3. D. N. M. Starkie. Transportation Planning, Policy and Analysis. Pergamon Press, Oxford, England, 1976.
4. R. A. Gakenheimer. Urban Transportation Planning: An Overview. In Taming Megalopolis (H. W. Eldridge, ed.), Anchor Books, Garden City, NY, Vol. 1, 1968, pp. 392-411.
5. M. A. Goldberg. Simulating Cities: Process, Product and Prognosis. Journal of American Institute of Planners, Vol. 43, No. 2, 1977, pp. 148-157.
6. A. G. Wilson. Entropy in Urban and Regional Modeling. Pion, London, 1970.
7. A. G. Wilson. Urban and Regional Models in Geography and Planning. Wiley, London, 1974.
8. J. F. Kain and J. M. Quigley. Housing Markets and Racial Discrimination. National Bureau of Economic Research, New York City, 1975.
9. M. Straszheim. An Econometric Analysis of the Urban Housing Market. National Bureau of Economic Research, New York City, 1975.
10. S. H. Putman. Urban Land Use and Transportation Models: A State-of-the-Art Summary. Transportation Research, Vol. 9, 1975, pp. 187-202.
11. F. J. Cesario. A Primer on Entropy Modeling. Journal of American Institute of Planners, Vol. 41, No. 1, 1975, pp. 40-48.
12. J. R. Pack. The Use of Urban Models: Report on a Survey of Planning Organizations. Journal of American Institute of Planners, Vol. 41, No. 3, 1975, pp. 191-199.
13. D. B. Lee, Jr. Requiem for Large-Scale Models. Journal of American Institute of Planners, Vol. 39, No. 3, 1973, pp. 163-178.
14. A. H. Voelker. Some Pitfalls of Land-Use Model Building. Oak Ridge National Laboratory, 1975.
15. D. L. Huff. Determination of Intraurban Retail Trade Areas. Real Estate Research Program, Univ. of California, Los Angeles, 1962.
16. G. M. Carter and E. Ignall. A Simulation Model of Fire Department Operations: Design and Preliminary Results. Rand Corp., Santa Monica, CA, 1970.
17. R. C. Larson and K. A. Stevenson. On Insensitivities in Urban Redistricting and Facility Location. Rand Corp., Santa Monica, CA, 1971.
18. M. A. Goldberg. Simulation, Synthesis and Urban Public Decision-Making. Management Science, Vol. 20, No. 4, Part 2, 1973, pp. 629-643.
19. M. A. Goldberg. On the Inefficiency of Being Efficient. Environment and Planning A, Vol. 7, 1975, pp. 921-939.

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How to Do a Transit Station Land-Use Impact Study

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Several improvements in the conceptual basis and methodology for studies of land-use impacts have occurred over the past two decades, but the framework is still incomplete because the need to incorporate the policy context into the study design has not been fully recognized. A revised model for impact studies is proposed, and the approach is illustrated by a case study of a planned rail rapid transit station. One of the major differences between this and previous methods is that the method described in this paper acknowledges several possible outcomes or impacts as a function of alternative public policies in addition to the transit station itself. Five categories of impacts are evaluated: public facilities, environment, market, neighborhood, and costs and revenues.

The purpose in asking the positive question, What are the land-use impacts of a major transportation project?, is to evaluate better the feasibility and desirability of such projects, and the answer to the question depends heavily on public policies other than the project itself. The theory and case study presented here are an attempt to construct a workable framework for executing land-use impact studies of major transportation investment projects from a planning- or policy-oriented perspective.

IMPACT MODEL

Refinements in the before-and-after and the more recent with-and-without impact methodologies have advanced the state of the art (1, 4), but the model, derived from experimental design in the physical and natural sciences, is still incomplete. Figure 1 shows schematically an extension of the with-and-without model in which the comparison is made between two sets of outcomes ("options" because they are a consequence of conscious policy choices) that result from the decision to build or not build the project. State-of-the-world assumptions are things that are held constant for comparative purposes: regional population and employment growth, aggregate travel demand, and the rest of the transportation system. Policy assumptions, in contrast, are specific to each option: For example, policy assumptions associated with intensive redevelopment are different from those associated with neighborhood preservation. The impact of the project is the difference between (a) the options available without the project and (b) the options available with the project.

Previous impact studies and the proposed model can be distinguished, in part, by the way the question is asked. In relation to the case study of the Metro transit station in Vienna, Virginia, the old research question is, What will happen if a transit station is placed at I-66 and Nutley Road? The policy research question is, What will be the differences between the choices available if a transit station is or is not placed at I-66 and Nutley Road?

CASE STUDY

Vienna, the town after which the proposed station is named, lies just to the north of the station site in the Virginia suburbs of Washington, D.C. The Vienna Metro station is the terminus of the Vienna line of Washington's Metro rail rapid transit system. The immediate station area, shown in Figure 2, is largely vacant now, and the station itself is located in the median of I-66 just west of Nutley Road.

Specifically, the question being asked in relation to this station is the following impact question: Given that a transit station is located at I-66 and Nutley Road, what will its impact be? Alternative questions that are not addressed include the following:

1. Given the locations of all other transit stations and lines, what are the impacts of locating the Vienna station at I-66 and Nutley Road versus other possible locations?
2. Given the general configurations of the line, what are the impacts of alternative numbers and locations of stations?
3. Given the existence of a system, what are the impacts of alternative line locations and lengths of extensions?
4. What are the impacts of a rail rapid transit system on the Washington, D.C., metropolitan area?

Figure 1. Proposed land-use impact model.

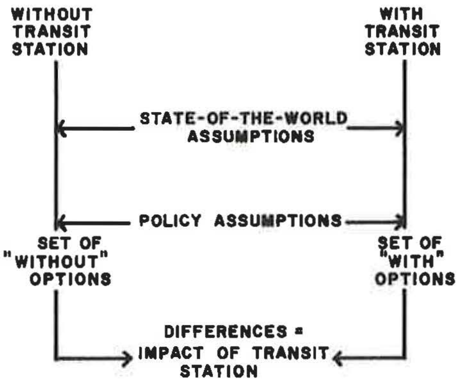
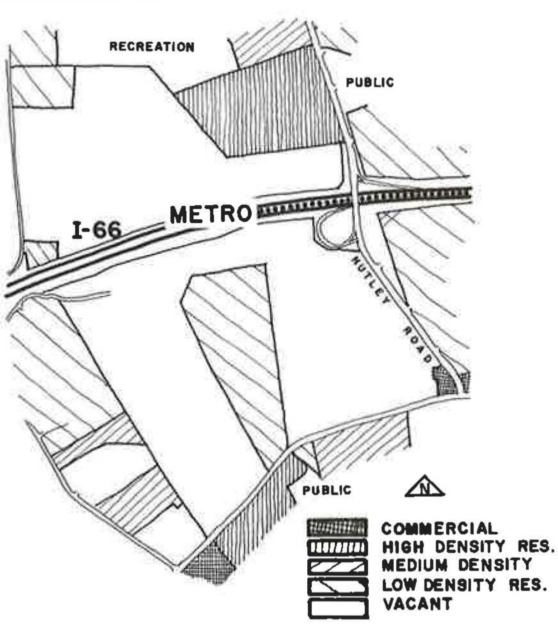


Figure 2. Existing land use and anticipated development at Vienna station site.



These questions represent respectively the station location, route decision, corridor decision, and build-no-build decision questions. Each is a separate question and must be addressed within a separate and suitable analytic framework. Most notably, it is not possible to add the pieces together to get the whole; the answer to the macroquestion is not the summation of the answers to the microscopic questions.

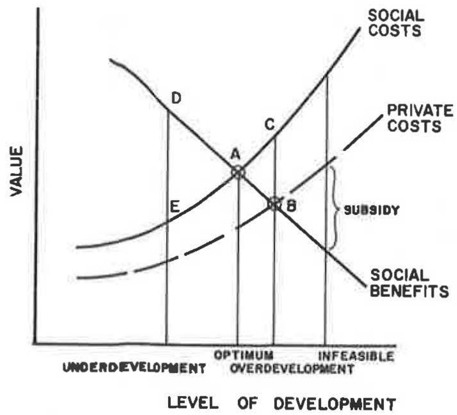
DESIGN AND SELECTION OF OPTIONS

It is important to emphasize that the options are discovered rather than invented although a good deal of creativity is often required to ferret out the real options that exist. Because the process of discovering options is largely heuristic and judgmental, it is misleading to break the process into separate steps. A working approximation might include the following:

1. List all possible alternatives for future development in the vicinity of the station. Clearly, it is not possible to carry this out to the letter, but it is not necessary to list most of the implausible alternatives because they will be eliminated in the next step.
2. Delete infeasible alternatives. Feasibility will, of course, be one of the judgmental determinations, but a key component will be market demand for various land uses at the particular site. Techniques for market studies are well-known applications of macroeconomic concepts (3, 5).
3. Group options into categories. The categories used for the case study are based on levels of development or development intensity, and this might be a dimension suitable to many impact studies although other dimensions can be used.
4. Rank the options within the categories according to normative objectives. These objectives are specific to each of the five impact categories and are described below in the context of the land-use impacts.
5. Evaluate the preferred option or options within each category. Impacts are estimated for each type, and results are tabulated as to costs, benefits, or residual impacts (those that are of interest but cannot be aggregated as either costs or benefits).
6. Revise options and categories as appropriate. Steps 3 through 6 can then be repeated until a stable set of options is generated.

The desired result of the option design effort is a limited number of real choices that can be reviewed from both technical and political perspectives. Thus, the impact study is also, not surprisingly, a planning study in that it provides information that will aid in resolving a problem of social choice. The choice among options, represented in abstract form in Figure 3, is an attempt to find a balance between social costs and social benefits. On the benefit side, demand is reflected in the prices consumers are willing to pay for such items as housing, personal services, retail goods, and hotel rooms; these benefits are transformed into demand for land development through entrepreneurs and lenders who are able to perceive the demand and willing to invest in the development. On the cost side, the supply curve represents the opportunity costs of resources foregone by both the private and public sectors to achieve different levels of development. The optimum

Figure 3. Social costs and benefits of development options.



(A) is the point at which marginal social cost equals marginal social benefit.

In practice, a number of varieties of market failure distort resource allocation from the optimum. Only one variety is of concern here: negative externalities, which, in the form of noise, dust, disruption, and environmental degradation, allow some of the social cost to be exported by the private market. Decision-makers in the private sector consider only those costs represented by the dashed line in Figure 3 and choose a level of development (B) that is higher than optimal; the area BAC represents the loss to society from this overdevelopment.

Normative objectives, which are described below, are explicitly intended to place the full burden of costs on those who derive the benefits and constitute, for each option, a vertical movement from the private to the social cost curve. If costs are fully internalized, then a suboptimal level of development (D) results in a social opportunity loss equal to ADE—undesirable but perhaps preferable if the negative externalities cannot be controlled. A level of development higher than B would require a private market subsidy (even if external costs were ignored) and is, by our definition, infeasible. Two additional points should be made about negative externalities: First, if not controlled they may have the effect of reducing benefits (a lower social benefit curve), which would further reduce the optimum level of development; second, they amount to transfers of income from those who suffer the externalities to those who create them.

Only the end product is presented for the specific case of the Vienna station so that the options—low, medium, and high—embody the best mix of development at each level and negative externalities are assumed to be largely controlled as a result of specified public policies. Policy makers must then make their own assessments of whether the mixes are desirable and to what extent they are willing and able to impose regulations that will reduce the negative externalities. The three types of options can be generally described as follows:

1. Low—This includes a mix of residential and commercial units, but the largest single land use would be single-family residential. This would have the effect of extending the existing neighborhood into the area around the station, thereby providing a transition and a buffer against the station and its ancillary activities. Arrivals at the station would be predominantly by bus, kiss-and-ride, and park-and-ride.
2. Medium—Slightly more emphasis is placed on commercial development and considerably more on multifamily residential units. Some clustering of structures could be accomplished, and most of the land not covered would be in public areas such as those around garden apartments.
3. High—More emphasis on commercial development and multistory apartments, lower land coverage, and more clustering would characterize this option. Pedestrians would form a relatively high proportion of the trips to and from the station.

Specific requirements in units and space for the three development options (2) are given below (1 hm^2 = 2.5 acres and 1 m^2 = 10.76 ft^2):

Land Use	Low	Medium	High
Residential			
Single family			
Units	364	0	0
Space, hm^2	37		
Townhouse			
Units	600		
Space, hm^2	24		
Garden apartment			
Units	825	1620	1830
Space, hm^2	22	44	49
Elevator apartment			
Units	1250	1850	3250
Space, hm^2	18	24	38
Total units	3039	4300	5420
Office space, m^2	22 300	33 400	65 000
Retail space, m^2	4600	14 000	23 000
Hotel rooms	100	200	300

Much of the substantive information presented here for the case study is taken from a study of three stations on the Vienna line (2), and these market forecasts project an adequate demand for any of the three options.

It is the conclusion of this study that the high option comes the closest to constituting the optimum (A in Figure 3). But this result depends on the many policy assumptions and other assumptions discussed below, and no implication that high levels of development are generally suitable for transit stations is intended. The Vienna station was selected in part because it is illustrative of situations in which a range of options are available and hence the impact of the station is not uniquely predetermined.

EVALUATION OF LAND-USE IMPACTS

Impacts are grouped in five categories—public facilities, environment, market, neighborhood, and costs and revenues—on the basis of policy treatment and underlying assumptions. Table 1 gives three aspects of each type of impact: normative (ideal policy) objectives, the nature and measurement of impacts, and the evaluation of impacts. Evaluation concerns the extent to which the impacts can be entered and aggregated in a cost-benefit framework as well as the extent to which the assignment of values is inherently political. Impacts of each option are summarized, evaluated, and compared with the options that are available without the station.

Public Facilities

Services provided by public facilities can be roughly separated into those that create direct benefits for the consumer (e.g., travel, water, and waste disposal) and those that create general benefits for the community as a whole (e.g., government and primary education). For facilities that benefit consumers, costs should be paid either through direct user charges such as parking fees and hookup charges or through development charges such

Table 1. Evaluation of land-use impact categories.

Category	Normative Objective	Impact Measurement	Evaluation
Public facilities	Costs of all facilities and services that create benefits that occur directly to the user should be paid for with suitable user charges; capacity of public facilities should be adequate to provide for expected demand	Measure (a) drawdown in capacity of existing facilities resulting from each option, and (b) extent to which demand has been anticipated and capacity programmed to meet demand	Value can be attached to the consumption of capacity only when the demand created by land-use development could not reasonably be foreseen and constraints such as long lead time and bonding limits exist on providing adequate capacity (this condition is, by definition, temporary)
Environment	Environmental resources should be protected by suitable constraints on development	Measure residual changes in environmental characteristics	Values to be placed on net changes in environmental variables can only be assessed through the political process because normal market mechanisms undervalue most environmental resources
Market	Resources such as labor and materials exchanged in private markets related to station development are properly valued in those markets (i.e., there are no significant externalities, inefficiencies, or market imperfections)	Estimate changes in market activities (employment, housing mix, land use), including those indirectly related to the existence of the transit station	No costs or benefits can be attached to market impacts except in cases where (a) there is specific evidence of significant market failure (public-sector imposition of D in Figure 3, for example) or (b) there are expressed community goals that pertain to certain market impacts
Neighborhood	Existing and constructed neighborhood resources should be protected by suitable constraints on development or compensation should be paid to affected parties	Measure residual changes in neighborhood characteristics	Inadequately compensated changes to existing neighborhoods should be considered costs; other changes are a matter of individual taste and perhaps political choice
Costs and revenues	Same as for public facilities	Estimate changes in annual revenues and expenditures for affected municipal budgets	Changes in general revenue patterns should be noted and corrective measures taken if problems appear; underpayments by users and direct beneficiaries of facilities should be regarded as costs of development to be minimized as much as possible

as fees or in-kind contributions from developers. Facilities that create general benefits can be financed from general revenues such as property, sales, and income taxes. If these policies are adhered to, the infrastructure required by development is paid for by those who benefit, and general facilities are supported by the community in proportion to ability to pay.

Facilities required to support development at the Vienna transit station are listed below:

1. Nutley Road should be widened from two to six lanes, and a number of similar improvements should be undertaken to increase the capacity of vehicle access to the station. All three options require these road expenditures.
2. The road and parking area immediately adjacent to the station needs to be redesigned in order to better facilitate pedestrian arrivals. This is especially needed to support the high development option. The present design requires pedestrians to cross a large parking area in order to reach the station.
3. Pedestrian walkways throughout the station area, public squares and furniture, landscaping, shelters, and other items should be constructed at the expense of developers. More amenities can be obtained under the high option because of higher intensity of use and economies from clustering structures.
4. Capital facilities needed to support each development option should be provided and financed in accordance with the guidelines given above. More recreation area and open space are needed for the high option than for the low, for example, and should be provided by developers.

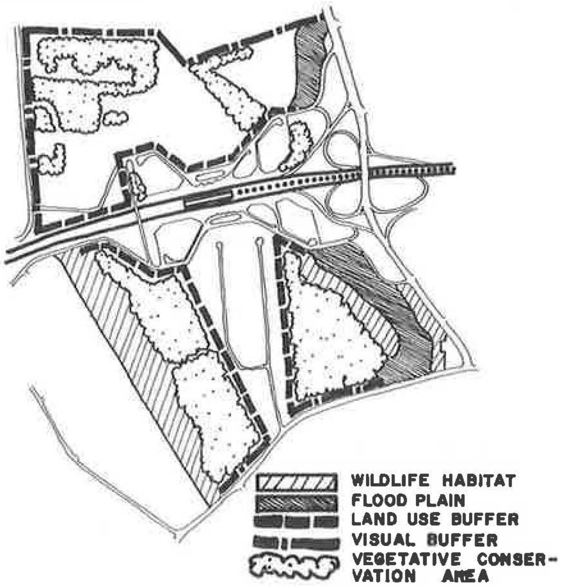
Environment

Clearly, some changes in the natural environment will occur if any development at all takes place; minor reductions in environmental quality may be offset by the absence of such reduction elsewhere. The first component of the problem is to determine which changes are acceptable, which changes are acceptable if minimized, and which are unacceptable. The second component is the design of standards or other methods to achieve only acceptable changes. The environmental controls required are given below:

1. Several notable stream valleys traverse the site, and these are generally wooded. No development should be permitted in any 100-year floodplains or within 30 m (100 ft) of a stream bed.
2. Portions of the stream valleys have been identified by Fairfax County as wildlife habitats. These should be protected by a minimum of 76 m (250 ft) of natural buffer on either side of the stream.
3. Because of the high clay content of the soil and the frequency of sudden, hard rains, water quantity must be explicitly controlled. Natural vegetation should be retained as much as possible, especially on slopes, and retention facilities should be required for all development so that the natural drainage capacity will not be overloaded.
4. Slippage-prone soils should be identified by the developer, and measures should be taken to ensure stability or to avoid the problem of slippage.
5. The county has delineated "environmental quality corridors" that are designed to create a network of open space and also protect stream valleys and other environmental resources. A portion of the site for the Metro station is included in this network.

Degradation of most aspects of the environment can be kept to tolerable levels by appropriate policies and attendant costs without detracting from development potential. Because the high-density option emphasizes clustering of structures and lower coverage, environmental resources such as open space, stream valleys, and quality and quantity of water are actually more easily protected under high development than otherwise.

Figure 4. Effect of environmental and development constraints on site planning.



Market

For the most part, market impacts are simply redistributive, spatially or among sectors; i.e., the activities (such as employment and housing) would have occurred somewhere, perhaps in a different form; the differences may be of interest, but it is seldom a matter of new jobs or net increases in land value. Changes that occur as a result of properly functioning markets can be legitimately diverted only by "buying out" responsible property rights, e.g., through acquisition of land for parks instead of development. The market impacts of the Vienna Metro station include the following:

1. Private market land-use changes resulting from the presence of the station could range from minor to major depending on public policies. If low-density development were the option followed, land-use changes would largely be limited to those involving vehicular access to the station. High-density development, however, would result in substantial changes in land use. Hence, market impacts of the station depend heavily on development policies and not solely on the presence or absence of the station.

2. Which development option was chosen would have only a small effect on the number of housing units constructed in the region, but location of the units within the corridor and perhaps within the region would be altered. High development would shift the mix of structure types away from single-family units toward townhouses and apartments and would allow (with suitable policies) more moderate- and low-income units to be constructed.

3. More specialized commercial activities would also be likely under the high-density option in comparison with the highway and shopping center development that would take place under the low- and medium-density options.

Neighborhood

Neighborhood quality depends on many factors. The group of factors that land-use controls attempt to ameliorate are those negative externalities, or "nuisances," created by land-use interactions. Protecting neighborhood resources means preventing the negative impacts of new development on existing neighborhoods as well as ensuring compatibility within new development. The potential impacts of the Vienna station on neighborhood quality are given below:

1. The neighborhood surrounding the station area is generally low-density residential so noise levels should be compatible: moderately low during the day and quiet at night. Potential sources of noise are traffic (especially trucks and motorcycles), loading and unloading of trucks, garbage containers, power equipment, stereos, parties, and discotheques. The source of most objectionable noise in the station area is motor vehicles, and the most efficient protection is design standards for buffering development from trafficways.

2. High-density land uses are visually incompatible with low-density neighborhoods, but the impacts can be almost fully eliminated by means of three measures: (a) placing the largest structures closest to the station and reducing the intensity of use outward, down to garden apartments and townhouses; (b) using vegetative buffers between different intensities of use that are incompatible; and (c) imposing a height restriction on structures of 12 m (40 ft) above the highest local grade to ensure that structures blend in rather than stick up (taller buildings would be permitted on lower grades). Because of the existing vegetation and the topography of the site, both of the last two measures would be very effective in this instance. Figure 4 shows the combined effects of environmental constraints and buffering requirements on site planning.

3. Low-density development will maintain the age, family structure, and income mix that already exist in the area, whereas high-density development would also allow the elderly, single people, young couples, and moderate-income households to join the community.

4. Dust, fumes, loss of important architectural sites or historic sites, vibration, and flooding can also reduce neighborhood quality; under the stated policy conditions, problems with these impacts are not expected. Suitable access control should make construction impacts on the largely vacant site minimal.

Costs and Revenues

Calculations of costs and revenues typically reflect little more than the number of school children that will be brought in by new development. Preferably, each direct-benefit government function, such as utilities, should be balanced separately, and user fees should be distinct from general revenues. Road users do not pay property taxes on the right-of-way, sales tax on gasoline (they pay an excise tax), or a share of construction, maintenance, and administrative costs; hence, any increase in highway capacity implies an increased and continuing transfer of advantage from general taxpayers to highway users. Unfortunately, this inefficiency cannot be corrected at the local level although the costs of some kinds of facilities can be levied on developers on the assumption that the costs will be passed on to those who create the need for the facilities. Several fiscal viewpoints are needed, including those of the county, the town of Vienna, Metro, and the highway department.

Summary

The impacts of the presence of the Vienna Metro station depend to a large extent on public policies that affect the amount of development that takes place in the immediate vicinity and the regulatory constraints placed on that development. Comparisons can be made among the three development options by using a cost-benefit framework and a tabulation of residual impacts.

Costs and Benefits

Given the assumption set forth, there should be no uncompensated costs of high-level versus low-level development. One possible exception would be traffic. To the extent that the high option generated more total trips than it substituted walking for automobile trips, there would be some negative neighborhood effects; one estimate is that there would be 1400 additional vehicles in the peak hour (2). If this factor is considered, the benefits of high-level over low- or medium-level development (area ADE in Figure 3) are as listed below:

1. Desirability of integrated, mixed land uses, housing types and price ranges, population ages and incomes, and commercial enterprises, as reflected by what consumers would be willing to pay in the market;
2. Additional public facilities and amenities that can be provided (instead of savings in the cost of public facilities caused by clustering or higher profits to private entrepreneurs);
3. Better use of the rail transit system (if other facilities would be needed for highway travel while there is excess capacity on Metro, the benefit is the savings in the cost of new facilities); and
4. Greater retention of existing vegetation and protection of environmental resources.

Because the low-density option is similar to what will occur without the station, the costs and benefits of the transit station under high-density development (relative to no station) are similar to the comparison between options. The major differences are in the road improvements and traffic impacts since these will occur under any development option.

Residual Impacts

For the Vienna site, the location of a transit station offers opportunities for development that would not be available without the station but will not necessarily occur with the station. In fact, rather stringent policy assumptions (the normative objectives) are required to realize the full potential of the opportunities; if these assumptions are generally not followed in implementation, the resulting impacts would be different from those stated. Assuming that a high level of development and the corresponding constraints are implemented, the remaining impacts would be limited to the following:

1. Impacts listed above as benefits;
2. A change in the character of the neighborhood from suburban to low-density residential with a small semiurban neighborhood core;
3. Impacts of increased traffic volumes in the neighborhood to the extent that these are not buffered (primarily in comparison with no station at all);
4. Some reduction in open space and vegetation (relative to no development) but an increase in public open space;
5. Somewhat higher ambient levels of noise, particulates, and air pollution in the immediate environs but less in the aggregate;
6. Increases in land value in the area immediately adjacent to the station but dampened increases because of the requirements for public amenities, facilities, and environmental controls.

Finally, although there has been little mention of citizen participation in the decision-making process, the structure of the impact analysis and evaluation is designed to be able to maintain (even depend on) a continuous dialogue between the technical and political sides of the process. Various groups—neighbors, developers, investors, residents, taxpayers, and modal lobbies—have both positive and negative considerations at stake in the outcome, and they should be encouraged to participate actively in the many choices to be made. The impact evaluation framework provides them with a solid yet flexible basis for debate.

CONCLUSIONS

An extension of the with-and-without impact methodology framework has been proposed and demonstrated in conjunction with a case study of a rail rapid transit station. The primary intent was to incorporate the policy context as a part of the impact study, and the result was to generate a range of possible outcomes rather than a single impact, each outcome being associated with a matched set of policy conditions. The impact of the station is then the difference between the options available with the station and those available without the station. Although the extended impact framework is still incomplete, it is offered as a step toward improved evaluation of major transit or transportation projects through the analysis of land-use impacts.

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REFERENCES

1. D. E. Boyce. Notes on the Methodology of Urban Transportation Impact Analysis. HRB, Special Rept. 111, 1970, pp. 41-44.
2. A Study of Land Use Planning Alternatives and Recommendations in the Vicinities of West Falls Church, Dunn Loring and Vienna Metro Stations. Kamstra, Dickersen Associates and Office of Comprehensive Planning, Fairfax County, VA, June 6, 1975.
3. W. Z. Hirsch. Urban Economic Analysis. McGraw-Hill, New York, 1973.
4. R. L. Knight and L. T. Trygg. Land Use Implications of Rapid Transit: Implications of Recent Experience. U.S. Department of Transportation, Aug. 1977.
5. S. C. Wheelwright and S. Makridakis. Forecasting Methods for Management. Wiley, New York, 2nd Ed., 1971.

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