. The strategies included interior traffic restraint measures and improvement of surrounding arterials. The selected strategies were compared with the no-control base condition. The assessment was on the basis of comparative flows, travel times, and fuel consumption rates on individual links and vehicle miles, vehicle hours, and fuel consumption for residential and arterial street subsystems. This assessment, supported by extensive literature review, served as the basis for developing initial policy guidelines for traffic management strategies in residential neighborhoods.

In recent years, transportation system management (TSM) has become a viable approach to solving traffic problems in various operating environments--dense networks, freeway corridors, arterial networks, rural highways, and so on. The key objective of TSM is to conserve fiscal resources, energy, environmental quality, and quality of urban life through short-term, low-cost transportation improvements. In order to effectively achieve this objective and predict consequences before implementation, analytical techniques are needed for these various operating environments.

This paper describes a research project that was concerned with the development and application of such an analytical technique for dense networks (1,2). The particular dense network covered in this paper was a residential neighborhood. A companion paper addresses a central-business-district-type of dense network.

LITERATURE REVIEW

A literature search was undertaken to make a survey of existing experience and to identify existing and emerging analytical techniques (3).

The survey of existing experience included identification of the problems encountered in the neighborhood areas, various types of TSM strategies implemented, and measures of effectiveness considered. Special attention was devoted to well-documented case studies.

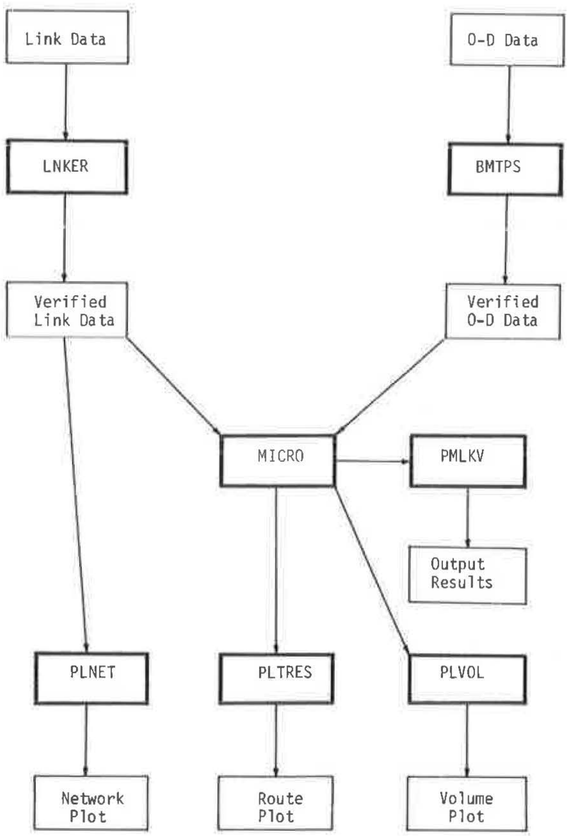
The literature survey also was directed to the identification of analytical techniques tht might be employed to evaluate TSM-type strategies (3). More than 30 such techniques were identified, and six models were evaluated in some detail (4).

MODEL SELECTION

As mentioned in the literature review, 30 models were initially identified (3), and six were selected for in-depth study (4). The six models were CATS (5), CONTRAM (6,7), DHTM (8), MICRO-ASSIGNMENT (9,10), MICRO-UROAD (11,12), and TRANSIGN (13). The six models were evaluated with respect to their input requirements, their method of representing driver behavior and intersection operations, and their history of use and potential for incorporating expanded impact capabilities. Two models, CONTRAM and MICRO-ASSIGNMENT, appeared to be the best-suited for this study. Their nearly offsetting weaknesses and strengths resulted in their both being recommended for use in an actual application to determine which one would be ultimately more suitable for the objectives of this project.

The two models were placed in operation on the IBM system at the California Department of Transportation (Caltrans) and applied simultaneously to the College Terrace residential neighborhood area. The results of these applications provided first-hand information concerning model use-related features. In addition, the theoretical basis of the models and

Figure 1. Component programs of microassignment.



the relative predicted cost of modifications were assessed. The final evaluations of the two models were almost equal, and the final selection hinged on the level of anticipated modification. Since the anticipated modification was relatively minor, the MICRO-ASSIGNMENT model was selected for use in this study (10,14).

MODEL DESCRIPTION AND REFINEMENT

The MICRO-ASSIGNMENT model is capable of assigning traffic to a finely coded street network by various time periods throughout the day. These time periods can range from as short as 6 min to 24-h. Although the model does not simulate queuing conditions resulting when demand exceeds capacity, it does attempt to account for the associated delays in minimum path selection.

The MICRO-ASSIGNMENT model incorporates separate programs that perform different activities related to input data, main program processing, output results, and plotting facilities. The model consists of seven programs as shown in Figure 1. The LNKER program is used to organize and check the supply data, and the BMTPS program performs the same function for the demand data. These data are then input to the main program, MICRO, which performs the traffic assignment procedure, and the results are printed by another separate program, PMLKV. The other three programs (PLNET, PLTRES, and PLVOL) are used, respectively, for plotting the network, the minimum route trees, and the predicted volumes.

The MICRO-ASSIGNMENT model has a number of unique features. For example, nodes are located at midblock locations (not at intersections), which permit each turning movement to have its own link and simplify turn restrictions and turn-control features. Another important feature is the wide variety of intersection control that can be modeled. Specifically, the model simulates the operation of various types of signalized intersections, as well as nonsignalized intersections that include two-way stop signs, four-way stop signs, and yield signs. A key element in the model is the traffic assignment feature. An improved iterative multipath assignment procedure was developed by Caltrans to overcome the disadvantages associated with the sequential assignment method used in the original version (15).

Several alternative refinements were considered and, after careful investigation of their anticipated costs and benefits, three were selected and implemented in the model. The first refinement was adding fuel consumption calculations, which provided information for each link, selected groups of links, and for the total network. The second refinement enables the user to specify in advance grouping of links for which overall impacts are calculated. For example, in the analysis of traffic operations in the College Terrace neighborhood, this feature was used to obtain overall impacts for neighborhood streets, collector distribution streets, and arterials separately. The third refinement was modifying the final calculations and tabulations of output results. One such example was warning messages on links that exhibited poor operational performances such as low fuel-economy rates, low average speeds, and near-capacity lane flows.

The final version of the model is operational on CALTRANS IBM/370 computer and the model, including the modifications, was extensively tested before proceeding with the case study.

CASE STUDY

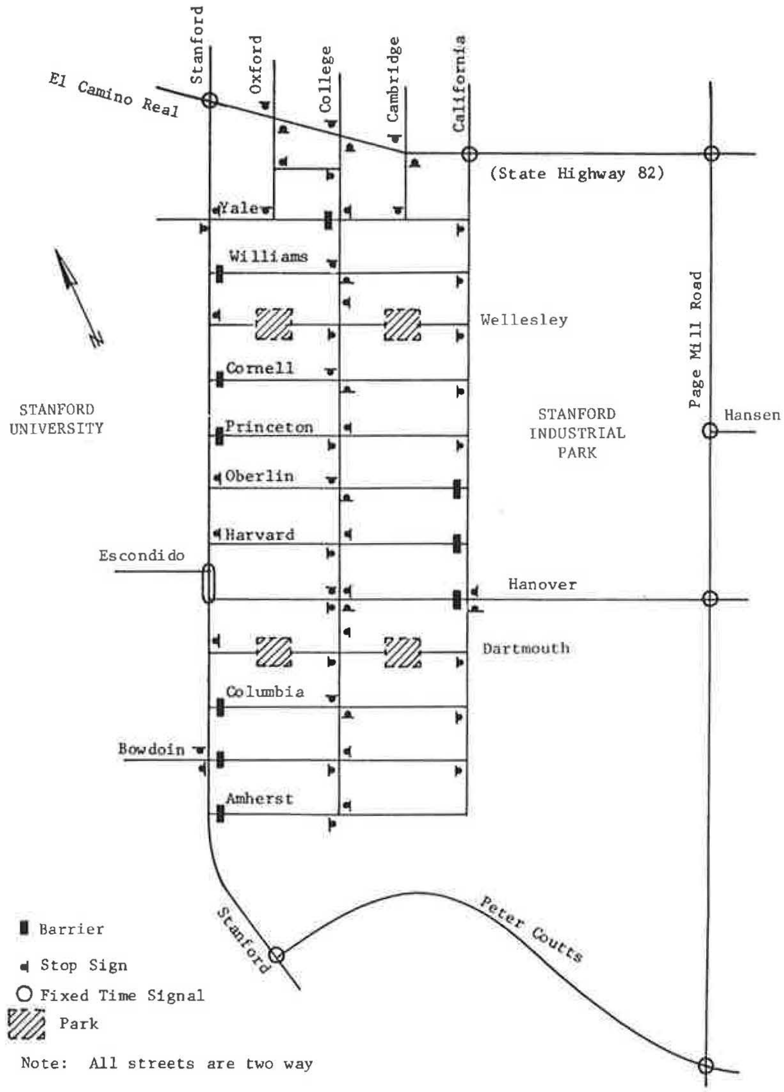
This section is devoted to the application of the MICRO-ASSIGNMENT model to a residential neighborhood area. The residential neighborhood area is the College Terrace neighborhood in Palo Alto, California. The purpose of this exercise is fourfold. First, it can be considered as a user's guide to illustrate the data-collection, model calibration, and model application procedures. Second, the results may have practical significance and be of value to the city of Palo Alto. Third, these real-world applications permit a detailed evaluation of the modified MICRO-ASSIGNMENT model. And, finally, the evaluation of several traffic management schemes provides additional insights toward the establishment of guidelines for traffic management in neighborhoods.

Study Area

The College Terrace study area was selected because of its typical residential area characteristics, the availability of origin-destination (O-D) data, and the excellent cooperation of the city of Palo Alto. A map of the study area is shown in Figure 2. The study area is approximately 1 mile long and 0.6 mile wide; it contains approximately 30 blocks and 50 intersections. The residential area lies between Stanford and California Avenues on the east and west and Yale and Amherst Street on the north and south. Stanford University is located west of Stanford Avenue, and the Stanford Industrial Park is located between California Avenue and Page Mill Road. El Camino Real (CA-82) and Page Mill Road are major arterials, while Stanford, Peter Coutts, and California might be considered collector streets. All other streets are residential streets.

The traffic problem in this neighborhood is primarily due to its location between Stanford University and the Stanford Industrial Park and the fact that over time El Camino Real and Page Mill Road

Figure 2. Study area.



traffic has increased. Eight signalized intersections are in operation along El Camino Real, Page Mill Road, and Stanford Avenue. All other intersections are controlled by stop signs, either for selected approaches or for all approaches.

Four small parks have been constructed (two on Wellesley and two on Dartmouth) to discourage through traffic from penetrating the residential area. Ten full-access control barriers have been constructed to further discourage through traffic. Six such barriers were installed just east of Stanford on Williams, Cornell, Princeton, Columbia, Bowdoin, and Amherst. Three others are located just west of California on Oberlin, Harvard, and Hanover, while the tenth barrier is located on Yale, west of College. This is the control plan that has been in operation since January 1979.

Data Collection

The MICRO-ASSIGNMENT model requires network-related data and O-D demand data. The network-related data were collected for January 1979 in a straightforward manner. The O-D demand data were more complicated because the complete data set was not available and also because the O-D data set had been collected in January 1973 for the neighborhood area only and had to be modified to conform to the large study area and to be projected to January 1979.

The O-D traffic demands used in the evaluation study corresponded to the afternoon peak period (3:00-6:00 p.m.) for January 1979. The demand data were based on a roadside interview survey conducted by the city of Palo Alto in January 1973. The interviews were taken at seven locations that represent the major entry (or exit) points to the area. The survey extended for 10.5 h (7:30 a.m.-6:00 p.m.), and drivers were interviewed as they entered the neighborhood.

Based on these interviews, the O-D traffic demands were established (on an hourly basis) from actual external origins to external destinations and from station-to-station on the neighborhood boundary. The station-to-station demands for the neighborhood were used since the study was particularly concerned with travel within the neighborhood. Two problems were encountered. First, origins (and destinations) within the neighborhood had to be disaggregated. Second, three of the interview stations were within the cordon line of the network and O-D data had to be transformed to artificial origins and destinations on the periphery.

In establishing the origins and destinations within the neighborhood, available information on dwelling unit characteristics was used. Such information included the average trip rate per dwelling unit, the number of dwelling units in each neighborhood block, and dwelling unit classification (single family or multiple family). The average trip rate was estimated as 10 trips per dwelling per day (note that these are one-way trips). Clearly, the estimated average trip rate would only be valid for the 24-h period of the day. In studying the morning or the afternoon periods, the average trip rate would certainly be different and, consequently, the trip-making frequency for neighborhood traffic was required.

With available information on the demands from the interview stations to the neighborhood and the directional volume counts at the interview stations, the trip-making frequency of the neighborhood trips was established at stations 1 and 5. It should be noted that these stations were the only stations at which volume counts and the roadside interviews were conducted on the same day. The trips originating from the area exhibited three peak periods, where the midday peak period is likely due to shopping and other nonpeak trips. For the trips destined for the neighborhood area, a substantial number of these trips occurred between 8:30 and 9:30 a.m. This is attributable to the fact that the trips destined for the neighborhood area include not only those trips to the neighborhood itself, but also those to a portion of the Stanford Industrial Park.

It was estimated that the number of trips originating from the neighborhood during the morning peak period (7:30-10:00 a.m.) was 25 percent of total daily trips produced by the neighborhood. The number of trips destined for the neighborhood during the afternoon peak period (3:00-6:00 p.m.) was estimated to be 40 percent of the total daily trips. These percentages were then applied to the total daily neighborhood trips in order to determine the number of trips originating from, and destined for, the neighborhood during peak periods.

As mentioned previously, some interview stations were located within the study network, and it was necessary to modify the demands corresponding to these stations in order to be compatible with the origins (and destinations) located on the periphery of the study network. Such a modification was required for stations 1, 2, 3, 4, and 5 since the remaining stations were already located on the periphery of the study network.

Establishing the O-D demands was accomplished in two steps. First, the trip demands at the five stations mentioned above were assigned to several O-D nodes on Page Mill, El Camino Real, and Stanford. The disaggregation of trip demands was accomplished by using the information that described the actual trip origins and destinations available from the roadside interview survey. Second, the reader can immediately see that restructuring of the trip demands at the interview stations was not sufficient. This is because other trip demands (mainly through trips) that used the surrounding highways and arterials were not included. Consequently, additional trip demands for El Camino Real, Page Mill Road, and Peter Coutts were fabricated, based on actual traffic volumes on these roads. For example, in order to match the observed volumes on El Camino Real, a demand of 4457 trips in each direction was assigned to that highway for the 3-h peak period. With the above procedure, the process of establishing the O-D demands for the afternoon peak period in January 1973 was completed.

Calibration Process

The O-D demand data available for January 1973 needed to be adjusted so that the predicted traffic was consistent with that measured in January 1979. It was found that a 5 percent overall O-D demand growth rate adjustment on the 1973 data was adequate to represent traffic demands in January 1979. In the following paragraphs, the selection of the growth rate and the comparison between the adjusted traffic and that measured in January 1979 are described.

Two types of O-D demand changes are generally possible: overall demand growth and specific local demand changes due to particular land utility changes. Since there was little local land utility change in the study area during the years from 1973 to 1979, the overall traffic demand growth was the only adjustment considered. Growth rates of 5 percent and 10 percent were tested. The results indicated that the demands obtained by a 5 percent increase from the 1973 data adequately predicted the traffic conditions in January 1979.

Two important measurable traffic operating quantities were used in the comparison of the predicted and the real situation. They were the traffic volume on important links and the travel time along selected streets. The quantities predicted, based on the 5 percent O-D demand increases, are compared with the measured values in the following paragraphs.

The comparison of the predicted and actual values in January 1979 included two measures: traffic volumes and travel times. The actual data were collected by the city of Palo Alto during the afternoon peak period (3:00-6:00 p.m.). Traffic volumes were collected at five intersections and at several midblock locations. In addition, travel time runs were conducted along four selected routes. Below are the results of the comparisons of predicted and actual traffic volumes and travel times.

The traffic-volume counting stations were arranged to emphasize the volume on the peripheral arterials as well as the cross traffic between the residential area and the peripheral streets. The comparison of the measured and predicted volumes indicated that 72 percent of the locations exhibit a difference of less than ±10 percent. For locations with higher volumes, the results were even better. For example, for locations with a volume range of 500 to 100 vehicles/h, 9 out of 12 locations (75 percent) exhibit a difference of less than ±10 percent, and for the 1000-1500 vehicles/h range the difference is less than ±10 percent at all locations.

The travel times along several selected routes were measured as another comparison between the predicted and actual values. The routes include the peripheral arterials in both clockwise and counterclockwise directions, the eastbound and westbound directions along College Avenue, round-trip travel along California Avenue, and the northbound and southbound directions along Hanover Street. These test routes cover the surrounding arterials, the main entrance to the residential area from the peripheries, and transverse streets in the residential area.

The differences were within 5 percent, except for the clockwise direction along the periphery and the eastbound direction along College Avenue. The overall difference was 9 percent.

From the above description, it can be seen that the 5 percent overall increase O-D adjustment matches actual traffic conditions within 10 percent without systematic deviation. Furthermore, the traffic management staff in Palo Alto reviewed the results and agreed, based on their knowledge of local traffic conditions, that the simulation results were acceptable and that TSM strategies could be evaluated, based on these calibrated O-D demands.

Evaluation of Control Plans

After the calibration process was completed, the

Table 1. Control plans selected.

Plan	Additional Action Taken: Within Residential Area	Additional Action Taken: On Surrounding Arterials
0	None	None
1	Existing control (10 barriers)	None
2	None	Proposed improvement (El Camino-Page Mill interchange)
3	None	Proposed improvement (Page Mill added lanes)
4	None	Proposed improvements (El Camino-Page Mill interchange and Page Mill added lanes)
5	Proposed control (Hanover barrier)	None

next step was to evaluate the impacts of several control plans. The selection of the College Terrace neighborhood as a study area provided a good standard for analyzing residential areas. The primary purpose of traffic management in this area was to reduce environmental impacts within the residential area while maintaining an acceptable level of traffic operations on the surrounding arterials and neighborhood accessibility. Based on these basic criteria, five control plans were studied and compared with the base conditions (no control).

Description of Control Plans

Five control plans, in addition to the do-nothing alternative, were selected for evaluation. The majority of these plans was proposed by the city of Palo Alto. A list of selected plans is shown in Table 1. For comparison purposes, the do-nothing alternative (no control) was designed as plan 0, and the five selected plans were compared with this plan. The control plan in operation today is designated as plan 1 (see Figure 2). In this plan, all cross streets were closed at one end or the other in order to keep the traffic out of the neighborhood. Plan 2 was to convert the El Camino Real-Page Mill intersection into an interchange that would improve traffic conditions along the El Camino Real and Page Mill Road. Another strategy selected, plan 3, was to add one lane in each direction to Page Mill Road. Plan 4 was a combination of plan 2 and plan 3, and plan 5 was to block Hanover Street each of California Street.

As noted, these plans can be classified into two groups. One group is designed to push the through traffic outside the neighborhood (plans 1 and 5) by restricting the access (or egress) to the area. The other group is designed to pull the through traffic out of the neighborhood (plans 2, 3, and 4) by improving the operations on the surrounding arterials.

Results of Control Plans

To evaluate the impacts of control plans, a separate input of network data was prepared for each plan. The calibrated O-D demand data were not changed, since all plans were evaluated for January 1979 conditions. Separate computer runs were then made for each plan. The number of iterations varied from plan to plan because of the convergence of the traffic assignment results. Both total vehicle hours and total vehicle miles were used as indicators of the convergence.

The impacts of the control plans on both traffic volume and travel time were calculated for selected locations. Traffic volumes were compared for each plan on three screen lines and travel times were compared for through movements at four major signalized intersections as shown in Figure 3. Section A-A is located immediately north of Cornell Street, section B-B is located north of Columbia Street, and section C-C is parallel to the longitudinal direction of the study area and is located just east of California Street. The intersections used for travel time comparison are located along Page Mill Road at Peter Coutts, Hanover, and El Camino Real, and along El Camino Real at California.

A number of predicted volumes on the streets crossing each section and the percentage differences (compared with plan 0) are shown in Table 2. A summary of predicted travel times for the various intersectional movements and percentage differences (compared with plan 0) are shown in Table 3.

Now attention is directed toward the impacts of the six control plans on the total system. Results for the residential, arterial, and total area portions are presented in Figure 4. Three curves are drawn on each of the nine diagrams. The six plans that were evaluated are denoted on the horizontal scale. The various measures of effectiveness are indicated on the vertical scale. The thresthold value for fuel rate was <5 miles/gal and for speed was <10 mph.

Assessment of Control Plans

The individual control plans will now be evaluated, considering the results of the previous subsection (see Tables 2 and 3 and Figure 4). Again, let it be stressed that only one point in time (January 1979) and only the effect on highway users were considered.

Plan 1 consisted of installing 10 barriers around the residential area and no modifications on the surrounding arterials. This plan had little effect either in flow levels or travel times on the surrounding arterials. While the flow level on interior streets was slightly reduced at a few locations, most locations show an increase, particularly on College Avenue. Areawide results indicated that total link flows, vehicle miles of travel, total fuel consumption, and total vehicle hours of travel increased; fuel economy rates decreased; and average speeds were unchanged. These adverse effects occurred on the residential streets as well as for the total study area. Based on these results, plan 1 was not an improvement over plan 0.

Plan 2 consisted of building an interchange at El Camino Real and Page Mill Road, with no additional actions within the study area. Flows on the arterials slightly increased, but arterial travel times were essentially unchanged except for the significant reduction at Page Mill Road-El Camino Real crossing. Flows on the collector and residential streets were slightly less. While total link flows and total vehicle miles remained unchanged, a greater proportion of travel was handled by the arterial portion of the network. Fuel consumption was reduced and fuel economy rates increased. Total travel time was reduced and average speeds increased. Based on these results, plan 2 was an improvement over plan 0 in almost every respect. However, the cost of this improvement would be significant.

Plan 3 consisted of adding a lane in each direction along Page Mill Road, with no additional actions within the study area. Flows on the arterial increased, while the travel times on Page Mill Road decreased. Flows within the residential areas were about the same except the flow at California (section A-A) decreased, while the flow at Hanover (section C-C) increased. While total link flows and total vehicle miles remained unchanged, a greater proportion was handled by the arterial portion of the network. There was little change in total fuel

Figure 3. Selected cross sections for volume and travel time comparisons.

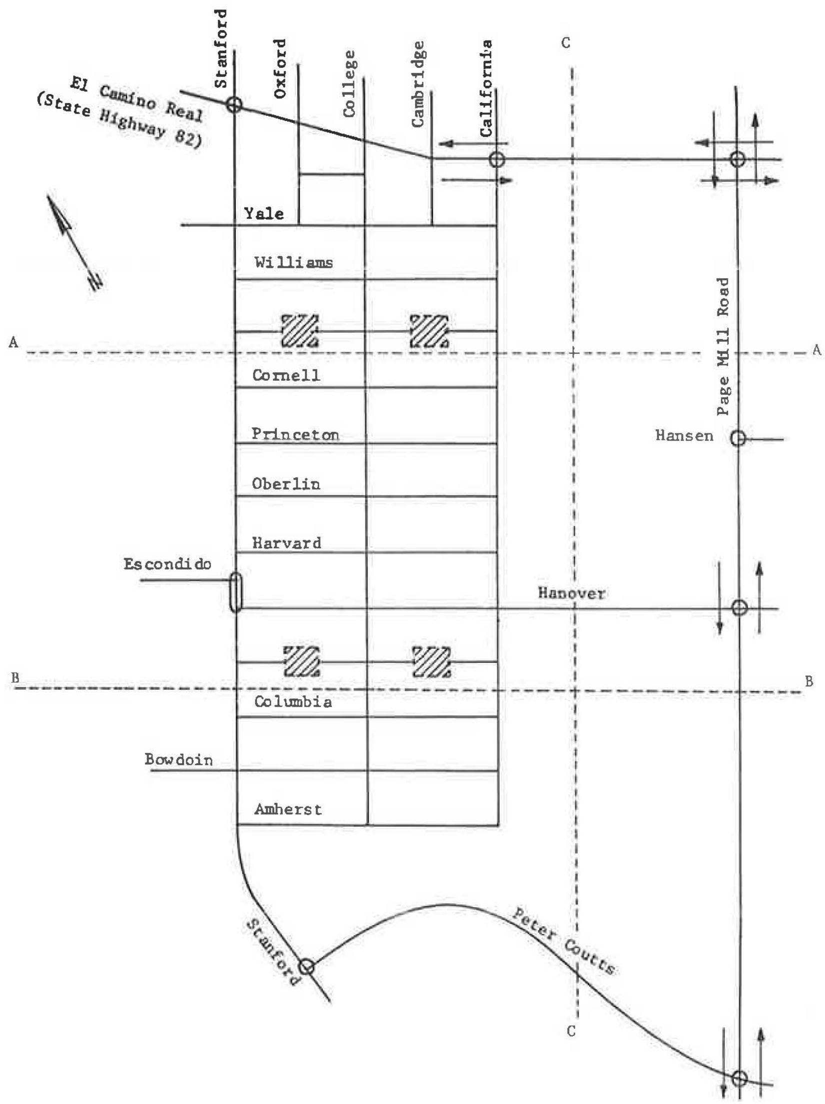


Table 2. Comparison of traffic volumes.

Section	Plan	Stanford Volume	Stanford Change (%)	College Volume	College Change (%)	California Volume	California Change (%)	Page Mill Volume	Page Mill Change (%)
A-A	0	2160	0	208	0	1847	0	7795	0
	1	2025	-6	356	+71	1751	-5	7877	+1
	2	2146	-1	206	-1	1728	-6	7929	+2
	3	2123	-2	209	0	1637	-11	8040	+3
	4	2146	-1	206	-1	1726	-6	7930	+2
	5	2087	-3	200	-4	1461	-21	8586	+10
B-B	0	1987	0	47	0	496	0	6697	0
	1	2264	+14	584	+1150	633	+21	6578	+1
	2	1978	0	44	-1	502	+1	6548	0
	3	1960	-1	47	0	521	+5	6544	0
	4	1978	0	44	-1	502	+1	6548	0
	5	2287	+15	272	+485	685	+38	7251	+11
		El Camino		Hanover		Peter Coutts			
C-C	0	8735	0	1945	0	612	0		
	1	8755	0	1832	-6	646	+6		
	2	9127	+3	1819	-7	606	-1		
	3	8923	+2	1698	-13	610	0		
	4	9126	+3	1817	-7	606	-1		
	5	9986	+10	0	0	1751	+185		

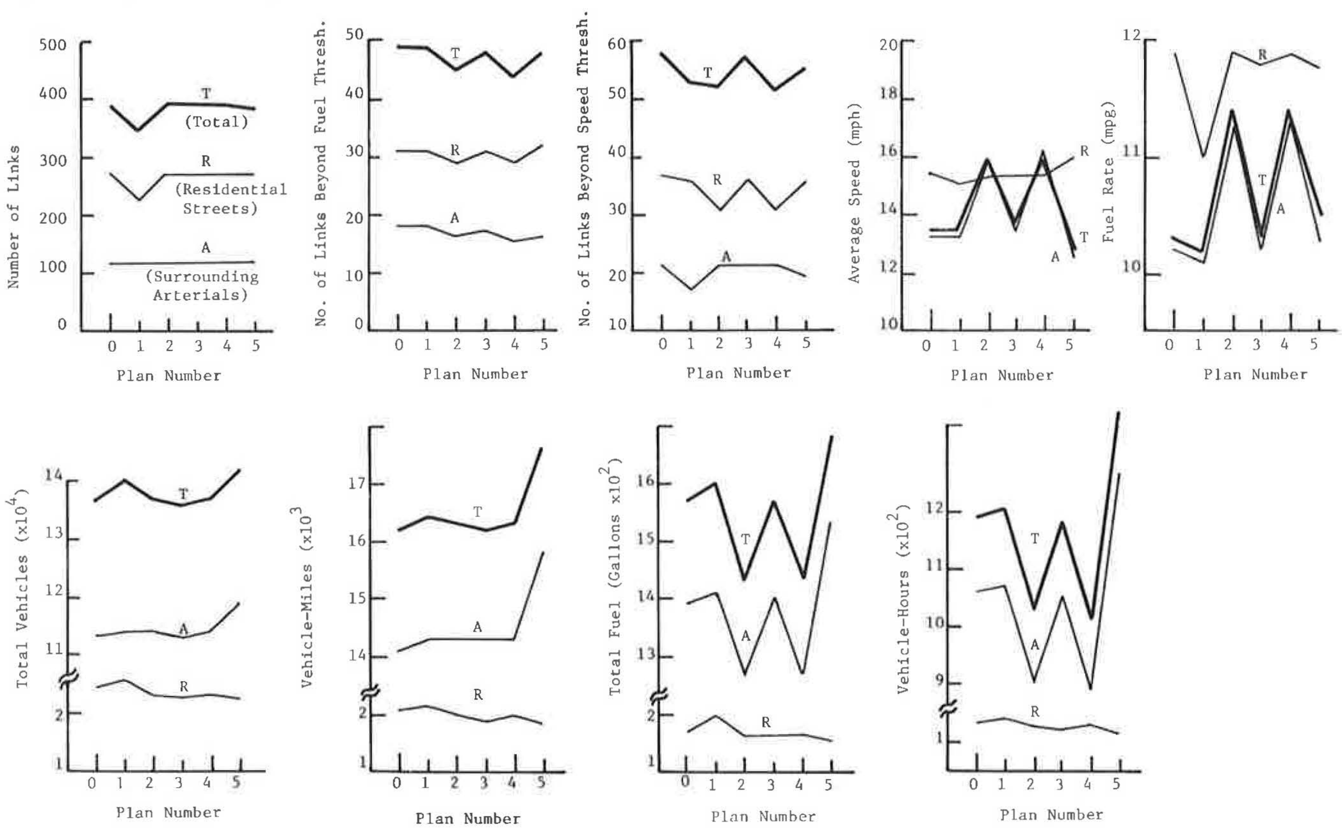
Table 3. Comparison of travel times at selected intersections.

	El Camino-California				Page Mill-California								Page Mill-Hanover				Page Mill-Peter Coutts			
	Westbound		Eastbound		Westbound		Eastbound		Northbound		Southbound		Northbound		Southbound		Northbound		Southbound	
Plan	TT	(%)[a]	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)
0	41	0	41	0	59	0	60	0	55	0	58	0	69	0	69	0	63	0	66	0
1	41	0	41	+2	59	0	60	0	55	0	58	0	69	0	69	0	63	0	66	0
2	41	0	42	+2	17	-71	18	-70	26	-53	25	-57	69	0	70	+1	63	0	66	0
3	41	0	42	+2	59	0	60	0	53	-4	56	-3	66	-4	67	-3	60	-5	63	-5
4	41	0	42	+2	17	-71	18	-70	24	-56	23	-60	66	-4	67	-3	60	-5	63	-5
5	42	+2	42	+2	59	0	60	0	55	0	48	0	68	-1	70	+1	62	-2	66	0

Note: TT = travel time.

[a]Percent change with respect to plan 0.

Figure 4. Comparison of overall performance of control plans.

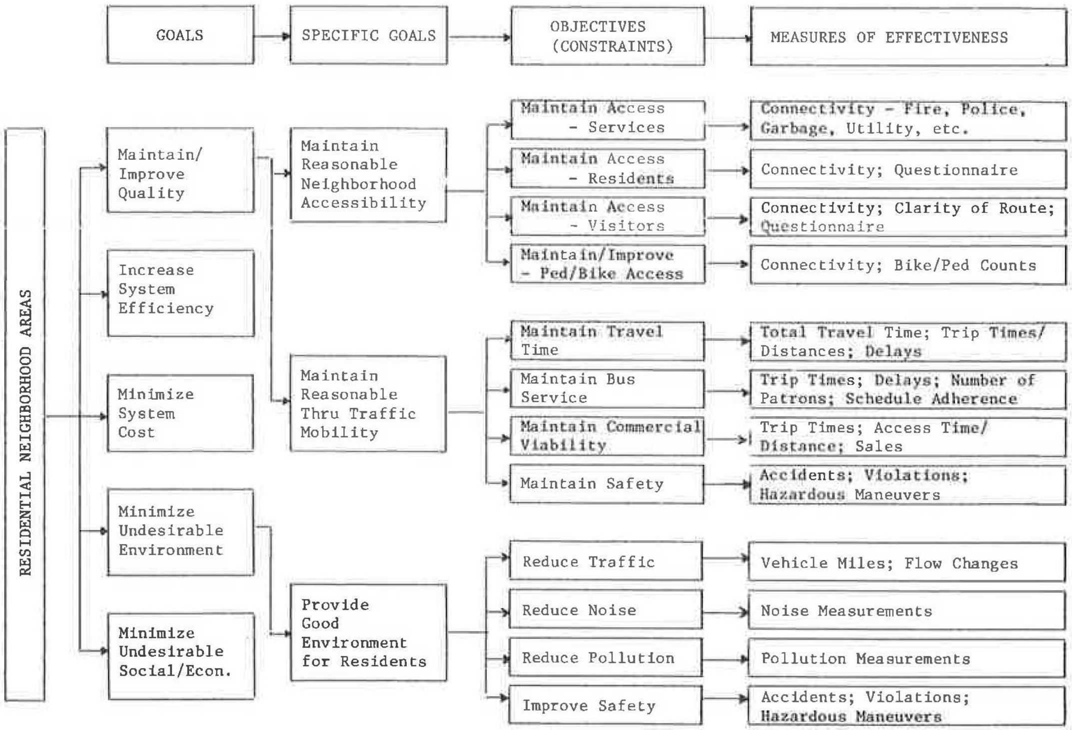


consumed and fuel economy rate. Total vehicle hours were slightly reduced and average speed slightly increased. Based on these results, plan 3 was an improvement over plan 0 and almost as good as plan 2.

Plan 4 consisted of adding a lane in each direction along Page Mill Road and building an interchange at El Camino Real and Page Mill Road crossing. No other actions were taken within the study area. Flows on the arterials slightly increased, while arterial travel times on Page Mill Road, including the crossing at El Camino Real were reduced. Flows on the collector and residential streets were slightly less. While total link flows and total vehicle miles remain unchanged, a greater proportion of travel was handled by the arterial portion of the network. Fuel consumption was reduced and fuel economy rates increased. Total travel time was reduced and average speeds increased. Based on these results, plan 4 was an improvement over plan 0 in almost every respect. Plan 4 results were very similar to plan 2 results. However, the cost of this improvement would be the highest of all plans.

Plan 5 consisted of a single barrier placed at a strategic location on Hanover just east of California. No other actions were taken within the study area. Flows on the arterials increased, while travel time on arterials only slightly increased. Flows on the collector and residential streets were reduced in the northern portion of the neighborhood and increased in the southern portion. The overall measurements for the residential portion of the study area showed significant improvements (i.e., lower vehicle miles of travel, lower vehicle hours of travel, less fuel consumption, etc.), while the overall measurements for the arterial portion of the study area showed significant disbenefits (i.e., higher vehicle miles of travel, higher vehicle hours of travel, more fuel consumed, etc.). Plan 5, when compared with plan 0, gave contradictory results.

Figure 5. Elements of traffic management in residential areas.



The neighborhood situation was improved at the expense of travel on the arterials.

Many additional control plans could have been developed and evaluated. Additional measures of effectiveness (MOEs) could have been investigated. However, the paper has presented an analytical framework and demonstrated its application, and further investigations and extensions are left to future research.

SOME INITIAL GUIDELINES

As mentioned earlier, one of the purposes of applying the MICRO-ASSIGNMENT model to the College Terrace neighborhood was to provide some insight into the development of preliminary guidelines for traffic management in residential areas. In an attempt to provide more comprehensive guidelines, traffic management studies in other residential areas were carefully reviewed. Based on this review, and with the information gained from the application to the College Terrace neighborhood, a list of goals, objectives, and MOEs was prepared and is shown in Figure 5.

In Figure 5, the specific goals for traffic management in residential areas that have often been considered are shown. These specific goals are subsets of the more general goals of improving quality of operations and minimizing adverse impacts on the operating environment. Little attention, however, has been given to other general goals such as minimizing system cost, increasing system efficiency, and so on. For the three specific goals, 12 objectives are shown along with their associated MOEs. The list shown in Figure 5 should be useful in providing the traffic analyst with the various objectives and MOEs that have been used for traffic management in residential areas.

ACKNOWLEDGMENT

We express deep appreciation for assistance given by the many persons involved with this project during the past two years and to Caltrans for its sponsorship and support in so many ways. Alan Willis of the Institute of Transportation Studies (ITS) receives our sincere thanks for his active involvement during the first year of the project. His assistance was indeed valuable and very much appreciated. Special thanks are due to D.C. Chenu (Department of Transportation Planning, Caltrans, Sacramento) for the thoughtful criticisms and comments offered as the work progressed; and to Frank C. Tedesca (Department of Transportation Planning, Caltrans, District 4) and members of his staff for their valuable assistance. We would also like to thank Dennis Robertson and his colleagues at the Transport and Road Research Laboratory for providing a copy of the CONTRAM program. Robertson's visit to ITS and his thoughtful critiques significantly contributed to the evaluation of models. Particular note is made of the contributions to the data-collection efforts and model calibration by Kent Dewell (Public Works-Transportation, city of San Jose, California) and members of his staff. Their willingness to review the calibration results several times significantly improved the application to the central business district of San Jose. Special thanks are also extended to Ted Noguchi (Transportation Division, city of Palo Alto) and members of his staff for their contributions to the data-collection efforts and for reviewing the calibration results. Undoubtedly, their continued input during the course of this project is reflected in the application work to the College Terrace neighborhood. Finally, Phyllis De Fabio deserves special thanks for the excellent typing service.

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Resource Implications of Electronic Message Transfer in Letter-Post Industry

ALFRED M. LEE AND ARNIM H. MEYBURG

As Western societies move more and more rapidly to information economies, the need for face-to-face human interactions and for the exchange of physical goods is being replaced by the need to exchange information. New technologies have been and are being developed that facilitate this flow. The impacts of this change in orientation are many. Substitution of personal travel and hard-copy communications transport by electronic means is a significant social development with implications for energy consumption, vehicle fleet, paper, and labor requirements, among others. This paper attempts to illustrate some of the impacts of substituting communication for transportation. The use of electronic message transfer technology by the U.S. Postal Service is examined in the context of current first-class mail shipment patterns. Limited energy, vehicle, and paper resource conservation possibilities could be enhanced by implementing policies to stimulate the development and use of electronic message transfer technologies.

Western societies are moving at a rapid pace toward information societies. The information flow required per person in personal life-styles, in research, in administration, in all service industries, etc., is increasing dramatically. All aspects of daily life and of society in general are affected by this acceleration in the exchange of information. Few households are without telephones or televisions. Banks and travel agencies without computers are rare. Government recordkeeping would be virtually impossible at the present scale without the extensive use of electronic devices.

Transportation and communications are closely related infrastructural elements of society (1). These modes are used to enhance and facilitate exchange in the national and international economy and to increase the level of human interaction. As society moves toward an information economy, the need for exchange of goods, defined in a very broad sense, is being replaced by the need to exchange information. This evolution is changing the nature of demand for these services.

In some instances communications may substitute for particular transportation needs. In other cases, they may be complementary. Patterns of telephone use serve as an example of the substitution potential of communications for transportation. Telephone communications have reduced the need to transport various kinds of messages and also the need to travel personally to communicate. Complementary relationships develop in situations where communication activities affect the operation, safety, efficiency, and effectiveness of transportation services.

This paper is concerned with the resource implications of transportation-communication trade-offs. In order to avoid confusion about the distinction between the substitutive and complementary relationships, which is at times difficult to maintain, substitution analyses will be confined to those situations in which a trip is entirely replaced by communications. Since extensive examples of the complementarity aspect were published previously, they will not be considered here (2,3). This paper concentrates on the substitution aspects of communications for transportation, specifically in the context of electronic message transfer.

Numerous studies have considered the substitution potential of communications for transportation (e.g., 4-8). Most research has dealt with technologies to reduce personal travel needs. Two technologies that seem to be particularly promising candidates to influence future travel demand patterns are the videophone and the teleconferencing unit.

The video telephone adds a visual dimension to the telephone, allowing transmission of pictures of the communicating parties or conveyance of visual information. Communication of graphic data, for example, could facilitate consumer decisions regarding purchases by telephone and also allow security monitoring. The motivation behind the development of this technology lies in a desire to enhance the performance of traditional voice communication systems to a degree that they are attractive alternatives for satisfying some traditional personal travel needs. The potential for augmented audio communications and the possibility of viewing textual and graphical material are considered to be the principal advantages of the technology. The potential benefits of this technology have not been fully realized due to the lack of development of a suitable market. While at the present time consumers have not perceived a sufficient increase in utility to justify purchasing and using this expensive equipment, demand is expected to grow in the future. In the United States, the videophone, developed by Bell Laboratories of the® Bell System, is known by the trade name Picturephone®.

Teleconferencing services are essentially an extension of the videophone capability. They are designed to reduce personal travel needs to attend meetings. Also, these services could have a substantial impact on the character of work trips. It is feasible to decentralize office locations by using teleconferencing services. Such workplace location decisions are significant since people working in the central business district (CBD) travel twice the distance and have approximately 2.25 times longer trip times than those persons with suburban employment. Obviously office or workplace locations in different cities can be connected by means of teleconferencing technology, thus reducing the need for intercity business travel.

New electronic message transfer technology now under development offers the potential to alter transportation demand in a significantly different fashion. Innovative electronic systems that transfer both messages and information can reduce needs to transport paper-based media. This discussion will sketch the rudimentary features of such systems and then consider the resource conservation implications of substitution possibilities, particularly with respect to the letter-mail market.

ELECTRONIC MESSAGE AND INFORMATION TRANSFER

Emerging electronic message and information transfer systems include a range of newly developed technologies that could have a dramatic effect on the volume of discretionary travel demand such as shopping, social-recreational, educational, human interaction, personal, and business travel needs. One such technology is known by the generic term as viewdata, and by the trade names Prestel (United Kingdom) and Bildschirm-text (Federal Republic of Germany), among others. Essentially it consists of modified telephone and television units that allow subscribers to gain access to complete libraries, newspapers, mail-order catalogues, entertainment information, electronic games, home computer services, news, sports, and weather information. The number of potential services is only limited by the willingness of information suppliers to make their products available to subscribers.

These systems offer primarily information retrieval, interactive gaming, or teleprocessing capabilities. Data are accessed by telephone lines from a central data storage bank and displayed on modified television receivers. At a somewhat more sophisticated level, this operational technology could allow subscribers with modified television-keyboard units to generate and exchange personal messages. Such systems could stimulate changes in methods of distributing books, publications, newspapers, etc. These practices could affect transportation, energy, and paper requirements.

A second objective of evolving electronic message transfer technology is to facilitate the exchange of person-to-person communications that are graphic or alphanumeric character-oriented and digitally encoded. Such services convey messages electronically but may at some stage produce and transfer paper copy by conventional means. The U.S. Postal Service (USPS) and private corporations are currently evaluating the operational and economic feasibility of electronic message transfer services. The private sector is concentrating primarily on terminal-to-terminal systems. The USPS has been developing a nationwide system that integrates conventional postal operations with electronic techniques.

The USPS has been developing this hybrid electronic message transfer system design for more than two decades. The current design will provide a nationwide service with next-day delivery for 95 percent of messages entering the system by 5 p.m. on the previous day. Plans are also being made to provide a priority service (i.e., 1-2 h transfer of messages) at a premium price. Both the overnight and priority service will use the conventional postal collection and distribution system along with new electronic equipment under development.

Various input alternatives will be available. Large-volume users, such as banks or credit card companies whose messages mostly consist of computer-generated material, will be able to drop off magnetic cards or tape containing encoded messages. The USPS will provide equipment to read and route these messages electronically. Other heavy users with messages already printed on paper will be able to submit paper packs (i.e., bundles of nonenveloped message pages boxed in cardboard containers), which will be facsimile encoded by USPS personnel. Individuals with single hard-copy messages will access the system by using coin-operated facsimile machines called "electronic mailboxes", which are to be located in post offices and public facilities (e.g., shopping malls). Those users with input terminals will be able to submit messages over local telecommunication links, although USPS is not encouraging wire-line input at this time.

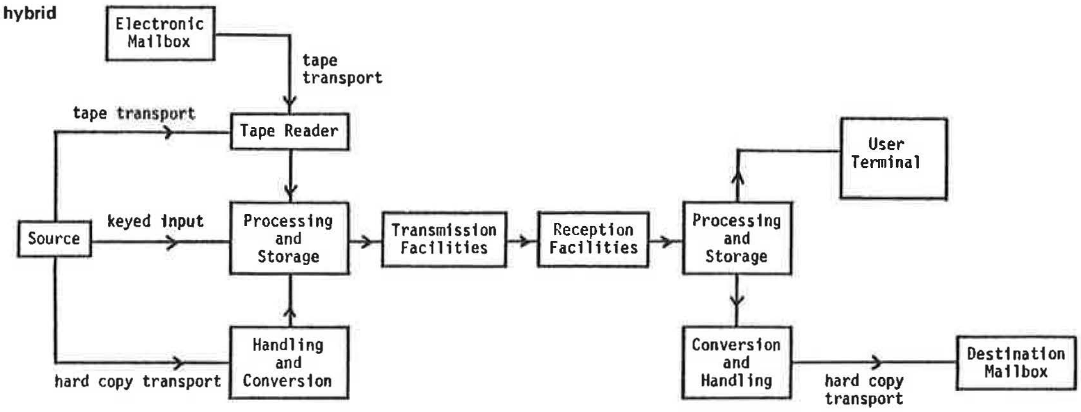

Figure 1. The USPS electronic hybrid system.

Messages contained in paper packs or on magnetic media can be deposited at post offices or regional postal facilities (called sectional centers). From there they will be transferred by truck to specialized message centers to be electronically routed toward receiving centers. In the case of remote electronic mailboxes, encoded messages will be moved electronically to message centers over local lines or stored on magnetic media and trucked to centers, depending on the cost-volume characteristics of each mailbox. The 87 electronic centers, which are expected to cost $320 000 each, will be located geographically according to generated message loads.

Messages arriving at destination centers can be conveyed to intended recipients by several means. Messages that are directed to user terminals will be routed to a communication processor and interface and are held until contact is made between message centers and remote terminals. Messages to be conventionally delivered are reproduced on paper, enveloped, and then sorted according to carrier delivery sequence. After hard-copy production, messages will be trucked to the local postal distribution stations to be fed into the conventional mailstream. Hard-copy message production requires the use of sophisticated paper-handling equipment to facilitate the movement of paper through the output subsystem. The USPS hybrid design is illustrated in Figure 1.

The integration of conventional and electronic message delivery activities suggests some resource conservation possibilities, which will be discussed later in this paper. Some competitors fear that eventually USPS may operate local telecommunications links for input and output directly between stations and message origin-destination points. Others feel that provision of all-electronic services to hard-to-reach rural areas would be a cost-effective move for USPS. Such an expansion of service might reduce both carrier personnel and vehicle requirements. However, suggestions that USPS operate either electronic collection or distribution services have been met with quite vocal oppostion.

RESOURCE SAVINGS POTENTIAL

During the last decade the general public has become increasingly aware of the unpredictable nature of energy supplies and the impending scarcity of nonrenewable energy sources (especially fossil fuels). As a result, there is greater public sensitivity to energy issues, more debate over which energy policies are most desirable (e.g., developing nuclear versus new nonnuclear sources, and conservation efforts), and also greater efforts devoted toward conserving resources, especially energy supplies. Therefore, the resource conservation potential of electronic message transfer cannot be ignored. The application of such technology in USPS letter-post operations could result in limited resource savings, especially in fuel and vehicle requirements, as will be illustrated in the following sections. Of course, additional resource savings are clearly possible as applications of new communications technology permit the elimination of various discretionary and business travel needs, as noted previously.

Energy Implications

The energy requirements of conventional postal technology can be compared with those of electronic message transfer. Any complete analysis of these alternatives would require an examination of the total energy use of each system (i.e., energy requirements to produce necessary machinery along with energy used in equipment operation). However, within the resource constraints of the research project that underlies this paper, only the energy used in electronic transfer operations is compared with that required for conventional transportation of messages. This concise analysis is only intended to initiate a larger discussion of the energy conservation potential of electronic message transfer. It is hoped that these order-of-magnitude calculations will be expanded and refined through additional research efforts.

The data in Table 1, provided by the Ford-Philco Corporation, list the labor, equipment, and power requirements of a model electronic hybrid transfer system. Notice the power requirements of the four transmission station types. A complete transfer system, consisting of a varied mix of these stations, would use 25 141 200 kW•h or 85.78 billion Btu's to move 30 billion messages. On a per-message basis, each transmission would require an average of 2.9 Btu's.

Table 1. Resource requirements of an electronic message transfer hybrid system (30 billion messages/year).

Item	Terminal	No. of Shifts	Requirement
Staffing	A and B	3	1 engineer[a], 2 technicians[b]
		2	2 technicians
	C and D	3	1 engineer and 1 technician
		2	2 technicians
Control		3	2 engineers
		2	1 engineer
Power	A		50kW = 438 000 kW·h/year
	B		30kW = 262 800 kW·h/year
	C and D		20kW = 175 200 kW·h/year

[a]Engineer salary = $40 000. [b]Technician salary = $25 000.

To derive an estimate of energy used by the equivalent conventional transportation activity, several assumptions must be made. First, the transportation of messages between conventional processing stations and transportation terminals, which is provided largely by the USPS fleet, is assumed to be similar to the transportation requirements of moving hard-copy messages between the electronic processing centers and conventional distribution centers. This simplifying assumption suggests that the transportation requirements of the intercity contract fleet will be equivalent to those of the electronic transfer activity. A second necessary assumption involves the distribution of messages carried by each mode. Virtually all nonlocal, first-class messages travel on airline passenger flights while the remaining messages move by truck. Since 40 percent of first-class mail is nonlocal, in this sample calculation 40 percent of the message load is assumed to move by air while the remaining 60 percent is moved by truck.

In FY 1977, USPS estimated that 400 million ton-miles of transportation moved 53.7 billion first-class mail pieces between processing centers (9). Assuming a 40/60 split in traffic by mode and that modal energy intensities are 3300 Btu/ton-mile for belly freight carried on passenger flights and 2700 Btu/ton-mile for intercity truck, it can be estimated that 1176 billion Btu's were required to move 53.7 billion pieces (10). Directly scaling this estimate to match the system output of the electronic system suggests that 30 billion messages required 657 billion Btu's. On a per-message basis, intercity transport of each message required an average of 21.9 Btu's.

Comparing energy use in the transfer of 30 billion messages by electronic message transfer to that required by current conventional transportation practices, only about 571 billion Btu's could be saved by sending messages via electronic message transfer or 19 Btu's/message. Such energy savings are equivalent to about 98 450 bbl of crude oil. In the event that energy intensities of both conventional and electronic transfer technologies could be improved by 10 percent over the next decade, the conservation potential would amount to only 88 638 bbl. Actual savings of crude petroleum could be greater than the above figures indicate since electronic message transfer uses electricity that can be generated from nonpetroleum sources. By shifting to electronic message transfer, message movement could be accomplished without relying so heavily on petroleum sources of energy.

In terms of the aggregate domestic energy consumption, the potential savings due to electronic message transfer are quite small (11). In 1977 energy use was estimated to total almost 76×10^{15} Btu's. Of this aggregate amount, petroleum use accounted for approximately 37×10^{15} Btu's or about 6.7 billion bbl. When electronic message transfer energy savings are compared with these statistics, such possibilities amount to only 0.5 percent of petroleum consumed in one day and an even smaller proportion of the total energy used in 1977. Yet, an annual savings of 98 450 bbl will not be completely insignificant as petroleum supplies become more scarce.

One might expect much greater savings if conventionally conveyed messages shifted to an end-to-end electronic message transfer system. However, USPS uses only 350 million gal of gasoline and diesel fuel to move all classes of mail (i.e., more than message traffic). This annual figure, which includes fuel used in all owned, leased, and contracted vehicles, amounts to only 0.1 percent of national petroleum consumption in 1977. While the implementation of electronic message transfer technology has the potential to save previous petroleum resource, it cannot offer the resource-saving potential that, for example, other transportation or space-heating conservation programs could provide. However, it can contribute to general energy conservation efforts. Much greater energy savings are possible as consumers learn to substitute electronic alternatives for a wide range of travel needs. As petroleum supplies become more scarce, the government may well encourage the use and development of electronic message transfer services.

Vehicle Fleet Requirements

In FY 1978, USPS delivered more than 96 billion items of which almost 56 billion were first-class message items. To accomplish this task, an average of more than 40 million stops were required each day, amounting to an equivalent mileage of four round trips to the moon for rural routes and 1 million miles for city routes (12,13). As one might expect, USPS operations represent a unique assembly of resources and management practices.

USPS has one of the largest vehicle fleets in the world, currently owning approximately 120 000 vehicles in active service with another 70 000 under contract. This sizable transportation pool is larger than the combined fleets of the top five commercial carriers. The physical plant, vehicle fleet, and labor force managed by USPS amount to much more than that available to the very largest corporations such as American Telephone and Telegraph.

It is difficult to judge the effect that electronic message transfer will have on postal-owned vehicles and on leased and contract vehicles. Over the short term, this fleet of 190 000 vehicles will remain relatively stable. In the more distant future, vehicle requirements may change more radically. For instance, the delivery fleet, which totaled about 150 000 vehicles in FY 1978, may shrink if patrons overwhelmingly adopt electronic collection and delivery options and also if they are willing to accept reduced conventional services (e.g., three-day-per-week deliveries). Intercity contract vehicle needs may also change. If messages migrate from conventional to electronic alternatives, both the size and the number of trucks required may be reduced. Any shift in vehicle fleet requirements will depend on public response to both conventional and electronic alternatives.

Paper Requirements

One can anticipate that electronic message transfer will have implications for paper, a medium that has historically recorded and stored messages. End-to-end electronic message transfer and office automation systems have been commonly depicted as catalysts for promoting the paperless society. Ideally, recipients could review their correspondence in video form and decide whether to produce a paper copy or simply store it electronically. Considering the amount of paper-based correspondence and transactions flowing among business and government, one could imagine that such potential for saving resources is great. The hybrid electronic message transfer technology could actually increase the use of paper resources since each time a message is sent from a public terminal two paper copies of the message will be created. While the technology offers real options for paper conservation, the actual amount will depend on user habits.

SUMMARY

We have suggested that resources, notably paper, vehicles, and energy, can be conserved if consumers react favorably to the introduction of hybrid electronic message transfer technology into the letter-post industry. Potential resource savings could be even greater if end-to-end systems become popular. Government may wish to implement policies to stimulate the development and use of electronic message transfer in order to realize these and other potential resource conservation possibilities.

This paper focuses on the resource implications of substituting communication services for transportation services. While the use of electronic message and information transfer services in the letter-post industry will not have the resource conservation possibilities of other programs, particularly in the transportation area, it could contribute to efforts to reduce the total resource consumption in the United States, in addition to offering potential speed and cost advantages. At a later stage, when the hybrid system equipment has been fully specified, it will be possible to make a much fuller energy analysis, comparing total energy use (i.e., construction and operation requirement) of the alternative systems. Of course, other applications of electronic message transfer technology (e.g., teleshopping, utility telemetry, and decentralized workplaces) could be even more significant.

In the context of this paper we were only able to cite one example of the likely impacts of this technology. The overall research effort that underlies this paper addresses a number of other dimensions, namely issues of privacy, liability, and capital or labor substitution possibilities in postal operations. The development of technically, economically, and socially efficient communication alternatives to transportation services requires that both the costs and the benefits be considered when designing and implementing such systems.

ACKNOWLEDGMENT

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Discussion

C. John Langley, Jr., and Rammohan Pisharodi

The first order of business is to compliment Lee and Meyburg for a very interesting and relevant paper. This contribution appears to comply with the intent as well as the spirit of the charge to the Subcommittee on Social and Economic Effects of Energy Constraints of TRB Committee A1B03. While the topic of substituting communications for transportation has received a variety of attention in the past 10 years or so, there is no question that the concept integrates the nature of general concern for these two areas of national priority.

This paper provides some very interesting insights into the resource implications of substituting communications for transportation, specifically in the context of electronic message transfer. This is in contrast with the fact that most of the past studies in this area have dealt with technologies to reduce personal travel rather than messages.

The hybrid electronic message transfer system being developed by the U.S. Postal Service (USPS) provides an excellent case study for investigation. Although the research project admittedly did not consider every imaginable aspect of the resource savings potential of electronic message transfer, it does represent a concise exploratory research study on an aspect of the transportation-communication trade-off in which several claims had been made previously with little empirical support. The paper also raises several issues regarding the energy conservation potential, vehicle fleet reduction, and paper conservation opportunities associated with electronic message transfer. The analysis indicates that the potential of the system for conserving energy supplies, while not completely insignificant, cannot offer the dramatic results of alternative programs such as public transportation or space-heating conservation.

It appears that the electronic message transfer system has the potential to substitute fully for letter mail, at least in the context of the needs of business and industry. The system can transmit product specifications, technical details, market information, purchase orders, copies of contracts, etc., in a very short time. This could lead directly to shorter market response times and purchase lead times, which in turn would permit companies to reduce their inventory levels, while simultaneously providing an equal or improved level of customer service. This in turn will reduce the waste of resources such as materials, manpower, and facilities that could result from a sudden change in market conditions. While it would be very difficult to measure the resource conservation potential of consequential impacts such as these, we can speculate that it would be considerable.

In an overall evaluation of the potential of electronic message transfer, we cannot help but agree that the level of innovation associated with the concept is high. Also, the energy saving potential is notable, particularly with regard to fuel and vehicles. While we would agree also with a contention of Lee and Meyburg that the USPS represents a unique assembly of resources and management practices, we have no evidence to believe that the results to date at the USPS have produced an unusual number of efficiencies, economic or otherwise. The simple fact is that without its exclusive franchise for the delivery of first-class mail, the USPS would have preceded the fate of REA Express by many years. Thus, innovation to date by the USPS has occurred largely in the environment of monopoly business enterprise, and has relegated economic efficiency to the role of sacrificial lamb. The net energy and resource savings that would result from a greater trend toward free market enterprise would without question far surpass the relatively meager savings resulting from electronic message transfer. Our recommendation is that any government interest in stimulating the development and use of electronic message transfer should place a high priority on coordinating its actions and policies with the skills and abilities of the private sector. Firms such as UPS, IBM, and ITT have proven themselves capable of operating in economically competitive environments, and they should be given an equal opportunity to contribute. What we are really saying here is that the problem is not with the technology but with the institutional realities.

Another perspective on the problem is the concern expressed recently by Sorkin (14) that the development of electronic message transfer capabilities on a fully competitive basis would spell financial disaster for the USPS. This conclusion is supported by three contentions, namely that

1. The postal service is far behind private industry in the area of technological development,
2. The postal service has performed little market research or evaluation of alternative technical systems for electronic message transfer, and

3. The postal service would be required to provide a standard set of services in competition with a set of diverse and unstandardized offerings by other firms.

Considering factors such as these, it seems that a cooperative, rather than competitive, environment between government and the private sector would be the most appropriate solution.

As a general statement, however, the success of the system will depend ultimately on how readily society accepts it. While the system itself could bring about tremendous changes in the habits of people, businesses can be expected to be early adopters due to the greater value they place on the prompt communication of information. When a considerable number of private persons and businesses do not consider an electronic letter to be a proper substitute for a regular letter, the simultaneous existence of two parallel systems of communication might result. The likely impacts would be an increase in the cost and a reduction in the efficiency of regular letter-mail service.

Lee and Meyburg have mentioned a number of other important implications of the transportation-communications trade-off--specifically, the issues of privacy, liability, and capital-labor substitution. Among these, the issue of privacy might have the greatest impact on the implementation of the technology. Business and private persons might not readily accept human handling of their uncovered private letters. This problem could be alleviated by a high degree of automation in the handling of letters and by technological development that would ensure that only authorized persons would have access to the information contained in the letter. We will look forward to learning of future developments in this area.

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Abridgment

Estimation of Gasoline Price Elasticities for New Jersey

JOHN G. J. DeJONG

Gasoline price elasticities are useful in projecting vehicle miles of travel, gasoline use, and gasoline tax revenues. The two objectives of the study were (a) to develop a method for the estimation of two types of price elasticities of demand for travel by automobiles and (b) to arrive at empirical elasticities for a state. One-year and medium-term elasticities were estimated for New Jersey. Travel counts and real gasoline prices from 1972 to 1979 were correlated to determine the one-year and medium-term elasticity for New Jersey. The elasticities that resulted out of this correlation were compared with other elasticities in the literature. The estimated four-year elasticity conforms very well with the medium-term elasticities in the literature. Four scenario adjustments were used to represent the growth rate in travel as caused by factors other than the real gasoline price. The first scenario resulted in elasticity estimates that conformed to the best of those in the literature: a four-year elasticity of -0.28 and a one-year elasticity of -0.14.

The purpose of the study was to develop a one-year and a four-year elasticity of demand for travel by automobiles. A price elasticity of demand for travel is defined as the change in the quantity of automobile miles demanded in response to a change in the gasoline price. Vehicle travel counts and real gasoline prices in New Jersey for each month from 1972 to 1979 were correlated to determine a one-year and a four-year elasticity for New Jersey. By comparing two of the same months with four years in between, or two of the same months in two consecutive years, a large number of elasticity estimates were arrived at and can be used in calculating an average elasticity estimate.

Four travel growth scenarios were used to adjust for the factors, other than the gasoline price, that affect miles of travel. An adjustment was made to determine how the quantity of miles traveled is affected by price changes only. A scenario approach was taken because it is not exactly known how much of the growth in vehicle miles of travel (VMT) is caused by factors other than a changing real gasoline price.

This paper will focus mainly on the methods used to estimate the one-year and the medium-term elasticities.

METHODOLOGY

Traffic volumes of 30 permanent counting stations on the major highways of New Jersey were used as a measure for VMT on these highways. Miles traveled by diesel-powered vehicles were not subtracted from the vehicle volume data. It was felt that the subtraction of vehicle counts for diesel-powered vehicles is not very relevant in developing an estimate for a price elasticity because most diesel vehicles are trucks and truck use is not significantly affected by fuel price increases. This means, however, that the elasticity estimates arrived at in this paper are probably somewhat low in absolute terms because the percentage change in quantity is somewhat larger when truck travel is taken out.

Monthly vehicle-volume data of 30 permanent counting stations were taken out of the Annual Traffic Count Summaries for 1972 through 1979, which are published by the New Jersey Department of Transportation (NJDOT).

The calculations for the individual elasticity estimates were done by computer. A price elasticity of demand represents the reaction of consumers to a change in price in the form of a change in the quantity demanded. The basic formula for a price elasticity is the change in quantity divided by the change in price. If the period in between the two quantities and the two prices is one year, it is a one-year elasticity. During one year, the fleet miles per gallon cannot change very much so that the price elasticity of demand for travel is equal to the price elasticity of demand for fuel.

The basic formula was adjusted to take into consideration the factors that historically have increased travel on major highways in New Jersey (e.g., increasing real per capita income, population, and supply of road facilities). A similar type of adjustment was made when Curry, Scott, Piske, and Scardino (1) calculated their expected quantity. They defined expected quantity as the quantity of travel that would have taken place if there would not have been an oil-supply crisis. The adjusted formula is

$$[(q_2 - q_1)/(q_1) - (\text{adjustment})]/(P_2 - P_1)/(P_1) \quad (1)$$

where q is the quantity of travel and p is the real price of gasoline.

The variable adjustment was made in the form of scenarios so that they can be evaluated by the reader. An upper limit for the adjustment was arrived at by calculating the average annual rate of change in VMT (VMT as a proxy for traffic counts) on New Jersey's highways from 1957 through 1972: 4.55 percent annual growth (as calculated by the NJDOT Bureau of Data Resources). This is an upper limit because one of the factors that has increased travel from 1957 through 1972 is a declining real price of gasoline. The lower limit of a 3 percent adjustment is arrived at by following the rule of thumb that total VMT on all roads is increased by about 3 percent up until 1972. This was an attempt to quantify the relation between real price and automobile travel; thus, all extraneous factors, other than a changing gasoline price, that have historically increased miles of automobile travel were deleted. Four scenarios, with 0.03, 0.035, 0.04, and 0.045 as adjustments, were used to calculate four different one-year elasticity estimates. Three four-year elasticity estimates were calculated with the three scenarios of a 0.03, 0.035, and 0.04 adjustment.

The effect of gasoline availability problems has to be taken out in an analysis that quantifies the relation between price and the quantity demanded. For this reason, months in which the governor of New Jersey had announced gasoline rationing (by means of odd and even license numbers) were eliminated. Odd-even rationing started officially on February 11, 1974, and ended in March. To take into consideration the possibility that the governor reacted late in imposing rationing and to take out the effect of an after shock of the oil crunch on fuel use, data for the months of October 1973 through June 1974 were eliminated. Similarly, data from March through October 1979 were eliminated.

AVERAGE FOUR-YEAR ELASTICITY ESTIMATE

After estimating the individual elasticities it was found that the four-year estimates were distributed closely together, while the one-year estimates had several outliers in the tails of a normal distribution graph. A moving average in calculating the four-year elasticity estimates was used with the thought that the moving average would take away minor fluctuations and would arrive at an underlying trend in the elasticity estimates (based on data from 1972 to 1979). An average four-year elasticity was calculated by using a three-month moving average. For example, the quantity of vehicles counted during January, February, and March 1976 was compared with the quantity during January, February, and March 1972.

AVERAGE ONE-YEAR ELASTICITY ESTIMATE

Another method was used to estimate the average one-year elasticity. Because the use of a moving average would create interdependencies among the individual elasticity estimates, which would prevent the use of a statistical method to exclude outliers, straight elasticities were used to calculate an average one-year elasticity estimate. Straight means that the quantity and price of a particular month were compared with the quantity and price of the same month in the next year. In contrast to the price changes during four years, the price changes during one year were sometimes very small. It might be that the price data that are used in the denominator are not expressed at the right level of precision. Price data have one decimal place, while quantity is in tens of thousands of vehicles. Sometimes, the resulting elasticity estimates are very large in absolute terms because of the very small price changes, even though the quantity change is moderate.

The average one-year elasticity estimate is calculated by adding a number of individual elasticities. Then it is divided by that number of elasticities.

If the frequency distribution for the individual elasticity estimates is plotted, an approximately normal distribution is produced: There is a central tendency about the mean and a portion of the values falls into the two tails. An average elasticity that includes observations in these tails may be unduly influenced by the magnitude of these relative infrequent tail values. The primary reason that

Figure 1. Total frequency distribution for individual one-year elasticity estimates in 0.03 travel growth scenario.

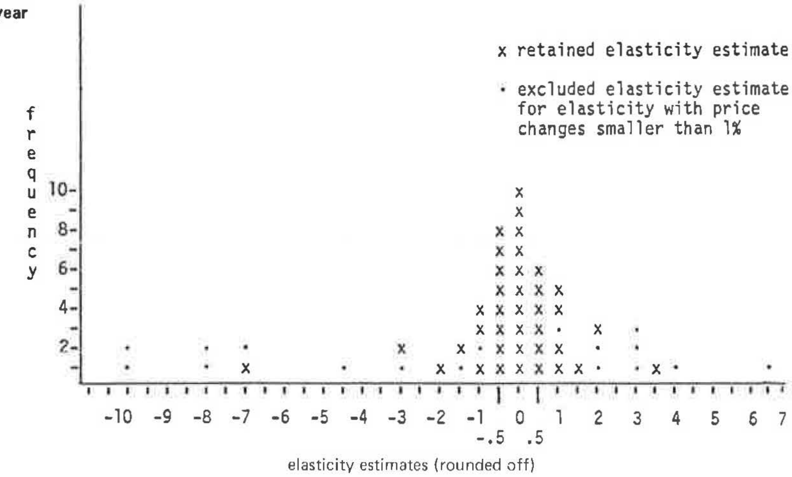

Table 1. One-year elasticity estimates based on four scenarios for background growth in miles traveled.

Adjustment Scenario	No. of Elasticities	No. of Elasticities Between -0.35 and -0.15	Range of Elasticity Estimates Without Screening	Average One-Year Elasticity Estimate
0.03	36	6	-10.17 to 6.53	(-4.988/32) = -0.14
0.035	33	7	-4.53 to 14.77	0.165
0.04	32	5	-5.36 to 16.83	(4.103/32) = 0.128
0.045	31	5	-6.2 to 18.8	0.084

Table 2. Four-year elasticity estimates based on three different scenarios for background growth adjustment.

Adjustment Scenario	No. of Elasticities	No. of Elasticities Between -0.45 and -0.25	Range of Elasticity Estimates	Average Elasticity Estimate
0.03	29	5	-1.72 to 0.217	-0.284
0.035	29	11	-6.57 to 1.14	-0.431
0.04	29	7	-11.77 to 3.38	-0.590

these values exist is attributable to the characteristic of a quotient and the fact that there are a number of one-year elasticity estimates with a very small price change. For this reason elasticity estimates with a price change smaller than 1 percent were excluded in estimating the average one-year elasticity. After excluding these elasticity estimates, there were still some suspect tail values.

The following might help the reader to appreciate the sensitivity of the elasticity ratios and further explain why a judgmental procedure was followed to exclude more quotients. The elasticity estimates are actually variables that are used to estimate the true value of the population elasticity parameters. These estimates have a distribution about the true population parameter; this suggests that a statistical technique could be used to detect the presence of outliers. In fact, direct analytical outlier detection of a ratio distribution must be approximated and can only be done if both numerator and denominator have a small coefficient of variation, i.e., if the standard deviation of the denominator (or numerator) is small relative to the mean (2). This requirement was not met by the data on hand, so an alternative, but more judgmental, procedure was followed. Because a statistical method, like a confidence interval analysis, could not be used, all elasticities of an absolute magnitude of 3.0 or more were excluded as outliers. Real-world observations of New Jersey drivers tend to support this exclusion since their reaction as a group was not very strong to gasoline price changes in the short term. A final common-sense reason for the latter exclusion is that, if the few large quotients are included in the calculation of the average elasticity estimate, they would totally overshadow the majority of the elasticity estimates that are in between -1.5 and +1.5.

As shown in Figure 1, the primary cause for excluding some estimated values was a very small change in the reported prices. Table 1 presents information about the individual elasticities used in the estimation of the average one-year elasticity.

RESULTS

One-year elasticities are expected to be lower in absolute terms than medium-term price elasticities of demand because people have had more time to react to the price change. The estimates for the one-year elasticities are presented in Table 1.

The change in sign of the average elasticity estimate going from the 0.03 scenario to the 0.035 scenario is a result of having a quantity change that becomes negative while the real price change is negative in both the 0.03 and the 0.035 scenarios. A declining quantity correlated to a declining real gasoline price results in a positive individual and sometimes positive average elasticity estimate.

Not one of the four elasticity estimates in column 5 of Table 1 conforms perfectly to the elasticities in the literature. Brookhaven National Laboratory reports that the estimates for a three-month gasoline price elasticity of demand for gasoline is in the range of -0.07 to -0.14 (3). One-year elasticities can be expected to be higher. Altshuler reviewed the literature and found that the range for one-year price elasticities of demand for gasoline is -0.2 to -0.3 (4).

The four-year elasticity estimates conformed very well to the elasticities in the literature (see Table 2). The reader can choose the most reasonable scenario from the three that follow.

Medium-term elasticities are expected to be larger in absolute terms than one-year elasticities. Column 5 of Table 2 conforms to this expectation. Green of Oak Ridge National Laboratory studied 1966-through-1975 gasoline consumption and estimated the medium-term gasoline price elasticity to be -0.34 (5).

Both the one-year and the four-year elasticity estimates of scenario one conform the best to the findings in the literature. The four-year elasticity for New Jersey appears to be on a better methodological base than the one-year elasticity estimate. The four-year elasticity estimate of -0.28 means that with a 10 percent increase in the real price, automobile travel in New Jersey decreases by 2.8 percent.

FUTURE RESEARCH

Further research on the question of how the estimation method of this type of one-year elasticity can be improved is desirable. As noted above, taking out truck travel will result in a more correct and higher elasticity estimate in absolute terms.

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Land Use and Energy Intensity

HERBERT S. LEVINSON AND HARRY E. STRATE

This paper summarizes the energy implications of urban land use in the metropolitan Toronto area. It identifies the transportation and nontransportation energy intensities of various land uses, assesses the effects of population density on energy consumption, and suggests measures to improve energy efficiency. The annual energy requirements of various land uses, including transportation energy, were manufacturing, 40 percent; residential, 35 percent; commercial, 19 percent; and other, 6 percent. The total annual energy consumption of various types of residential development was computed by adding the annual transportation energy consumed to the annual energy required to build and operate buildings. Composite annual energy requirements were single-family attached—504 000 MJ/unit; single-family detached—376 000 MJ/unit; walk-up apartment—284 000 MJ/unit; and high-rise apartment—216 000 MJ/unit. Single-family residences consumed 50 percent more energy than did apartments on a per-unit basis. However, on a per-capita basis, apartments were found to be only 15 percent more efficient. Better land use planning to encourage compact urban development, increase residential densities, balance jobs and people, expand transit ridership, encourage ridesharing, and reduce per-capita space requirements would improve energy efficiency. These are desirable actions, especially in rapidly growing metropolitan areas. However, they appear difficult to achieve in view of public preferences and the incremental nature of implementing land use plans. Consequently, the greatest near-term gain in energy conservation probably will come from improving the operating energy efficiency of existing and new buildings and from improving transportation energy efficiency.

This paper summarizes the energy implications of urban land use in the metropolitan Toronto area (1). It overviews the state of the art, identifies the direct and indirect transportation and nontransportation energy intensities of various land uses, assesses the effects of population density on energy consumption patterns, and suggests measures to improve energy efficiency. It is based on a review of travel behavior and energy data for both Canada and the United States.

Much has been written on urban form, transportation, energy, and density; yet, many key parameters have not been quantified. There are differences of opinion among analysts regarding the effects of development density on energy consumption. Accordingly, the paper addresses two basic areas: (a) What are the energy requirements of various types of urban land? and (b) how does development density affect both transportation and nontransportation energy consumption?

STATE OF THE ART

The specific building factors that influence energy consumption include construction techniques, exposed surfaces, exposed surface-to-volume ratio, heating and cooling systems, insulation and fenestration, and climatological characteristics. However, most studies relate energy consumption to building types, age, and density, which may obscure many valid causative relationships. For example, a poorly insulated high-rise luxury apartment with spacious units may consume more energy per dwelling unit, per capita, or even per square foot, than a medium-density development of the same number of units per acre (2).

More study has been done of patterns of residential energy consumption than any other land use segment, and many of these findings are applicable to other land uses, such as commercial. For example, the cube minimizes the surface-to-volume ratio, thereby reducing heat-transfer potential; another example, shared walls, can reduce per unit energy consumption equally as well for retail establishments as for residential units.

Generalizations

From current literature, some generalizations may be made:

1. Higher residential densities relate to lower energy consumption;
2. Single-family detached homes consume more energy than low-rise, attached, and multistory housing;
3. Estimates for Ontario indicate that, for space heating, semi-detached houses require 25 percent less energy than single-family houses, and row houses require 50 percent less (3);
4. Decreasing exposed surface per enclosed volume minimizes heat transfer; surface can be minimized by creating cubical space or sharing common walls;
5. Landscaping and massing of buildings can serve as a shield to wind, sun, or other climatological extremes;
6. Increases in residential density may create opportunities to (a) increase efficiency of electromechanical systems through area heating and (b) minimize appliance use by sharing (e.g., washer-dryer);
7. Higher-density housing units tend to be smaller than single-family houses and thereby require less energy for heating and cooling; and
8. High-density living often means greater public transport use and lower automobile use.

Costs of Sprawl

The Costs of Sprawl study carried out for the U.S. Council on Environmental Quality attempted to isolate the variables of density from neighborhood age, obsolescent design, and low-income population, and to measure the most important consequences of urban form (4). Detailed estimates of the energy, environmental, capital, and operating costs were made of six hypothetical new communities--each containing 10 000 dwelling units, each housing an average urban fringe population mix, and each constructed in a typical environmental setting. The six communities varied by density (high, medium, low) and community design (optimal, typical). At the extremes were an optimally designed high-density community (19 units/net residential acre) and a typical low-density community (3.5 units/acre).

The analysis dealt with residential heating and air conditioning and with automobile use. The well-designed high-density community was found to be optimal with reference to all four key indicators examined, and the typical low-density community was least desirable with reference to all four. The overall consumption of the well-designed high-density community was 44 percent less than consumption in the typical low-density community.

In contrast, Altshuler (5) points out that many of the energy savings reported for high-densities dissolve on close examination. He indicated that the 44 percent savings in energy use for space heating and air conditioning reflected the different indoor space standards used:

> Overall, the high-density community had 34 percent less residential floor space than the low-density community and this accounted for five-sixths of the claimed energy savings....
>
> If one holds dwelling unit size constant and allows only 20 percent of the claimed auto travel savings (but still levies no charge for mass transit energy usage), the energy demand differential between the well-designed high-density community and the typical low-density community shrinks from 44 percent to 14 percent. If one compares the well-designed high-density community with the report's well-designed low-density community, moreover, the differential narrows to 6 percent.

Urban Form and Density

People living in cities with high population densities, concentrated employment in the city center, and extensive transit systems use substantially less gasoline per driver than those residing in low-density communities with dispersed employment. Each driver in New York and Chicago consumes less than 10 gal/week compared with some 15 gal consumed per driver in Los Angeles, Tucson, and Houston (6).

A few studies have modeled the future travel requirements associated with alternate urban development options over the past several decades. A study of five regional year-2000 plans in the Hartford, Connecticut, area showed that a balanced plan would have a work-trip length of 0.92 times that for the trend development. Corresponding ratios for linear development, satellite cities, and strong center plans were 0.96, 0.97, and 1.14, respectively (7).

A study on Energy, Land Use and Growth Policy: Implications for Metropolitan Washington analyzed six alternative 1992 development scenarios in terms of future energy consumption: wedges and corridor, dense center, transit oriented, wedges and corridors with income balance, sprawl, and beltway oriented (8). The dense-center scenario would consume about 8 percent less energy in the design year than with sprawl conditions.

STUDY APPROACH

Land use, transportation demand, and energy consumption are closely interrelated. Figure 1 illustrates this land use, transportation, and energy cycle and summarizes the steps followed in developing energy intensity factors: (a) the energy consumed in buildings and in operating various types of residential and nonresidential land was quantified, (b) the travel resulting from separations of various urban activities was estimated for various development densities, (c) composite energy intensity factors were obtained by adding the transportation and nontransportation energy, and (d) policy implications relative to energy consumption were identified.

The MTATES study assessed urban form, transportation, and energy relationships based on an earlier work by the Metropolitan Toronto Transportation Plan Review. Transportation system performance, based on assumed land use and transportation configurations, was tested by a number of criteria, including simulation of travel demand and performance. Three of the criteria used have direct bearing on energy consumption:

1. Average automobile trip length,
2. Average transit trip length, and
3. Mode split.

The selected systems tested and results of these evaluations are summarized in Table 1. Of the systems summarized, the Eglinton Corridor plan had the highest overall mode split at 47 percent. The shortest automobile trip length was achieved by the Metro Dispersion/Toronto Center plan--more than 0.5 mile less than the decentralized concept of regional dispersion.

Evaluating the energy consumption characteristics

Figure 1. Land use energy cycle.

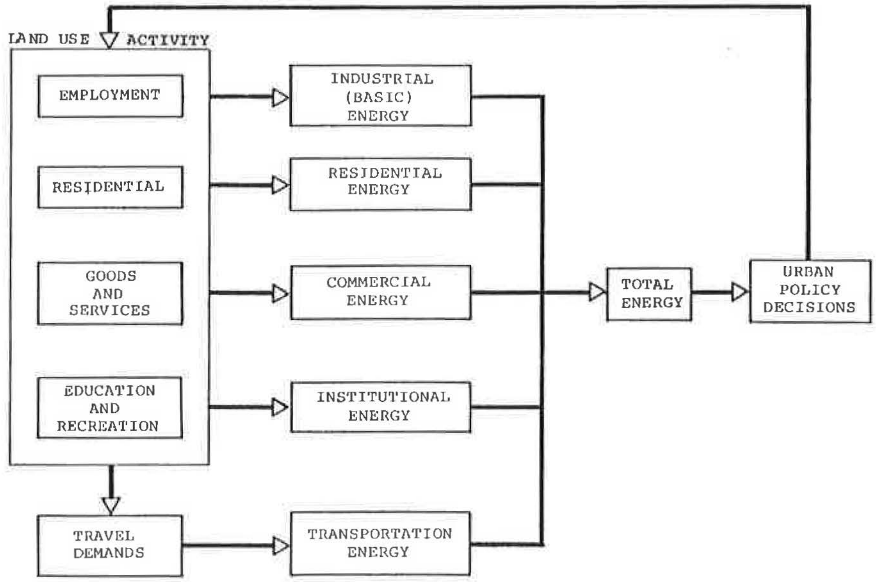


Table 1. Transportation performance of preferred land use and transportation combinations.

Development Designation	Description	Avg Automobile Trip (km)	Avg Transit Trip (km)	Mode Split (%)
Centralization (M3)	Highest level of central area growth	14.77	11.41	40
Binodal (O6)	Downsview Airport major center	14.51	11.09	39
Subcenter (D3)	Subregions at North York, Mississauga, and Oshawa	14.74	11.42	45
Corridor development				
(G2)	Eglinton corridor	14.69	11.39	47
(F1)	Lakeshore corridor	14.92	11.73	46
Metro dispersion (C3)	Toronto Center	14.42	11.13	38
Regional dispersion (L3)	Decentralization	14.95	11.89	39

Note: Data from Metropolitan Toronto Transportation Plan Review, Report No. 63, Jan. 1975.

Table 2. Influence of land use on transportation energy.

	Centralization[a]			Subcenter[a]			Regional Dispersion[a]			Load Factor Fix[b]		
Analytic Factors	Car	Bus	Total	Car	Bus	Total	Car	Bus	Total	Car	Bus	Total
Daily urban person work trips per household	1.39	0.92	2.31	1.27	1.04	2.31	1.41	0.90	2.31	1.31	1.00	2.31
Mode share	60.00	40.00	100.00	55.00	45.00[b]	100.00	61.00	39.00	100.00	57.00	43.00[c]	100.00
Avg trip length	14.77	11.41	-	14.74	11.42	-	14.95	11.89	-	14.95	11.89	-
Daily person kilometers	20.53	10.50	-	18.72	11.88	-	21.08	10.70	-	19.58	11.89	-
MJ/person kilometer	4.60[a]	0.70[a]	-	4.60[a]	0.76[b]	-	4.60[a]	0.70[a]	-	4.10[c]	0.60[c]	-
Total daily MJ/household	94.44	7.35	101.79	86.11	7.13	93.24	96.97	7.49	104.46	80.30	7.13	87.43
Total energy (MJ)			50 895 000			46 619 000			52 228 200			43 715 000
Equivalent gasoline (39.84 MJ/L)			1 461 000			1 338 000			1 499 000			1 255 000
Savings over dispersion (%)			2.70			10.90			-			16.40

Note: Data from Wilbur Smith and Associates.
[a] Assumes automobile occupancy of 1.36 passenger/vehicle and single value for all transit trips—subways, street cars, bus, etc.
[b] Assumes transit load factor increases 6 percent (ridership increase of 12 percent).
[c] Assumes transit load factor increases 5 percent (ridership increases 10 percent), and automobile occupancy increases 10 percent to 1.50.

of each, the subcenter plan that closely approximates the current Metro official plan consumes 10 percent less energy than the regional dispersion plan. As summarized in Table 2, subcenter even outperforms the centralization plan focused on the Toronto central business district (CBD).

Even more significant increases (11 percent) in energy efficiency can be achieved through strategies aimed at increasing automobile occupancy 10 percent and transit ridership 10 percent, as illustrated by the load-factor-fix scenario. These behavioral changes are not easy to obtain, yet hold potential for significant increases in efficiency. To illustrate, a 10 percent increase in automobile occupancy would require that one out of every eight drivers would no longer drive alone.

LAND USE AND ENERGY CONSUMPTION

The energy consumed by urban land use reflects the types, intensities, and spatial separation of the activities that take place. It includes the energy involved in construction and actual operation.

Energy Profile

The annual energy consumption profile of each region

Table 3. Relation of land use to travel and energy consumption.

Use	Distribution of Developed Land[a]	Person Destinations[b] (%)	Energy Consumed by Sector 1978[c] (%)	Transportation Energy Redistributed, Ontario	Energy Consumed with Transport Energy Distribution According to Columns 3 and 4
Residential	28.0	50.1	20.5	+14.7	35.2
Commercial	2.6	27.5	10.2	8.1	18.3
Manufacturing	5.7	8.5	37.7	2.5	40.2
Transportation, common, utilities	6.2	1.0	29.3	-29.1	0.2
Public and semipublic buildings and open space	29.9	12.9	2.3	3.8	6.1
Streets and alleys	27.6	-	-	-	-
Total	100.0	100.0	100.0	0	100.0

[a]Data from H. Bartholomew, Land Uses in American Cities, Harvard Univ. Press, Cambridge, MA, 1955.
[b]Data from TARMS, 1971.
[c]Data from Ontario Royal Commission on Electric Power Planning, 1978.

Table 4. Typical values for annual energy consumption in Buffalo and Toronto metropolitan areas.

Land Use	Annual Energy Consumed (MJ/m²)			
		York[a]	Oakville[b]	Buffalo[c]
Residential				
Single-family detached (120m²)		1540	-	1710
Single-family attached (110m²)		-	-	1240
Multifamily low-rise (100m²)		1470	-	1160
Multifamily high-rise (60m²)		1470	-	1520
Composite residential (110m²)		-	1420	-
	Annual Operating Toronto[d] (%)	Toronto[d]	Oakville[b]	Buffalo[c]
Commercial				
Hotel, motel	9	2320-1700	1700	1310
Office (large)		1940	1640	2290
Office (small)	47	1740	1640	1200
Shopping center	-[e]	-	2270	2040
Service station	10	3210	-	-
Store	23	2320	-	1620
Theater, auditorium	-	-	-	-
Composite wholesale	-	-	1700	-
Food store	11	4450	-	-
Total	100			
	Annual Total[d] (%)	Toronto[d]	Oakville[b]	Buffalo[c]
Institutional				
Clinic	-	-	2160	1460
Community center	-	-	-	1140
Gymnasium	-	-	-	1470
Hospital	32	4530	2160	3330
Nursing home	2	890	2160	1340
School, elementary[f]	17	1320	1360	1200
School, secondary[f]	19	1740	1360	1420
Community college	4	2130	-	-
University	24	2520	-	-
School administration building	2	-	-	-
Total	100			

[a]Data from Analysis of the Relationship between Urban Form and Energy Consumption. Ministry of State for Urban Affairs, Toronto, March 1979.
[b]Data from Energy Management at the Local Level. Royal Commission on Electric Power Planning, Toronto, 1975.
[c]Data from Federal Register, Vol. 44, No. 20, November 28, 1979.
[d]Data from Patterns and Levels of Commercial and Industrial Energy Consumption: A Case Study of Metropolitan Toronto. Ministry of Energy, Mines, and Resources, Toronto, 1979.
[e]See entry for stores.
[f]Ottawa school range = 970 to 1470 MJ/m². Data based on Energy Consumption in Schools. Ministry of Energy, Mines, and Resources, Toronto, 1979.

or municipality will vary, depending on the economic base and mix of activities. The annual energy consumption within the metropolitan Toronto area was estimated to be the following (9):

1. Residential, 20 percent;
2. Commercial, 11 percent;
3. Institutional, 2 percent;
4. Industrial, 38 percent; and
5. Transportation, 29 percent.

The composite annual energy requirements by land use were estimated by redistributing the energy involved in transporting people to each type of use. The resulting estimates of the overall energy consumed in the Toronto metropolitan area by sector are shown in Table 3. Estimates were derived as follows:

1. The distribution of developed land by type of use was based on Harlan Bartholomew's classic study of developed land in North American cities (column 1);
2. The distribution of person-destinations by land use was based on 1971 data for the Toronto area regional model study (column 2);
3. The distribution of energy consumed by sector was based on Ontario energy consumption for 1978 (column 3);
4. The transportation energy consumed was redistributed to the various types of use in accordance with the distribution of person trip generations (column 4) (for example, 50.1 percent of the 29.3 percent transportation energy, or 14.7 percent, was reallocated to residential land use); and
5. The composite energy consumption (column 5) represents the sum of columns 3 and 4.

The results are as follows:

1. Residential land occupies about 28 percent of the total developed land and consumes about 35 percent of the total energy,
2. Manufacturing consumes about 6 percent of the developed land and consumes about 40 percent of the total energy, and
3. Commercial activities consume about 3 percent of the developed land and 19 percent of the energy.

Changes in the distribution and density of residential land would involve about one-third of the area's total energy. If residential energy consumption could be reduced by half, it would result in about a 17 percent reduction in areawide energy consumed.

Building Operating Energy

The annual building operating energy requirements for the various land uses in Buffalo, New York, and in the Toronto metropolitan area are shown in Table 4. (Buffalo has similar climatic conditions to Toronto, and thereby provides a good data source where Toronto specific data are unavailable.)

1. Single-family detached homes have the highest residential consumption rate. They consume nearly 50 percent more energy than a multifamily, low-rise unit. Multifamily, low-rise units are the most efficient of the four types or residential forms with 1160 MJ/m² annually.

2. Among commercial establishments, foodstores consume the most energy each year, i.e., 4450 MJ/m². Hotels, motels, and office buildings consume about 2000 MJ/m² annually.

3. Hospitals represent the most energy-intensive institutional use; they consume more than 4500 MJ/m² annually.

Building Construction Energy

The total direct and indirect energy consumption involved in new building construction is shown in Table 5. The total construction energy is highest for hospitals (19 540 MJ/m²) and office buildings (18 530 MJ/m²) and lowest for residential construction (7100-8400 MJ/m²).

Table 5. Typical values for construction energy.

Land Use	Direct Energy for Actual Construction (MJ/m²)	Other Manufacturing, Component Parts, etc. (MJ/m²)	Total
Residential			
Single-family, detached	990	6 970	7 960
Single-family, attached	1170	5 920	7 090
Garden apartments (low-rise)	1320	6 030	7 350
High-rise residential	1710	6 640	8 350
Commercial			
Hotel, motel	2790	10 020	12 810
Office building	4110	14 420	18 530
Garage, service station	1740	7 010	8 750
Store, restaurant	2500	8 080	10 580
Miscellaneous	3560	12 880	16 440
Institutional			
Dormitory	3720	11 520	15 240
Religious building	2830	11 440	14 270
Educational	3020	12 700	15 720
Hospital	4020	15 520	19 540
Miscellaneous	3560	12 880	16 440
Industrial			
Industrial building	1120	9 920	11 040
Warehouses	880	5 950	6 830

Note: Data from Energy Use for Building Construction, U.S. Energy Research and Demonstration Administration, 1967; and Center for Advanced Computation, Final Report, Energy Use for Building Construction—Supplement, C00-2791-4 CAC Document No. 228-A, Oct. 1977.

Total Building Energy Intensity

The total annual building energy intensity for various types of buildings was derived by annualizing the construction energy and adding it to the direct operating energy. The results are summarized in Table 6. A 30-year service life was assumed for warehouses, service stations, and single-family residences; a 40-year service life for apartments, hotels, and stores; and a 50-year service life for institutional and other commercial and industrial uses. Hospitals are the most energy intensive, consuming 4920 MJ/m² annually. Residential single-family detached buildings consume about 2000 MJ/m², compared with 1370 for garden apartments and 1760 for high-rise apartments. These values are subsequently used in assessing the total energy requirements of differing development densities.

TRANSPORTATION AND TRAVEL IMPACTS

The effects of population density on urban trip generation and travel modes have been well documented (10,11). These relationships provide a basis for deriving the transportation energy impacts associated with various types and densities of land use.

The generalized effects of population density on urban trip rates are shown in Figure 2. As population density rises, there is an increase in the total number of person trips, including pedestrian trips, and a corresponding decrease in the number of trips in vehicles. This is because many shopping, social, and school trips and some work trips are made by foot, and a greater proportion of the nonwalking trips are made by public transport in high-density environments. As a result, the number of automobile trips per dwelling unit reduces from about 10 at 3000 persons/mile² to less than two at 30 000 persons/mile² and even less at higher densities.

Residential trip generation rates derived by the Institute of Transportation Engineers were used to quantify the effects of residential density on travel demands and energy consumption. These trip rates are shown in Table 7. Total person trips were estimated, assuming an occupancy of 1.4 persons/car, and modal-split characteristics observed in Toronto and other large urban centers.

COMPOSITE RESIDENTIAL ENERGY REQUIREMENTS

The estimated effects of various types of residential developments on annual energy consumption in

Table 6. Total annual energy consumption.

Structure Type	Construction Energy (MJ/m²)	Service Life (MJ/m²)	Annual Energy (MJ/m²)		
			Construction[a]	Operating	Total
Residential					
Single-family, detached	7 960	30	260	1710[b]	2000
Single-family, attached	7 090	30	240	1240[b]	1510
Garden apartment (low-rise)	7 350	40	180	1160[b]	1370
High-rise residential	8 350	40	210	1520[b]	1760
Commercial					
Hotel, motel	12 810	40	320	2000	2320
Office building	18 530	50	370	1900	2270
Garage, service station	8 750	30	290	3210	3500
Store, restaurant	10 580	40	260	2320	2580
Institutional					
Dormitory	15 240	50	300	2000	2300
Religious building	14 270	50	280	2500	2780
Educational	15 720	50	310	2000	2310
Hospital	19 540	50	390	4530	4920
Industrial					
Industrial building	11 040	50	220	NA	NA
Warehouse	6 830	30	210	910	1120

[a]Rounded to the nearest figure.

[b]Add 30 MJ/m² for delivery of municipal services to obtain total energy.

Figure 2. Generalized effects of density on urban trip rates.

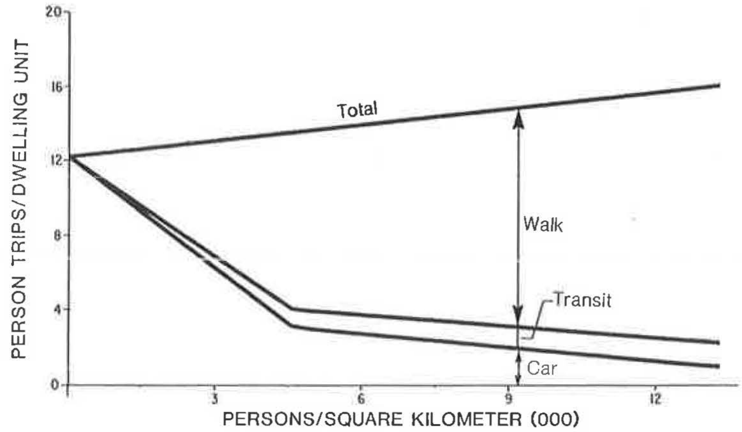


Table 7. Trip rates for dwellings.

Type of Dwelling Unit	Units per Net Acre	Avg Weekday Vehicle Trip Ends per Unit	Car Trips (1.4 persons/car)	Assumed Car Trips as Percentage of Total	Assumed Total Person Trips[a]
Single-family, detached	3.0	10.0	14.0	95	14.7
Single-family, attached	6.0	7.9	11.0	90	12.0
Low-rise apartment	15.0	5.4	7.5	80	9.0
High-rise apartment	30.0	3.7	5.2	65	8.0

Note: Data from Trip Generation—An Institute of Transportation Engineers' (Washington, D.C.) informational report, 1976.
[a]Rounded to the nearest figures.

Table 8. Estimated energy intensity of residential land use.

	Single-Family Home			Single-Family Attached			Apartment Walkup			Apartment High-Rise		
Item	Car	Transit	Total	Car	Transit	Total	Car	Transit[a]	Total	Car	Transit	Total
Transport												
1. Person trips (%)	95	5	100	90	10	100	80	20	100	65	35	100
2. Daily urban person trips/ dwelling unit	14.0	0.7	14.7	11.0	1.0	12.0	7.5	1.5	9.0	5.2	2.8	8.0
3. Avg trip length[b]	10.5	11.3	-	10.5	11.3	-	10.5	11.3	-	10.5	11.3	-
4. Daily person kilometer (2x3)	147.0	7.9	-	115.5	11.3	-	78.8	17.0	-	54.6	31.6	-
5. Annual person kilometers (4x300 days)	44 100	2370	-	34 650	3390	-	23 640	5100	-	16 380	9480	-
6. MJ/person kilometer[a]	5.9	1.5	-	5.9	1.5	-	5.9	1.5	-	5.9	1.5	-
7. Total annual transport energy (MJ/s/unit) (5x6)	260 190	3555	263 745	204 435	5085	209 520	139 476	7650	147 126	96 642	14 220	110 862
Nontransport												
8. MJ/m²			2 000			1 510			1 370			1 760
9. m²/unit			120			110			100			60
10. Total annual MJ/unit (8x9)			240 000			166 100			137 000			105 600
11. Total annual MJ/units (7-10) (000s)			503 745			375 620			284 126			216 462

Note: Data from Wilbur Smith and Associates.
[a]Mode used. [b]TARMS, 1971.

the Toronto area are shown in Table 8. These computations reflect the preceding estimates of direct and indirect residential energy construction, and the trip rates and modal split.

This table also reflects the following additional assumptions:

1. Average trip lengths of 10.5 km for car trips and 11.3 km for transit trips, based on the Toronto area regional model study (July 1971).
2. The total direct and indirect energy for automobiles, assumed at 8.28 MJ/vehicle-km, based on a specific analysis of energy consumption in Toronto. This translates into 5.9 MJ/person-km (12).
3. The total direct and indirect energy for public transport, assumed at 21.01 MJ/vehicle-km. In 1978, the Toronto Transit Commission averaged 13.96 passenger-km/bus-km. This corresponds to 1.5 MJ/person-km.
4. The square meters per residential unit for various types of residential construction, based on Ontario conditions.

The results of these computations are summarized in Figures 3 and 4. They are as follows:

Building Type	Annual Energy Consumption per Unit (MJ)	Index
Single-family home	503 745	1.00

Building Type	Annual Energy Consumption per Unit (MJ)	Index
Single-family attached	375 620	0.75
Garden apartment	284 126	0.56
High-rise apartment	216 462	0.43

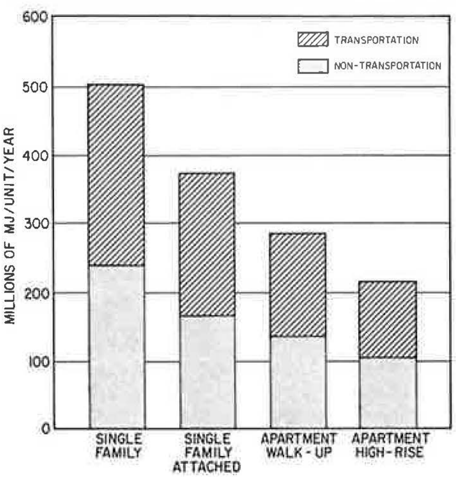
Several qualifiers should be taken into account in evaluating these results:

1. A large part of the energy savings associated with multifamily units results from the smaller amount of space they occupy.
2. There is a tendency for the number of persons per dwelling unit to decrease as density rises.

Assuming an approximate uniform amount of square feet occupied per person, the following indices of energy efficiency on a per-capita basis are obtained:

Building Type	Assumed Persons per Unit	Annual Megajoules per Person	Index
Single-family home	4.0	125 936	1.00
Single-family attached	3.3	113 824	0.90
Apartment walk-up	2.6	109 279	0.87
Apartment high-rise	2.0	108 231	0.86

Figure 3. Estimated annual energy intensity of residential land use.



These figures imply that a 15 percent energy savings on a per-capita basis would result from apartment development--gains that fall within the range identified by Altshuler. Equally as significant, the analysis shows the sensitivity of energy consumption estimates to the assumed number of persons per dwelling unit.

LAND USE IMPLICATIONS

The preceding analysis suggests several land use implications and future directions. Some of these are briefly noted below.

Land Use Planning

There are major savings in energy consumption as population density rises. Land use planning to achieve compaction, increase densities, relate people to jobs, coordinate public transport with jobs, and encourage transit ridership and ridesharing is desirable from an energy perspective.

1. Gains in energy efficiency can be achieved by better arrangement of urban activities, by encouraging higher development densities, and by limiting single-family construction. These gains could reduce total residential energy consumption by about 50 percent on a per-dwelling-unit basis and about 15-20 percent on a per-capita basis. They would be accompanied by savings in the commercial sector--since high-density developments would reduce transport requirements to shopping and work areas and encourage clustering and building efficiency.
2. While it is difficult to model, energy gains could likely result from reducing the journey to work by increasing self-containment of new communities and/or by creating a better balance between employment and population. (Quantifying these efforts remains an essential research project.)
3. Without any overall increase in gross density, clustering and associated modifications in street layout can reduce the length of streets and utility installations. Energy is saved in the construction and, later, in the maintenance of streets, transmission of electricity and water, and provision of services like garbage collection.
4. At the community level, higher density and mixed zoning (a) can potentially reduce travel distances and make transit more feasible by locating home and work places closer together and (b) bring major traffic generators near to each other. Inten-

Figure 4. Estimated effect of residential density on energy consumption.

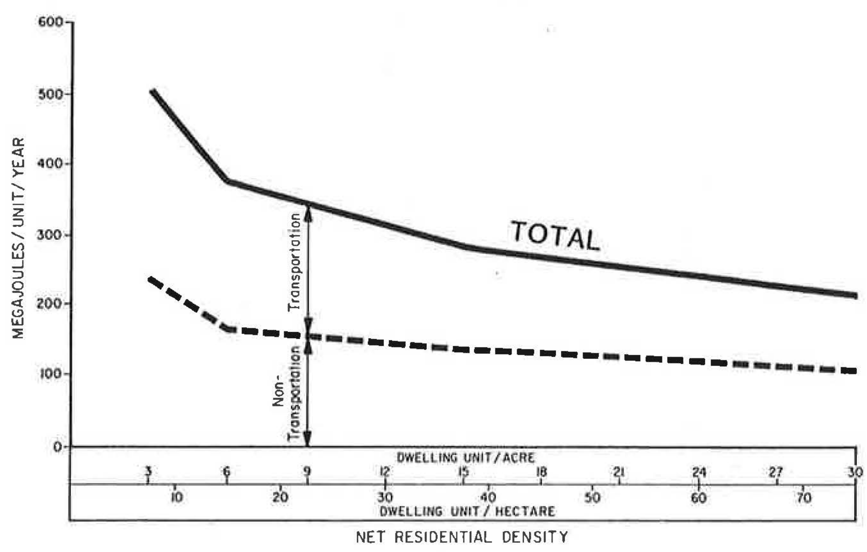


Table 9. Impact of conservation design on energy use and construction costs.

Structure Type	Reduction in Energy Consumption with Conservation Design (%)		Change in Construction Cost with Conservation Design (%)
	Northeast United States	North Central United States	
Single-family	30	30	+1
Single-family	15	15	+0
Low-rise apartment	51	32	-2
Office building	62	61	-2
Retail store	42	43	-1
School building	46	44	-2

Note: Data from D. Elliot Wilbur, Jr., Energy Conservation and New Technologies in Building, California Energy Seminar, May 10-11, 1977.

sifying land use along transportation corridors can encourage the use of public transit and give people a choice of travel modes--a valuable option whenever shortages arise.

5. Reducing the per-capita space requirements of new residential construction would substantially reduce energy consumption over the long run. However, this runs contrary to the trend and desires to increase space as incomes rise.

In sum, an energy-conservant transportation and land use strategy should:

1. Provide residential densities in all parts of the region that can support transit;
2. Concentrate new urban development along major transit corridors and around suburban centers;
3. Increase multifamily residential construction throughout the metropolitan area;
4. Improve the balance between people and jobs in all parts of the metropolitan area;
5. Increase the mix and integration of land use;
6. Provide closer residential developments on smaller lots and locations where houses can be served by public transport;
7. Encourage infilling of vacant parcels within the central city and its surrounding suburbs, especially with uses that enhance functional integration; and
8. Encourage mixed-use buildings where large office, shopping, and residential complexes are combined into single structures (for example, Eaton Center, Toronto; Water Tower Place, Chicago; and Peachtree Center, Atlanta).

These are important actions, and urban development policies should provide necessary incentives and controls to help achieve them. At the same time, it should be realized that attainment in many metropolitan areas will be difficult because (a) implementation of land use plans has not been effective, (b) much of the future metropolis is already in place today, and (c) people continue to increase their space requirements, especially as their incomes rise. Consequently, only limited gains can be anticipated from these land use measures over the near-term future in many metropolitan areas, even though they represent a desirable public policy direction.

Building Improvements

The greatest gains in future energy conservation, therefore, will probably come from two other sources: (a) improving the gasoline mileage efficiency of private automobiles and (b) increasing the operating energy efficiency of existing and new buildings. These gains will probably exceed those associated with land use planning per se, since they can be applied on a metropolitan basis. They will be especially desirable in those metropolitan areas where population has stabilized and little growth is anticipated.

Efforts should be directed toward improving space-heating efficiency since this accounts for more than two-thirds of the annual building energy consumption; and energy-conservant design represents another important way to save 30 to 50 percent of energy in new building construction. The potential savings from adhering to the standards developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) are shown in Table 9. These standards have been adopted by all the model building codes.

Extension to Other Areas

The research methodology outlined in this paper has been applied to the metropolitan Toronto area. Similar procedures can be used to estimate the energy impacts of various land uses in other North American cities. These efforts should reflect variations in population density, city size, transit use, and rates of growth. Thus, a broader cross section of relationships and implications can be derived to provide a sound basis for establishing energy-conservant transportation and land use decisions.

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Alternative Reuses of Abandoned Highway Right-of-Way

MARY R. KIHL

The combination of organized citizen opposition, increased environmental awareness, and rising construction costs has halted construction of an increasing number of proposed highways. Where this has happened after right-of-way was already acquired and partially cleared, cities have been confronted with the need to find alternative land uses that are both creative and broadly acceptable. Representatives of planning bodies of four affected cities—Atlanta, Milwaukee, Minneapolis, and Lincoln (Nebraska)—presented case studies that emphasized both the planning process and the alternative selection. Despite the unique characteristics of each project, the four cases underscored three major recurring themes: (a) the importance of selecting alternatives consistent with density, use, and cultural characteristics of adjacent neighborhoods; (b) the essential quality of broad and active participation of key interest groups, government officials, financial interests, and developers; and (c) the critical need for an atmosphere in which interest groups are willing to compromise specific objectives in order to further the broader goal of community revitalization.

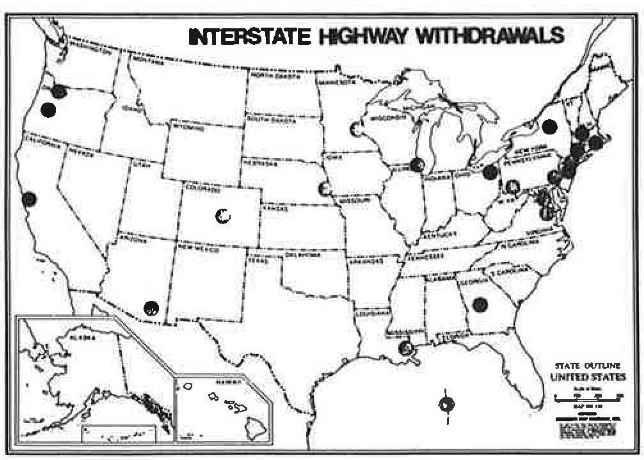
The legacy of rapid postwar highway development programs and of the organized citizen opposition they engendered has been the demapping of state and federal highways after right-of-way had already been acquired and partially cleared. As of June 1980, the Federal Highway Administration (FHWA) has demapped 31 sections of the Interstate system as proposed in the 1960s (see Figure 1). Numerous state and municipal highways have been similarly withdrawn. Ironically, the neighborhoods that citizen groups fought to save have deteriorated as urban blight spread from cleared right-of-way to properties flanking it.

Although the specific circumstances surrounding each case differ, affected cities share the opportunity to stimulate community revitalization through creative redevelopment of land reclaimed from abandoned highway right-of-way. They also share the challenge of finding alternative land uses acceptable to all concerned interest groups.

Believing that shared experience would prove to be mutually beneficial, the Transportation Research Board Committee on Land Use and Transportation assembled a panel of planners from four affected cities: Atlanta, Milwaukee, Minneapolis, and Lincoln (Nebraska). These cities represent withdrawals ranging from Interstates to municipal highways and stages of redevelopment ranging from preliminary planning to construction.

A spokesperson for the Office of the U.S. Secretary of Transportation introduced the issue by placing it into the broader context provided by the federal perspective. The Atlanta Great Park experience underscores the conflict and controversy engendered by competing interests as well as competing visions of future land use. In Milwaukee the Park West Project, a project emphasizing neighborhood revitalization, is now at the implementation stage. The key role of citizen groups is also apparent in Minneapolis where approaches to reuse of two corridors provide useful contrasts. The problems of abandoned highway corridors are not only the province of large cities. Medium-sized cities including Lincoln, Nebraska, are also seeking alternative uses for highway right-of-way. The case of the Northeast Radial Highway in Lincoln also provides the opportunity to review the reuse planning process at an earlier stage.

Figure 1. Location of demapped highways.



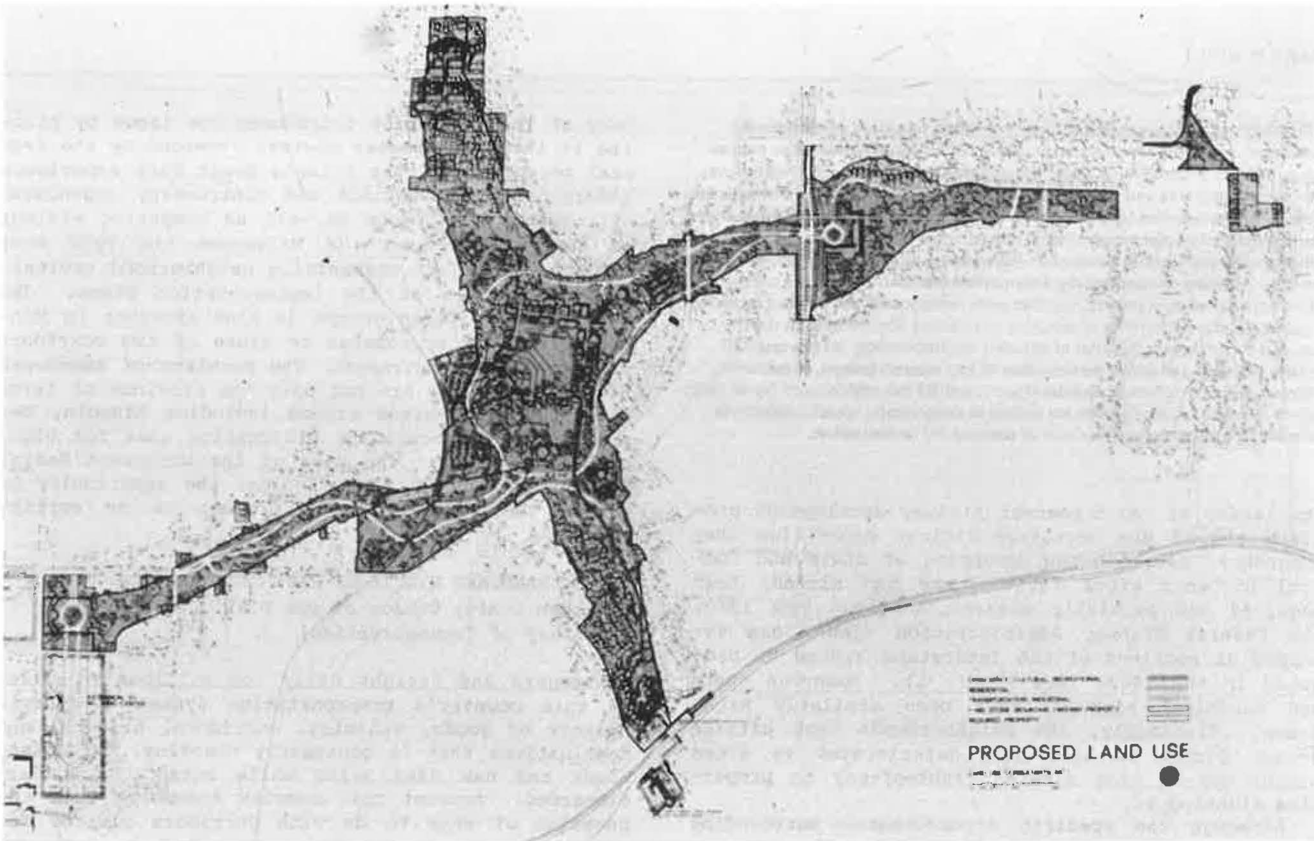
USING ABANDONED RIGHTS-OF-WAY: AN OVERVIEW
(Maureen Craig, Office of the U.S. Secretary of Transportation)

Passengers and freight daily log millions of miles on this country's transportation system--a dynamic network of goods, vehicles, corridors, origins, and destinations that is constantly changing. Unforseen needs and new uses arise while outmoded ones are discarded. Against this complex framework lies the question of what to do with corridors cleared for highways never constructed. The prudent reuse of these corridors demands an appreciation of both past and potential uses, a knowledge of pertinent policies and legislation, and an understanding of the most outstanding problems. A hard look at what the future face of the United States should look like is an absolute necessity.

Legislation addressing this topic has been passed at all levels of government. The Surface Transportation Act of 1978 provides for disposition of property acquired by states that used FHWA monies in connection with these kinds of projects. Subsequent amendments and proposed rulemaking have further defined procedures for doing this. The payback issue has been a particularly thorny one--i.e., how much should the federal government be repaid if the purpose for which public funds were originally intended has changed? The situation sharpens considerably if private interests stand to profit from these kinds of project modifications. Payback preference is now given to right-of-way uses deemed consistent with U.S. Department of Transportation (DOT) policies and the public interest.

Numerous problems have arisen despite the best of intentions. Money is a perennial one. Proponents of reusing these rights-of-way insist that enough is not available. However, potential sources can indeed be found in both the public and private sectors. U.S. Department of Housing and Urban Development (HUD) grants have covered the construction of housing projects and community facilities located in abandoned rights-of-way. Some localities have used U.S. Department of Labor Comprehensive Employment Training Act (CETA) monies. Property originally purchased with FHWA monies can be thought of as resources of high financial value. State and local governments have used a variety of funding mechanisms, as have groups like the National Trails Council and state trail associations. The private

Figure 2. Atlanta's Great Park.



sector has spent millions in realizing development opportunities along abandoned corridors.

With so many actors involved, coordinating the reuse of these abandoned rights-of-way is no inconsiderable undertaking. Federal interests are divided among the U.S. Department of Interior (DOI), DOT, HUD, the Federal Commerce Commission (FCC), and others. Garnering state and local support both in and out of government is a challenge of multilevel dimensions.

Nuisance problems have arisen as well. Neighboring landowners complain about the newly introduced activities. However, property values adjoining these rights-of-way have been shown to actually rise once new uses have been established.

Two looming problems must soon be faced. One is legal--i.e., the transfer of the title to the lands involved. The process can be a particularly lengthy, complex, and expensive one. Well-intentioned local groups are easily frustrated by the maze of easement restrictions, reversionary clauses, and other limitations that has been previously placed on transportation rights-of-way. The second major problem is potential conflict among national priorities. Federal urban policy calls for redevelopment of available city land in a manner supportive of urban revitalization. This includes the dense, mixed-up development being planned for and constructed on abandoned rail and highway rights-of-way. Such development effectively precludes any future transportation use of the corridor. Opponents of these projects argue that the aging cities need breathing space and therefore support conservation of the open space qualities typifying these linear rights-of-way. Conservationists support the creation of linear parks accessible to large portions of the urban population. Other proponents of preservation maintain that we may once again need these very same corridors for future transportation uses in the coming age of petroleum scarcity and decreasing mobility. In any event, these conflicts can be expected to continue.

Despite these conflicts and opportunities, what does the future hold? Close questioning of the need for completing the Interstate highway system and/or adding other roadways to a network already requiring major repair will continue. Greater demand will be experienced for urban recreational opportunities as well as alternative means of transportation, plus less public money to pay for either. Overall, more parties competing for reuse of abandoned transportation rights-of-way and one-time-only opportunities that cannot afford to be missed are likely prospects for the future.

ATLANTA'S GREAT PARK (Catherine Thomas, City Planning Bureau, Atlanta, Georgia)

The issue of abandoned highway rights-of-way has been called an urban phenomenon of the 1970s. Atlanta's contribution to this phenomenon is a tract of land located immediately east of the central business district, which was cleared for the construction of two major highways, the Stone Mountain Tollway and Interstate-485 (see Figure 2). This property, which is known as the Great Park, is the largest single tract of abandoned expressway right-of-way in the country. It is bordered by medium-density, single-family neighborhoods being renovated that have active community organizations.

In 1973, Governor Jimmy Carter, following the recommendations of a blue-ribbon committee, declared that the Stone Mountain Tollway would not be built. I-485 was the first of a number of expressways that were to form an inner loop to be removed from the region's plans. Community opposition to this facility was intense; it was accompanied by court action and, ultimately, led to withdrawal of political support for the project. In 1975, shortly after the environmental impact statement for this project was rejected, I-485 was demapped. About 219 acres of right-of-way had been acquired and cleared for these two freeways. The right-of-way is in a cross-shaped configuration. The east and west legs are where the Stone Mountain Tollway would have been constructed, and the north and south legs were to be I-485. There is a large area in the center where the interchange of these two expressways would have been built. The reuse of these abandoned rights-of-way has engendered a controversy as intense as that over the construction of the expressways themselves.

In 1974, the city of Atlanta took the reuse planning initiative by proposing a Great Museum Park in the abandoned right-of-way of the Stone Mountain Tollway (this was the origin of the term Great Park now used to describe the properties). This plan called for the construction of a museum complex with associated parking facilities and contained no provision for a transportation artery in the area. In 1975, an ad hoc committee was established by the city to advance the Great Park concept. Neither of these plans gained the support of the governor, the state transportation department, or community organizations. As a result, a new group was formed in 1976--Atlanta Great Park Planning, Incorporated--with representatives from the neighborhoods around the rights-of-way and government organizations. In 1977, the group presented its plan, which called for new housing units and parkland devoted primarily to passive recreation. This plan, like its predecessors, did not include a major transportation facility.

A major obstacle to the implementation of any revised plans has been the insistence of the Georgia Department of Transportation (GDOT) that a major east-west traffic carrier be constructed in the right-of-way to substitute for the expressways that will no longer be constructed. The GDOT, not the state of Georgia, actually owns the properties in question. The cooperation of this agency, therefore, is an essential ingredient to any reuse solution. The transportation issue, however, has been the overriding source of disagreement in the development of a reuse plan.

Governor George Busbee attempted to resolve the impasse by soliciting the services of an Atlanta architect, John Portman. Perhaps the most interesting part of the Portman plan, which was presented to the governor in 1979, was the transportation solution. Portman basically rejected the GDOT's desire to build a highway through the areas as infeasible, both from the standpoint of political acceptability and the reuse alternatives. Instead, Portman proposed that the freeway terminus be extended in tunnel through the right-of-way. This tunnel was estimated to cost about $64 million. Portman also proposed 1500 housing units and that a variety of major community facilities, such as an amphitheater and an aquarium, be constructed in the right-of-way.

Unfortunately, neither the imagination of Portman's proposal nor the prestige of its creator could produce a consensus on reuse. In 1980, the state legislature established a seven-member Great Park Authority to study all previous plans and recommend a new solution to the stalemate. This authority conducted a round of public hearings and decided to concentrate its efforts on the transportation question; it had concluded that an answer to this was essential before addressing other parts of the reuse question. The authority's recommendations included several transportation options. Further development of the park appears now to hinge on the possibility of developing a Jimmy Carter Presidential Library in the rights-of-way (see Figure 3).

There are many similarities between Altanta's experiences and those of other cities. In regard to the types of reuse, Atlanta was similar to other cities in its desire to "reweave the fabric of the city" by incorporating housing and recreational facilities in its reuse plan. Commercial and industrial reuses were not as common as in other cities, probably because the right-of-way is almost totally surrounded by residential areas. The question of alternative transportation facilities was important in many cities, but it has assumed a paramount role in Atlanta.

One unfortunate aspect of Atlanta's experience has been the unwillingness of all groups to compromise. On the housing issue, for example, the neighborhoods proposed 500 units, while Portman recommended 1500. This has been a major issue of controversy on which both sides might compromise by supporting the construction of, for instance, 1000 units. But no one has been willing to do this. Similarly, the GDOT has always contended that a new parkway through the areas is needed.

On a philosophical plane, reuse presents an interesting contract between the comprehensive, grand-plan approach and incremental planning. The 219 acres in Atlanta have always been regarded by government authorities as an opportunity to develop something truly unique and magnificent, an approach that is embodied in the Portman plan. The surrounding residents, in contrast, would prefer to see development put back approximately as it was before the GDOT acquired the land--that is, single-family houses to blend in with the existing residences, local streets to provide access to the housing, and a few parks for quiet relaxation. If the grand plan cannot be implemented and the land is sold back to previous owners, this is probably what will occur.

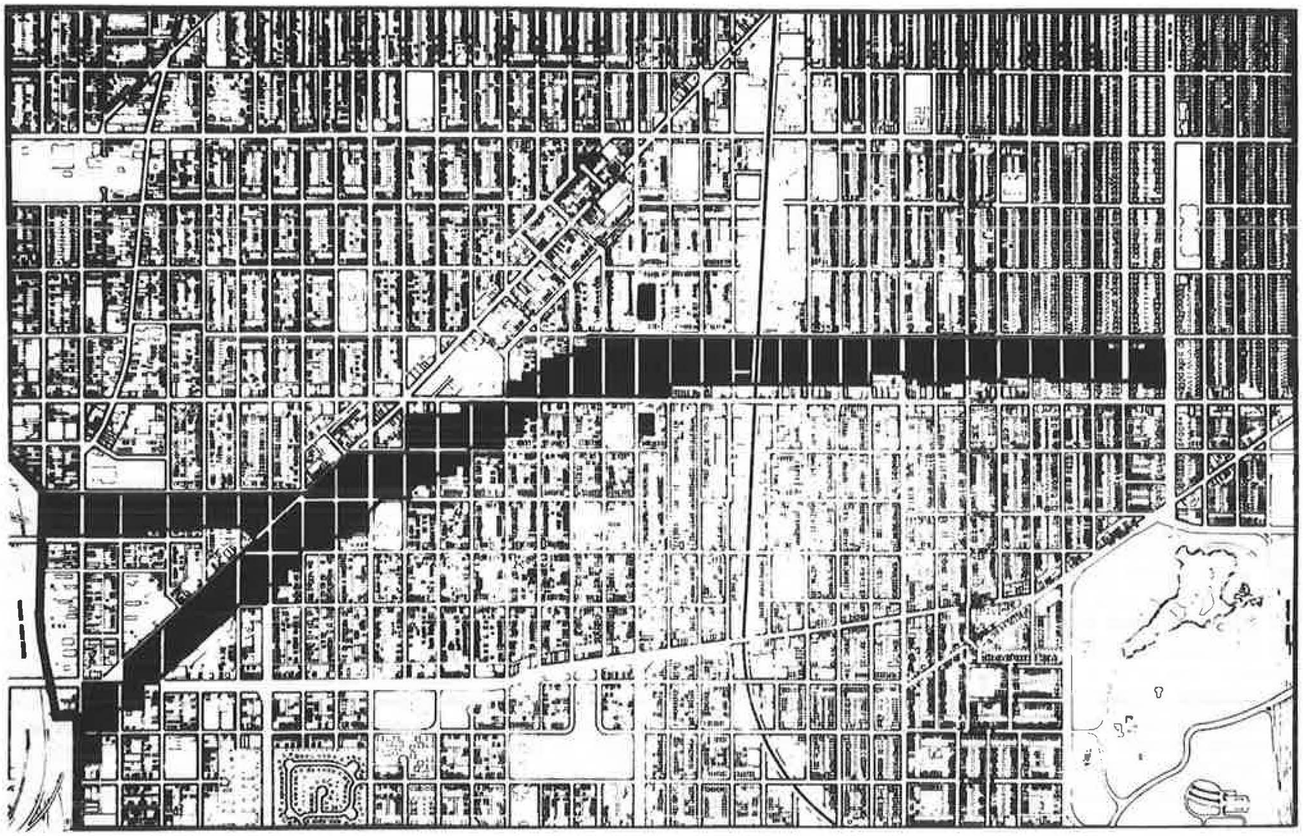
THE PARK WEST PROJECT (David Hoeh, Park West Redevelopment Task Force, Milwaukee; based on printed reports)

The history of the Park Freeway West began 20 years ago. In 1954, the North Avenue Expressway was designated, running north of and parallel to North Avenue. In 1957, the freeway route was changed to bypass the Sears and Roebuck store. In 1964, the expressway was renamed Park Freeway West. Acquisition and clearance for the highway occurred from 1966 until 1972 when a coalition of west-side citizen groups succeeded in winning an injunction to halt further activities until an environmental impact statement had been prepared and approved. In 1976, the statement was submitted to the DOT and in December 1976 it was rejected as inadequate. In January 1977, the Park West Redevelopment Task Force, comprised of elected officials who represented the Park West area, representatives from community groups, and a small at-large membership, was convened by Congressman Henry Reuss.

Between March and August 1978, approximately 40 workshops were held with community and church groups, business and professional associations, and other interested parties. In each workshop, a series of alternative plans for the corridor was presented, issues were discussed, and reactions from the participants were gathered. Comments and reactions were incorporated in later workshops and planning documents to refine redevelopment plans.

In July 1978, an amended urban development action grant application was approved to provide commercial revitalization loans. The $100 000 grant was to be

Figure 3. Park West Development project area.



used to leverage $1 million in conventional loans for the area. Responding to suggestions developed at community workshops, the Park West Task Force worked with business leaders, as well as industrial and civic groups, to develop an integrated multipurpose approach to revitalizing the corridor.

A draft property disposition plan was adopted by the task force in August 1978. In December 1978, the Milwaukee Common Council and the Milwaukee County Board of Supervisors approved a revised disposition plan for the Park West corridor. When this was accomplished, Acting Governor Martin Schreiber transferred all state interest in the land to Milwaukee County. Since that time, negotiations have continued between the city and county, with task force participation, and have led to a transfer of approximately one-half of the cleared land to the city of Milwaukee for housing and commercial redevelopment.

The redevelopment project that is now under way includes a linear pedestrian parkway, several county-developed parks, an expanded school site, housing development of varying types and densities, commercial district improvements, and industrial site preparations. An incomplete interchange from the old freeway will be constructed to provide improved access to the community. As part of the redevelopment program, house moving is being considered as are programs that will stimulate revitalization of the existing residential and commercial properties adjacent to the cleared land. A new farmers' market is under construction and will serve as an attraction for new commercial activity. Existing industries have expanded both plant and employment. The city of Milwaukee has appropriated $3 million for capital improvements and an application for $1 million in Economic Development Administration (EDA) funding for industrial site improvements is pending.

A developer for the housing has been designated and is pulling together the details of construction and permanent financing. Architects are at work on detailed site plans and a housing unit program. Construction of the housing is expected during the current construction season.

The redevelopment process in Milwaukee has begun. New challenges continue. Yet the cooperation between government units and active citizen participation that brought the project to this stage should help weather new challenges as well.

REUSE OF I-335 AND HIAWATHA AVENUE RIGHTS-OF-WAY IN MINNEAPOLIS (Ollie Byrum, City of Minneapolis; presented by Ghaleb Abdul-Rahman, Metro Council, St. Paul)

Interstate-335 was to have been the 4-mile north leg of a freeway belt around downtown Minneapolis that would create a major transportation facility in a corridor where before only local streets had existed. The Hiawatha Avenue project was to have been a 13-mile freeway connecting downtown, Wold-Chamberlain Airport, and suburban communities to the southeast. In contrast to I-335, Hiawatha Avenue has historically been, and always will be, an important transportation corridor.

In each case, right-of-way for the proposed project was acquired and cleared with major relocation. I-335 has been withdrawn from the Interstate system and no major facility will be built. The plans for Hiawatha Avenue are being scaled down from a freeway to a major upgrading of the existing highway, possibly to include high-occupancy-vehicle lanes or light rail transit.

In the case of I-335, the land in question encompasses about 50 acres. Major considerations in determining reuse were (a) there would be no major transportation facilities, (b) the proposed right-of-way had removed both residential and industrial property and was located in an area where residential and industrial edges had met and overlapped, (c) the land is less than a mile from downtown Minneapolis, (d) most of the corridor is bordered by a railroad, (e) in Minneapolis--as in most central cities--there is a need for both industrial and residential land as well as an opportunity for riverfront recreational land in this neighborhood, and (f) strong politically sophisticated citizens' groups had experienced urban renewal projects and had been able to stop the freeway when their original goal had only been to redesign it.

Reuse issues in the corridor tended to center around land use, density, who would decide, and who would implement.

The I-335 Alternate Use Advisory Committee, established by the city council in 1976 and which consisted of neighborhood and city agency representatives, had several objectives:

1. A balanced land use plan that attempts to meet the diverse, and often conflicting, needs--from a physical, social, and economic standpoint--of the affected neighborhoods, the Northeast and Near North communities, and the city as a whole;
2. A coordinated land use plan that attempts to consider and incorporate the expressed concerns and plans of a large number of organizations and agencies (the Minneapolis Housing and Redevelopment Authority, Minneapolis City Planning Commission, Joint Powers River Committee, Minneapolis Park Board, Minneapolis Industrial Development Commission, Neighborhood Project Area Committees, Minnesota Highway Department, etc.);
3. An economically feasible land use plan that takes into consideration not only the benefits but also the costs and marketability of any recommended actions;
4. An intensive land use plan that, without negatively affecting the neighborhoods' needs, recommends where appropriate an intensive level of development to increase the taxes generated and thus ease the tax burden on Minneapolis property owners; and
5. A land use plan that preserves and enhances the natural amenities within the I-335 right-of-way, particularly the Mississippi River Corridor, and that provides access to those amenities for community and citywide residents.

In order to meet these objectives, this committee recommended that the land be acquired by the Minneapolis Housing and Redevelopment Authority as a redevelopment district.

Because there would be no major transportation facility, the committee was able to recommend structuring or amenity elements that would enhance land use choices. These were a riverfront park and a residential parkway. These in turn set the stage for recommending that a major portion of the land be reused for low- and medium-density residential purposes.

The major reuse debate concerned only 4 acres of land. This tract was abutted by the proposed parkway, existing residential area, a small industrial tract, a major street, and a railroad. The neighborhood argued that to use the land for industrial reasons was not making use of the parkway amenity. Others, including many at city hall, argued that the land was unmarketable as residential land and that the industrial use should be permitted to provide space for expansion of the adjacent industrial operation. This was principally because another operation by the same owner would be relocated by another city project. After debate by the planning commission and the city council, the neighborhood was given three years to market the land for housing.

After three years, the land is still held by the state, but the neighborhood has a long waiting list of potential residential buyers, and it appears the use will be residential.

The Hiawatha Avenue land is quite different. The land cleared was adjacent to an existing transportation facility. The excess land, which will not be specifically defined until redesign work is completed, will be a narrow strip of variable width along one side of whatever project is finally decided on.

The transportation corridor has always served as a boundary between industrial and residential land use. The cleared land is on the residential side, and the adjacent residential use is largely for low-density, detached single-family houses.

As in the case of I-335, years of debate over the nature of the transportation improvement for Hiawatha Avenue have helped create a very knowledgeable, alert, and influential citizenry that has substantial impact on transportation planning and will now also have substantial impact on land use planning. However, in this case there will be a highway with which reuse must reckon and be compatible. Also, serious consideration is being given to major transit improvement. Active community participants tend to favor light rail transit as the preferred transportation alternative. However, justification for transit in a corridor with industrial use on one side and low-density housing on the other is marginal. High-density reuse would help the cause but is viewed with concern by present residents. Thus, in this corridor, the issues are (a) reconciling the interests of the city and various neighborhood groups, (b) compatibility of land use and design of the transportation facility, (c) balancing land use density with existing land uses and with the need for transit patronage, and (d) maximizing the development potential that may result from transportation improvements.

The process for determining the reuse of land in Minneapolis in the I-335 and Hiawatha corridors is not yet complete. The experience to date suggests several conclusions, some of which are probably quite obvious. First, citizens who develop the power and expertise to stop a freeway will be a major determinant in reuse of land in the corridor; second, more choice is open in corridors where no major transportation facility exists or will exist; third, in a corridor where mixed uses were present before clearance, the residential area tends to expand in the reuse plan, as adjacent residents strive to use the new development as a buffer between them and nonresidential use; and fourth, the narrow linear character of such land use planning areas naturally results in existing adjacent land uses being a principle determinant of reuse. Much less flexibility is available than in other shaped tracts of similar land area. In a sense, it becomes an "edge problem" throughout.

NORTHEAST RADIAL REUSE (Gordon Scholz, University of Nebraska, Lincoln)

Lincoln, the state capital of Nebraska, lies about 50 miles west of the Missouri River in the southeastern part of the state. With a population of 172 000, Lincoln is second in size to Omaha. Interstate-80, built through Nebraska in the late 1950s and early 1960, connects Lincoln with Omaha to the northeast.

The concept of a northeast radial highway to connect downtown Lincoln with northeast areas of the city has been proposed, developed, and altered numerous times over a 30-year period as a part of the city's planning efforts. In 1967, a preliminary design for a roadway was prepared. The proposal was for a four-lane, median-divided roadway 2.3 miles in length to be built over a 17-year period at an estimated cost of approximately $30 million.

Following this design study, the city proceeded with land acquisition and expended approximately $3.4 million for that purpose between 1967 and 1973, when the city council called a halt to all land-acquisition activity in response to opposition to the proposed roadway.

After attempts to revive the radial concept failed in 1979, the Radial Reuse Task Force was established in the summer of 1979 as an advisory group to the city council. Its 12 citizen members were appointed by the mayor and city council to represent the following interests: citizens-at-large, neighborhood organizations, businesses, commercial and industrial interests, alternative energy, and the financial community. The general charge to the task force was to present recommendations to the city council within six months on alternative uses of the city-owned land along a major portion of the proposed corridor.

The city-owned land in the reuse area, approximately 50 acres, is primarily rented to private tenants, although some acreage is used for public purposes. There are broad expanses of vacant land and mature trees. A natural waterway crosses the corridor area and nearby are large grain elevators. There are many unpaved and unimproved streets. A variety of types, styles, and ages of housing (including mobile homes) exists in the area, as do commercial and industrial establishments.

Based on a study of existing conditions and plans, the task force prepared a book of background information, which provided a problem statement and base information for an interdisciplinary visiting team of volunteer professionals called a Regional/Urban Design Assistance Team (R/UDAT). This group was invited to Lincoln by the task force to assist in generating reuse ideas. The R/UDAT is a public-service program offered by the national office of the American Institute of Architects.

During the four-day R/UDAT visit to Lincoln, the seven-person team was taken on a bus tour of the reuse area, and special briefing sessions were arranged with various city department staff members. An important part of the R/UDAT weekend was a public hearing at which anyone could voice opinions to the team.

Following the R/UDAT visit, the task force defined and prioritized reuse goals. This was accomplished by synthesizing the findings and results from earlier studies and the R/UDAT recommendations. A list of 23 goal statements was formulated and arranged in priority order through a process that allowed each task force member to allocate 100 points across all 23 goals. Median and mean weights for each goal then determined the order and relative importance assigned to each goal. Based on the goal statements, reuse recommendations were prepared and A Plan for Urban Growth and Redevelopment was published.

The overall design concept that emerged featured industrial land on the north that was separated from residential land on the south by a continuous linear park and bikeway. The linear park and continuous commuter bikeway became a central organizing feature of the reuse proposal. In addition, the proposal included provision for cluster housing along the reuse corridor and in-fill housing on vacant parcels.

The reuse plan was presented to the planning commission and city council in August 1980; it was subsequently endorsed by the planning commission in September and adopted by the city council in November 1980. Implementation of the plan, however, has been delayed by efforts to reconsider the build and no-build options for another section of the corridor.

To date, the case reemphasizes the importance of including a broadly representative task force in the planning process and of providing for the opportunity for public involvement. Outside experts may provide ideas and stimulation, but goals and land use alternatives must ultimately be determined by local representatives if they are to be supported for implementation.

CONCLUSIONS

These cases illustrate a variety of alternative land use proposals ranging from a mixed-use concept to a major emphasis on housing rehabilitation. The opportunity for preservation of open space through the linear park concept was recognized in several of the cases. Radical departures from previous land use patterns were not encouraged, although opportunities for community revitalization were noted both in housing mix and in commercial patterns selected. In most cases, the transportation use for which the corridor had originally been designated seemed to be all but overlooked in the emphasis on creating an improved urban environment. All cities seemed determined to regard the abandoned highway right-of-way as a valuable resource for community redevelopment.

The primary contribution of the case studies, however, was not in the field of urban design but in illuminating key elements in the planning process that would facilitate development of alternative land uses. These elements included references to both planning substance and to implementation strategy. They should blend with both existing city land use plans and with the built environment adjacent to the corridor. Grand revitalization schemes should be replaced by proposals consistent with the density, use, and historical or cultural character of adjacent neighborhoods that fought successfully to prevent dissection by a highway.

The panelists stressed that political cooperation at all levels is essential if the proposed alternate uses are to be implemented. The citizens successful in opposing highway construction must be involved in proposing viable alternative uses. Other interest groups represented by chambers of commerce, industrialists, environmental lobbists, or government officials must not only be consulted but coopted by participation in a task force primarily responsible for developing an alternative land use proposal. Continued participation of such varied interests is only possible given considerable patience and a spirit of compromise among all parties. Outside consultants may stimulate thinking or add specificity but they cannot substitute for the local planning effort if the plan is to have sufficient popular and government support for implementation. In the final analysis, however, community dedication must be reflected not only in broad public participation but also in the financial support of lending institutions, industrial developers, business interests, and real estate developers who are convinced of the need for and viability of the alternative land use plan.

(Editor's Note: This paper highlights presentations made during a panel discussion on "Alternative Land Uses for Abandoned Right-of-Way" during the January 1981 TRB Annual Meeting. Publication is sponsored by Committee on Transportation and Land Development.)