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The Impact Assessment System: A New, Systematic Approach for the Evaluation of Socioeconomic Impacts Of Urban Tunnel Projects

by Peter Wolff, Martin Stein** and Ralph Gakenheimer****

1.0 INTRODUCTION

DENSELY POPULATED urban areas have relatively greater transportation needs than rural areas. In attempting to meet these needs, the transportation decision-maker often faces resistance. This resistance results from the sensitivity of urban areas to disruption and other aspects of transportation construction.

Substitution of alternative construction methods and system designs technology (e.g., use of tunnel instead of an at-grade or elevated facility) may enable the highway or transit decision-maker to eliminate or mitigate undesirable consequences of transportation projects. The transportation project tunnel is considered to be a high cost option for reducing these undesirable consequences and therefore to be a mechanism for reducing community opposition to a transportation improvement. Decision-makers may, however, not be aware of the possibly u n i q u e effects of tunnel projects. In addition, the criteria for selection between alternative tunnel construction technology options are not clearly specified.

The research effort reported here was designed to clarify the impacts of urban transportation tunnels and to facilitate their assessment approaches may provide valuable guidance to decision-makers and planners; this in turn can improve interaction with community organizations, help identify areas where mitigation measures could be desirable and assist in the implementation of tunnel transportation projects.

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This research was done as part of contract DOT-FH-11-9351, and is drawn from Vol. I of the Final Report (available from NTIS).

2.0 BACKGROUND

Transportation tunnel projects in urban areas are very large and expensive undertakings. Often, the non-tunnel alternative appears to be less expensive than the tunneling option. Nevertheless, tunnels are frequently preferred in urban areas because they can reduce the non-dollar costs of a transportation project.

Exhibit 1 indicates the status of urban transportation tunnels in the United States in 1978. There was a total of 166 lane miles of highway tunnels and 354 route miles of transit miles, as indicated by the testimony of Dr. Gerald Love, Associate Administrator of the Federal Highway Administration, at budget hearings before Congress. This figure included existing tunnels, tunnels under construction, and tunnels planned between 1978 and 1995. Although construction plans slowed down between 1978 and 1982, it is anticipated that new projects will be created and others accelerated as a result of the 1983 increase in the federal gasoline taxes.

3.0 ADVANTAGES OF THE IMPACT ASSESSMENT SYSTEM

In this paper, we summarize the key features of the Impact Assessment System (IAS) which was developed to identify and predict the social and economic impacts of transportation tunnels. We provide a step-by-step description of the steps necessary to utilize the IAS and present an illustration of its application in an evaluation of a tunnel project being constructed by the Massachusetts Bay Transit Authority in Cambridge (the so-called "Red Line" extension). Advantages of the system for transportation researchers and decision-makers are:

- The IAS simplifies a complex and often inconsistent process of evaluation. Environmental I m p a c t Statements are required in the U.S. for most transportation projects and the ingredients as well as procedures for these evaluations often

STATUS OF URBAN TRANSPORTATION TUNNELS

STATUS	TRANSIT		HIGHWAY		TOTAL URBAN TUNNELS		PERCENTAGE OF TOTAL		TOTAL
	Number of Route Miles	Percentage	Number of Route Miles	Percentage	Number of Route Miles	Percentage	Number of Route Miles	Percentage	
Existing	242	68.4	119*	71.7	361	69.4	33.0	67.0	100.0
Under construction	63	17.8	7	4.2	70	13.5	10.0	90.0	100.0
Planned (1995)	49	13.8	40	24.1	89	17.1	45.0	55.0	100.0
TOTAL	354	100.0	166	100.0	520	100.0	--	--	--

*Estimated in Feasibility Analysis of Urban Transportation Systems with Special Reference to Tunnels, prepared by Systan Inc., October 1977.

Source: Department of Transportation and Related Agencies Appropriation for 1979: Hearings Before a Subcommittee of the Committee on Appropriations, House of Representatives, Ninety-Fifth Congress, Second Session, Committee on Appropriations, U.S. Government Printing Office, Washington, D.C., 1980 (Part 5, p. 539).

EXHIBIT 1

are respecified for each project. Use of the IAS approach shows that there are commonalities that can be utilized for evaluations even if these involve large and complex undertakings such as urban transportation.

- The system can be considered to be a management tool if assembled as the project evolves. As a management information system, it can help managers identify impacts and predict their occurrence in advance of this actually happening. Problems that are encountered from affected groups can be addressed readily (e.g., complaints about noise from trench excavation by a school principal) and put into perspective.

As the IAS is refined, further applications are possible (for example, to bridges, airports, non-transportation tunnels, or any large-scale project). Furthermore, the system is readily converted for use on microcomputers. Since there is a backlog of urban transportation projects worldwide, future applications of the Impact Assessment System seem likely and desirable. Below, we provide an overview of the system and its major components.

4.0 TASKS, PHYSICAL CHANGES, AND IMPACTS

The characteristic feature of the Impact Assessment System is that it disaggregates a tunnel project into many small, finite parts. The purpose of the IAS is to enable the impacts associated with urban transportation tunnel projects to be predicted. Tunnel projects are very large, very costly, and last a long time. The size and complexity of tunnel projects makes it difficult to know how to approach predicting impacts.

Using the IAS, a tunnel project can be broken down into small tasks. These tasks are physical events that take place in the life of a tunnel: some tasks occur while the tunnel is being planned, others while it is being designed, yet others while it is being constructed, and finally some while it is being operated and maintained as either a subway or a highway facility.

Most of these tasks, in turn, bring about physical changes. (Some tasks, particularly in the planning and design phase, do not bring about any physical changes; they are conducted solely at the desk of some planner or designer.) Typical physical changes are the noise associated with an operating tunnel facility, either from automobiles or trains, and barriers that are put into place when a tunnel is constructed or that arise when the tunnel is finally finished, because of facilities such as exit ramps or subway stations.

The IAS identifies just eight different kinds of physical changes that may occur as a result of tunnel tasks. They are:

A. Air quality changes
B. Noise level changes
C. Vibration
D. Water quality changes
E. Visual quality changes
F. Traffic changes
G. Barriers
H. Land use changes.

These physical changes in turn produce social and economic impacts; that is, these physical changes bring about some effect on the social or economic well-being of persons or groups in and around the tunnel project. The IAS identifies just ten different kinds of impacts, five are social and five are economic.

Social Impacts

1. Public service activity
2. Community cohesion
3. Family and individual well-being
4. Ownership patterns and turnover
5. Ability to achieve other planned actions

Economic Impacts

6. Replacement costs
7. Business activity
8. Tax revenues (other than property)
9. Employment
10. Property value and taxes.

The underlying connection is that tasks produce physical changes; and physical changes, impacts. There can be no impact without a causative physical change; and there will be no physical change unless there is a task producing it.

Exhibit 2 presents a flow chart of the Impact Assessment System. It is designed to summarize several key conceptual features of the system. At the "general" level of application, for example, an analyst can utilize the system to evaluate alternative transportation facility options without delving into micro-level detail associated with the "specific" level of the system. A typical application of the "general" level consists of the following steps:

- **Specification of transportation mode and project component identification.** Here, the analyst defines the relevant mode and project characteristics (e.g., transit tunnel).
- **Construction method.** The analyst specifies the form of technology relevant to project tasks or activities (e.g., boring, mining, or cut-and-cover).
- **Phase determination.** Choices here include planning, design, construction, and operation.
- **Selection of activities, steps, and tasks.** The breakdown of major and minor operations associated with the project and selected from a specified, structured listing.
- **Determination of physical changes.** The analyst is provided with relevant, physical changes associated with each task for the specific construction method and mode.
- **Definition of relevant impacts.** The system cross-references each physical change to specific predetermined impacts.
- **Assess importance of impacts.** The analyst interprets the level of impact by considering project characteristics, size, scope and nature of impacts, as well as affected groups.
- **System output.** Summary output available by the period for each alternative for each affected group. Additional breakdowns are possible for different geographic areas, impact direction (beneficial or adverse) and impact duration.

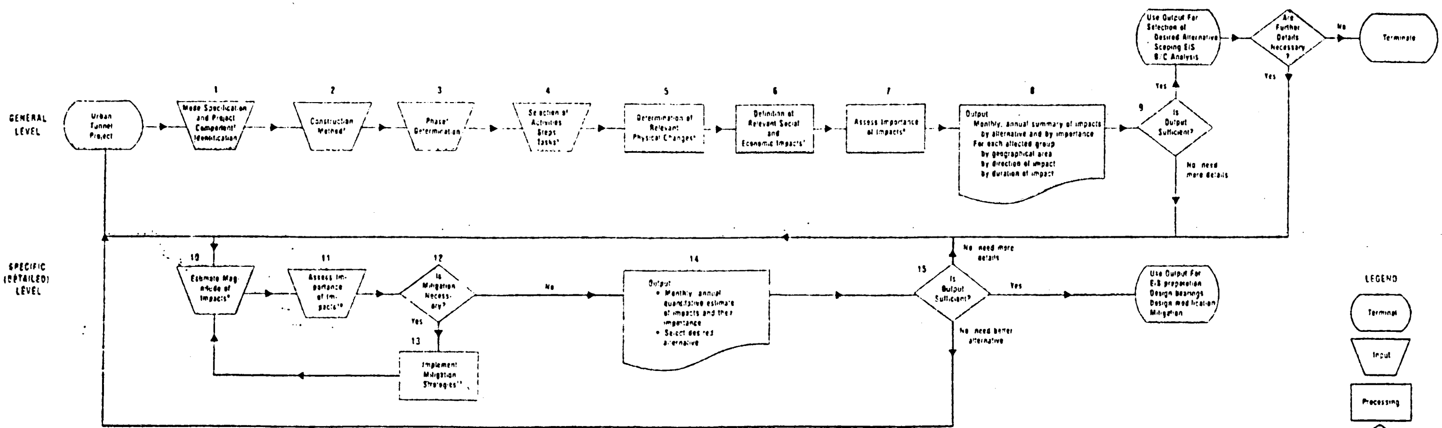
At the "specific" level, the additional steps required to assess the magnitude of impacts and means for mitigating them are superimposed on the general level. Key steps here are:

- **Estimates of the magnitude of impacts.** Here, the system provides methods and techniques (e.g., survey instruments) for evaluating the nature and size of each relevant impact.
- **Mitigation.** Selected impacts are screened out by the use of a predefined threshold for possible special treatment. For example, in the planning phase it is possible to consider additional relocation assistance, in the design phase, features can be built into the project to reduce the severity and/or incidence of negative impacts.

Results of either level are input to Environmental Impact Statements, and to design hearings of modification decisions. Planners and decision-makers can utilize the methodology to organize a complex information and research process into one that is manageable. Environmental specialists can perform tasks in advance of project design to anticipate work requirements and possibly speed up the process of completing an evaluation. "Instant" assessments become possible for a variety of alternatives at an early stage of the evaluation. With the potential for computerization, the system can provide an efficient tool that facilitates and expedites project implementation.

Of special interest is the fact that the

IMPACT ASSESSMENT SYSTEM (IAS) LOGIC FLOW CHART



*Transit or highway
*Line segments, station, roadway, ramps, combinations
*Cut-and-cover, boring (tbm), mining, combination
*Planning, Design, Construction, Operation & Maintenance
*26 Activities, 72 Steps, 189 Tasks (for all methods), by project month, 64 major tasks, 125 minor tasks
*8 physical changes (5 primary, 3 secondary)
*5 social impacts, 8 economic impacts, short term, long term, site, corridor/(region), by affected group
*Considering magnitude, number of persons, proportion of persons, duration of impacts, timing of impacts, ability to cope
*High, medium, low, or numerical values
**Scale values to indicate importance of impacts to affected groups, using same factors as in footnote 8
**Priority for mitigation: (1) severe disbenefits, no benefits, for one group; (2) severe disbenefits, inclusive future benefits for one group; (3) small or moderate disbenefits for one group; (4) few or no disbenefits, or one group

EXHIBIT 2

IAS enables planners to make impact assessments that are not merely trivial or overly general, such as statements that during construction there will be a lot of noise and dust and that these will be harmful to the community. Instead, the planner can associate (for example) noise with specific tasks, identify the timing of the tasks and the associated noise, estimate the magnitude of the noise and then identify the social impact (such as reduced community cohesion) resulting from the noise and estimate its magnitude. Because of the association of tasks with physical changes and of physical changes with impacts, predictions of impacts are easier, more useful, and more likely to lead to mitigation measures.

In the following pages, further details of the elements of the system and a case study of its use are presented.

5.0 APPLICATION OF THE IAS TO THE RED LINE EXTENSION

In order to understand how the IAS can be applied, we have prepared an illustrative application of its use on a tunneling project included in the Red Line extension now under construction in Cambridge, Massachusetts.

Relatively early in the planning stage, the route now under construction was selected over other alternatives. The new subway tunnel from Harvard Square to Porter Square basically follows the alignment of Massachusetts Avenue.

At first, it was planned that the tunnel would be constructed by the cut-and-cover method. Large-scale opposition from residents and businesses along Massachusetts Avenue, however, brought about a change in plans. Except for the station in Harvard Square and a short section of the tunnel under Flagstaff Park next to the station, the tunnel is now being constructed by boring and mining methods. Exhibit 3 shows the route of the tunnel under Massachusetts Avenue from Flagstaff Park to Porter Square. The Porter Square station necessarily had to be quite deep, since the tunnel from Harvard Square has to pass below existing railroad tracks in a cut near Porter Square. The Porter Square station, therefore, was planned to be excavated by mining methods. The tunnel from Porter Square to Davis Square is again a bored tunnel. From Davis Square on, cut-and-cover techniques are being used, since the tunnel follows an existing abandoned railroad right-of-way. Because several different construction contracts are involved, none of the contractors building a bored section had a long enough segment to warrant use of a boring machine. Hence the construction method consists basically of drilling and blasting.

Specific Level Application of the IAS. The choice of boring over cut-and-cover techniques was clearly based on community assessment of anticipated impacts. Since the decision was made early in the planning stage and before any design decisions had been made, it was based on impact predictions at the generalized level.

In many cases, application of the IAS

ROUTE OF THE SUBWAY TUNNEL FROM HARVARD SQUARE

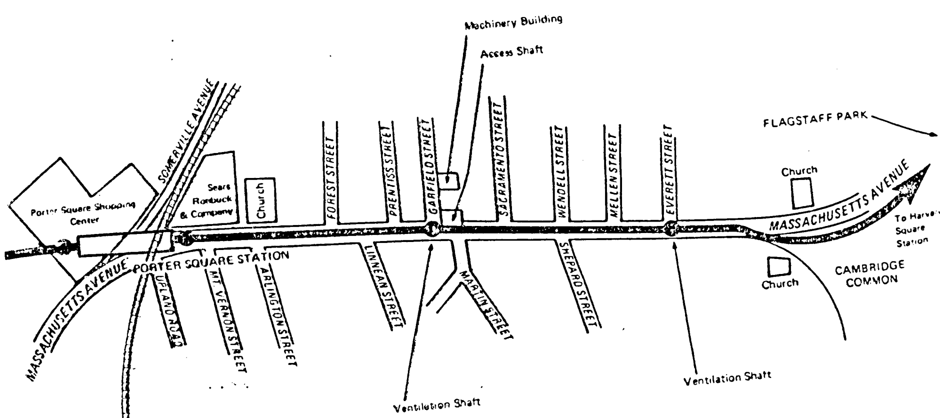


EXHIBIT 3

at the generalized level suffices. Sometimes, however, it is necessary to predict and assess impacts at a more specific level. For example, once it was decided that construction along Massachusetts Avenue would be by boring, some residents and some business owners/managers may have wanted information on impacts at the access shaft: what would they be, how large would they be, would they be mainly adverse, could some mitigation be instituted?

The answers to these questions can be provided by the IAS at the detailed Specific Level (see Exhibit 2), but at a later stage in the life of the project than the general predictions. It is clear that questions about impacts at the access shaft can only be answered after it has been determined where the access shaft is going to be. Furthermore, in order to predict the impacts with any kind of precision, it must be known whether construction will be by blasting, by mining with small machines, by use of a tunnel machine, and the like. To remove the muck, will trucks drive down to the tunnel level, or will the muck be lifted out by use of cranes or elevators or in some other way? It is apparent, therefore, that predictions concerning impacts during the construction phase, if they are to be quantitative and answer the kinds of questions indicated above, can only be made during the design phase of the project, when considerable detail about the project will already be known.

The area of Massachusetts Avenue near the access shaft is shown on Exhibit 4. The anticipated impacts in this area arise from the tasks displayed in Exhibit 5.

One of the devices which the IAS uses is a series of matrices. One of them can be used to display the impacts, on an activity-by-activity basis, the opportunities for mitigation are made evident: if an impact is unacceptably large or severe, the activity (and the tasks subsumed under it) can be changed for the purpose of avoiding or lessening the impact.

Exhibit 6 is a filled-out Matrix, with estimated magnitudes of the impacts provided, for the area near the access shaft. Sources of the estimate are also indicated. In a few cases, the data sources are hypothetical; these have been indicated by an asterisk. Only one half of the matrix is presented; viz. the half dealing with disbenefits. A similar matrix could be filled out for predicted benefits. In this case, no benefits are anticipated.

The impacts near the access shaft, as displayed in Exhibit 6, may be summarized as follows:

1. They are due to two kinds of activities, viz. the excavation at the access shaft (Activity 14) and the necessary relocation of utilities (Activity 18).
2. Impacts fall on four kinds of groups: residents, property owners, businesses, and employees. Since there are no public service agencies in the vicinity, no impacts are felt by any such agencies.
3. Property owners and businesses seem to suffer the most severe impacts. Impacts on residents (i.e. people who live in the vicinity even though they don't own property such as renters) and on employees of local businesses are relatively small.
4. The major source of the impacts are barriers to pedestrian and automobile traffic, the changed traffic patterns, and the construction noise.
5. The actual impacts due to excavation (Activity 14) as displayed in the exhibit are the following.

   —changed (reduced) community cohesion. This affects residents. It is due to the barrier that was created on Massachusetts Avenue, effectively separating one side of the street from the other.

   —changed (reduced) family and individual well-being. Based professional judgment, it seems that the noise and air pollution negatively impacted individuals and families who lived near the construction area. Some evidence of this was found in the fact that a near-by residence was provided with double-glazed windows and air-conditioning so that residents could continue to live there.

   —greater ownership turnover than the historical pattern. This is a likely but hypothetical impact, since no real estate study was done.

   —reduced property values. The prediction of this impact, which falls on property owners, is based on similar occurrences that were observed in Washington, D.C. during subway construction. Reduced property taxes should go along with reduced property values, thereby slightly mitigating this impact.

   —reduced business activity (reduced revenues and profits). This impact falls on businesses along Massachusetts Avenue. The prediction of this impact is based on similar impacts observed dur-

TO PORTER SQUARE
MASSACHUSETTS AVENUE NEAR THE ACCESS SHAFT FOR TUNNEL CONSTRUCTION

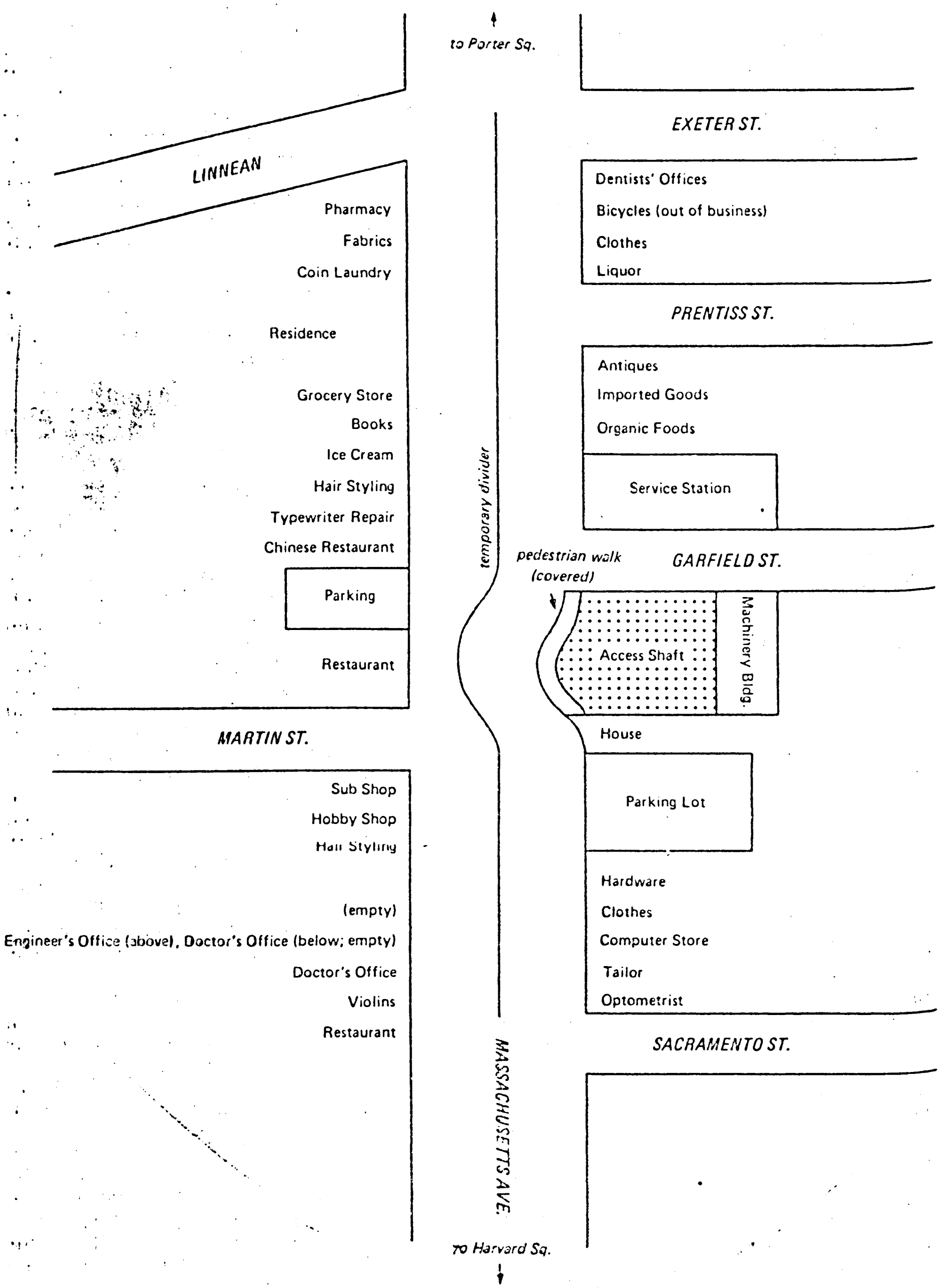


EXHIBIT 4

MAJOR TASKS RELEVANT TO BORING/MINING CONSTRUCTION OF SEGMENT FROM EVERETT STREET TO MT. VERNON STREET

		Associated Physical Changes								
Task Code	Task Description (abbreviated)	Air Quality	Noise	Vibration	Water Quality	Visual Quality	Barrier	Traffic	Land Use	Comments
	Activity 14: Excavation to Plan and Depth of Structure									
C-1	Soil Excavation	x	x		x	x	x	x		At access and
C-2	Rock Excavation	x	x	x	x	x	x	x		ventilation shafts
C-3	Materials Transport	x	x	x		x		x		Truck traffic near access
C-4	Acquire Disposal Area					x			x	Away from corridor
C-5	Water Control and Pumping	x	x				x			Very important for bored tunnel
	Activity 18: Utility Relocation and Support									
C-21	Trenching	x	x	x		x	x	x		At access and vent point
C-22	Provide Wall Supports, etc.	x	x			x		x		
	Activity 19: Support of Existing Structures									
C-26	Pile Driving	x	x	x				x		In front of access shaft
	Activity 20: Pedestrian and Vehicular Traffic Control									
C-34	Construct Temporary Bypass Sections	x	x					x		In front of access shaft
	Activity 21: Tunnel Driving									
C-40	Excavate Earth or Rock	x	x	x	x			x	x	
C-47	Advance Shield	x	x	x						

EXHIBIT 5

ing MARTA subway construction in Decatur, Georgia.

—reduction in employment. This was predicted to be a small impact here, since it arises from the small reduction in business activity. It falls on the employees who work in Massachusetts Avenue businesses. Similar small reductions in employment were observed as a result of MARTA (Atlanta) and WMATA (Washington, D.C.) construction.

After magnitude of impacts has been predicted and displayed (as in Exhibit 6), the affected groups must assign scale values to them in order to strengthen the value judgment made at the general level by the planner. In the example, the affected group must indicate, on some scale (such as −3 to +3) what the meaning of the predicted impact is to them.[1]

Exhibit 7 is another filled out matrix, showing the scale values assigned by the affected groups to the impacts which are predicted. The values are hypothetical. In a real world situation, these values would be obtained by presenting the predicted impacts to the affected groups and obtaining their input as to how they rate the impacts. For several impacts, we have assumed the value "0" because the impact seems so slight that it is insignificant.

For a planned tunnel, this kind of matrix would be filled out for each proposed alternative (different alignments, different construction techniques), so

IMPACTS FOR TUNNEL CONSTRUCTION NEAR THE ACCESS SHAFT ON MASSACHUSETTS AVENUE BY ACTIVITY AND AFFECTED GROUP

Affected Group	Physical Change	Related Impacts	Magnitude	Source of Estimate
Phase: Construction		Activity 14: Excavation to Plan and Depth of Structure		
		Disbenefits		
Residents	Noise Traffic Visual quality	Community Cohesion	Small, because barrier is small	Professional judgment, or O-D study for walking trips
Residents	Air quality Noise Vibration Traffic	Family and Individual well-being	Medium-size, because near shaft there is considerable activity	Professional judgment
Property Owners	Visual quality Barrier Traffic	Ownership pattern and turnover	15% greater turnover than without project	Real estate study*
Property Owners	Air quality Noise Visual quality Vibration Barrier Traffic Land Use	Property value and taxes	5% decrease in assessed value and taxes, because impact is (relatively) short-lived	Comparison with similar situation in D.C.*
Businesses	Noise Air quality Vibration Barrier Traffic	Business activity	10%-15% decrease during construction when access is limited and parking is difficult	Comparison with MARTA/Decatur events
Employees	Same as for Businesses	Employment	Small drop. Small businesses most seriously affected where owner usually constitute all or most of labor force	Professional judgment. Comparison with D.C. [D Street] and MARTA/Decatur
Public Service Agencies		N/A - There are no public service agencies near the shaft.		
		Activity 18: Utility Relocation and Support		
Residents	Barrier	Community Cohesion	Small. Excavation for utilities is small and quick	Judgment or O-D stpdy of walking trips
Businesses	Air quality Noise Vibration Barrier Traffic	Business Activity	Small. Dwarfed by same impact arising from Activity 14	Judgment
Employees	Same as for businesses	Employment	This is derived from business activity impacts and is a small part of a small impact	Judgment

*Indicates hypothetical data.

EXHIBIT 6

that the impacts can first be predicted for each different alternative and then rated by the affected groups. By comparing the matrices prepared for different alternatives, the planner can see—for each alternative—which groups are adversely impacted and which ones are benefited. He can also see which groups experience the most important benefits or the most important disbenefits, through the scale values assigned by the planner and the affected groups.

Mitigation. At this point, matters will pass from the hands of the planner to those of the decision-maker. Confronted with the displays of matrices showing the importance which different groups assign to impacts the decision-maker(s) can do several things:

1. Decide, without further action, on one alternative. This is easy only if one alternative is clearly dominant; i.e., if there is no group for which the chosen alternative is worse than the discarded one, and

SCALE VALUES FOR IMPACTS ON AFFECTED GROUPS NEAR THE ACCESS SHAFT ON MASSACHUSETTS AVENUE BY ACTIVITY (boring construction)

		Relevant Construction Phase Activities				
		Excavation to Plan and Depth of Structure	Utility Relocation and Support	Support of Existing Structure	Pedestrian and Vehicular Traffic Control	Tunnel Driving
Affected Group	Impact	14.	18.	19.	20.	21.
Residents	Community Cohesion	-1	0	N/A	N/A	-1
	Family and Individual Well-Being	-2	N/A	-3	N/A	N/A
Property Owners	Ownership patterns and turnover	-1	N/A	N/A	N/A	-1
	Property Values and Taxes	-2	N/A	N/A	N/A	-1
Businesses	Business Activity	-3	-1	-2	-3	-1
Employees	Employment	-2	0	-1	-2	0
Public Service Agencies	Public Service Activity Tax Revenues	Not applicable--there are no public service agencies in this segment.				

EXHIBIT 7

there are some groups for which it is better. ("Better" or "worse" would be judged through the scale values that have been assigned.)

2. Implement mitigation strategies which make one alternative dominant over the other one.
3. Implement mitigation strategies following specific decision rules. For example, the decision could be based on an attempt to mitigate the worst impacts for those groups that are least able to cope with them on their own. This might be called the "rule of equity." An example would be mitigation of reduced community cohesion and family and individual well-being by mitigating reduced access.

   Implementation of such mitigation strategies may still not make one alternative dominant. I.e., there may be still greater benefits for one group from Alternative 1, while another group experiences greater benefits from Alternative 2. Or, conversely, Alternative 1 may cause greater disbenefits for group, while Alternative 2 causes greater disbenefits for another group.

   It is at such a point that the decision-maker must make a decision. It will be a political decision—i.e., the decision-maker will have to decide to favor one group over another, on the basis of what he perceives to be compelling reasons.
4. In the same fashion, the decision-maker may decide in favor of one alternative over the other even without implementing any mitigation strategies.

   Again, he will please some groups and displease others. The decision not to implement any mitigation may be based on sound reasons—it may be too expensive, not cost-effective, too time-consuming or too dangerous.

6.0 CONCLUSION

The Impact Assessment System application described above illustrates its utility in the context of a transit tunneling project. Other applications include transit stations, urban toll tunnels and toll plazas and freeway tunnels. By repeatedly using the system in a variety of contexts, it is anticipated that the system user will develop predefined sets of input data files and possibly revise matrix elements. Despite the need for, and likelihood of refinement, the conceptualization of the system in its current form provides researchers with a consistent methodology for impact assessment and the design for a system that can be easily computerized. Given the increasing costs of transportation projects, it is likely that the efficiencies derived from this systematic approach will help offset initial costs associated with the system, and that its capacity for providing managers with an operational approach for monitoring impacts will reduce time requirements for overall project implementation.

FOOTNOTE

1 If the scale goes from —3 to +3, the interpretation of the numerical values is as follows: Very important disbenefit = —3; moderately important disbenefit = —2; small disbenefit = —1; no benefit or disbenefit = 0; small benefit = +1; moderately important benefit = +2; very important benefit = +3.