A Method for the Evaluation of Transportation Plans

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The paper questions the efficacy of traditional cost-benefit analysis for the evaluation of transportation plans designed to serve a broad set of objectives. Cost-benefit analysis was designed for the evaluation of plans in terms of a single objective—economic efficiency. An alternative method of evaluation, known as goal-achievement analysis, is proposed and described. Plans are examined in terms of the entire set of objectives in a single system. Goals are defined operationally and goal achievement is measured in units which are relevant to the particular objectives. The relative effectiveness of alternative plans in achieving the set of desired objectives is determined by applying a weighting system to objectives and to the subgroups, sectors, locations and activities affected.

•IN RECENT years it has frequently been emphasized that plans for transportation improvements should reflect broad community objectives. Cost-benefit analysis has been increasingly employed in the evaluation of alternative transportation plans. How effective is traditional cost-benefit analysis for the evaluation of plans in terms of their probable achievement of a broad array of community objectives?

Cost-benefit analysis, after all, was developed as a technique for examining plans with respect to their achievement of the single objective of economic efficiency (8). This objective may be broadly defined as the maximization of net project or system contribution to the regional income or national income. Thus, in a manner analogous to the profit-maximizing firm, a public agency in pursuit of economic efficiency should allocate its resources in such a manner that the most "profitable" projects are executed. Traditional cost-benefit analysis requires the translation of both the costs and the benefits of a transportation improvement into monetary terms. Some of these costs and benefits are determined in market prices while others are imputed as if they were subject to market transactions. However, some costs and benefits known as intangibles are outside the scope of the market and cannot be priced in monetary terms.

Although lip service is paid to the consideration of intangibles, they do not really enter into the analysis. The net result is that the effects of investments which can be measured in monetary terms (whether imputed or derived from the market) are implicitly treated as being the most important effects, if only because they can be measured in this way. In fact the intangible costs and benefits may be as significant for the community under consideration. Furthermore, the expression of some costs and benefits in monetary terms and the restriction of the evaluation process to an economic analysis may lead to a deficient decision since the essence of particular costs and benefits may be lost through their conversion into monetary terms. Economic efficiency can perhaps be measured more precisely than other objectives, but this does not entitle it to an honored status. In the words of Tillo Kuhn, an important theorist in the economics of transportation (5), "Urban objectives have several dimensions—cultural, political, ethical, aesthetic, economic. To pursue only one dimension would indeed lead to a suboptimum from the total point of view."

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THE GOALS-ACHIEVEMENT MATRIX

How might a large array of transportation objectives be considered in a single system? This paper demonstrates how the problem may be handled by goals-achievement analysis. For the purposes of the paper we shall assume that those community objectives that are affected by a proposed transportation improvement have been identified and that the relative weights attached to these objectives by the community have been established. We shall further assume that alternative plans designed to serve these objectives have been prepared. The next step, therefore, is the comparison of the plans in order to determine which plan best realizes the objectives of the community.

The Hierarchy of Goals

Let us first outline a hierarchical goal system and identify that level of goals within it which primarily concerns us. In this discussion we shall use goal as the generic term and define it as "an end to which a planned course of action is directed." Goals may involve getting something the actor does not have or giving up something the actor does have. The goals of planned action may be categorized on the basis of specificity as ideals, objectives and policies.

An ideal is like a horizon allowing for indefinite progression in its direction but always receding. Ideals are characteristically of intrinsic value and are prized in themselves. Typical ideals are equality, freedom, justice.

An objective denotes a goal which has instrumental value in that it is believed to lead to another valued goal rather than having intrinsic value in itself. Objectives are defined operationally so that either the existence or nonexistence of a desired state or the degree of achievement of this state can be established. A qualitatively defined objective is one which, following the execution of a course of action, is either obtained or not. A quantitatively defined objective is one which is obtained in varying degree. The extent to which such an outcome is obtained can be measured. Typical objectives of transportation plans, for instance, are increase of accessibility, increase of safety, etc. An objective may be either instrumental in the achievement of an ideal or instrumental in the achievement of another higher objective, which, directly or indirectly, is instrumental in the achievement of an ideal.

A policy is the specification in concrete details of ways and means for the attainment of planned objectives. Policies may refer to specifications of practice, physical facilities, fiscal arrangements, legislative proposals, etc.

For the purposes of the goals-achievement matrix, goals should, as far as possible, be defined operationally, i.e., they should be expressed as objectives. In this way the degree of achievement of the various objectives can be measured directly from the costs and benefits that have been identified. Thus, the ideal of increased economic welfare can be defined in terms of objectives relating to the rate of increase or the absolute increase of the gross national product or the gross regional product. Similarly, the ideal of a healthy environment can be expressed in terms of objectives such as reduction in air pollution, reduction in the rate of accidents, etc.

Requisites

There is another category of values which are not specific goals of plans but which enable the planner and decision-maker to set guidelines. Requisites set limits to objectives and the policies by which objectives may be realized. They enter into consideration primarily at the time that the alternate plans are generated and developed, i.e., before the plans are evaluated in terms of the desired goals. Requisites indicate the necessary conditions which must be satisfied in order that the plans will not be rejected. However, they do not provide a sufficient basis for the acceptance of plans. The satisfaction of both a set of objectives and a set of requisites is necessary and sufficient for a plan to be acceptable.

Typical requisites are feasibility, immediacy and interdependence. By feasibility we mean, is the plan capable of being executed? Do existing fiscal, legal, political and social conditions facilitate the execution of the plan? Immediacy refers to the priority

to be assigned to the execution of the planned facility and its various components, given the existing political and social conditions. Interdependence refers to significant interaction between the sector under consideration and any other sector. For instance, when planning transportation facilities, the interaction between these facilities and the nature, magnitude, intensity and location of the activities served by the transportation route or system is a primary consideration.

Constraints are a particular type of requisite. The achievement of specified levels of particular objectives may serve as constraints on the acceptability of alternative plans irrespective of the weight of these objectives in the total array of objectives. Thus, the maintenance of air pollution below specified levels may serve as a constraint on the choice of alternative transportation plans even though the reduction of air pollution, expressed as an open-ended objective, may not be highly valued by the community.

Before proceeding, it is necessary to define some additional terms. A consequence is a change in a given situation caused by a course of action or a policy. Consequences which are positively valued in terms of a given end are benefits; consequences which are negatively valued in terms of a given end are costs.

Procedure

The procedure which we employ is as follows: Given (a) the ordering of the goals of a community, and (b) a determination of alternative courses of action designed to achieve these goals, we must identify that course of action which best serves the community's goals. The evaluation of the alternative courses of action requires a determination for each alternative of whether or not the benefits, measured against the total array of ends, outweigh the costs, measured in terms of the total array of ends.

The only weighting introduced into the analysis is that which reflects the community's valuation of the various objectives. The weights are applied irrespective of the units in which the achievement of the objectives is measured. However, the weighting may also reflect the incidence of goal achievement since the extent of achievement of particular objectives may be considered more important for some groups of people than for others.

Incidence—It is therefore necessary to identify those sections of the public, considered by income group, occupation, location or any other preferred criterion, that are affected by the consequences of a course of action, since inevitably the consequences are unlikely to affect uniformly all sections of the public served. The incidence of the favorable and unfavorable consequences accruing to sections of the public should, of course, be taken into consideration by the decision-makers. This information is extremely important if charges and compensation payments are employed in order to implement a planning proposal. It is also necessary to have this information available in order to predict the reaction of the existing institutional power structure to the planning proposals. Therefore the principle should be firmly established that those sections of the community to which the costs and benefits accrue should be identified.

Uncertainty—Any rational determination requires the evaluation of anticipated consequences while allowing for the possibility of unanticipated consequences. The validity of the evaluation is, of course, strengthened by the increase of knowledge of anticipated consequences and the minimization of unanticipated consequences. Uncertainty concerning anticipated consequences is best treated by probability formulation. In general, a range of possible outcomes is preferable to the prediction of a unique outcome. To simplify the computation the following procedure may be used. If an outcome would be substantially affected by a particular contingency, e.g., technological innovation, a supplementary comparison of alternative courses of action can be made in terms of this modification. In general, allowance for uncertainty should be made indirectly by use of conservative estimates, requirement of safety margins, continual feedback and adjustment and a risk component in the discount rate. Estimates made at low discount rates are highly sensitive to variations in the estimate of future events. Higher discount rates lead to less sensitivity to such variations.

Time Preference—The time dimension of costs and benefits deserves mention at this point. Costs and benefits occurring in different time periods are not of equal weight. One cannot fully describe the costs and benefits of alternative courses of action without saying when they are to be incurred. This aspect has received considerable attention in the literature (6, 8) and will not be discussed in detail in this paper. The essence of the problem is, how are benefits and costs occurring at different times to be valued? Are benefits and costs accruing to the present generation more highly valued than costs and benefits accruing to future generations? The future is not usually valued as highly as the present, and a discount rate for future consequences is applied. The rate of discount reflects the opportunity costs of deferred consumption (or of social time preferences) applied to annual costs and benefits over time reduced to present values. Monetary costs and benefits lend themselves easily to the application of discount rates. Tangible nonmonetary costs and benefits may, in an analogous manner, be discounted for those time periods when they are less valuable and the worth of different time paths may be compared. Alternatively, and this procedure holds for the intangibles as well, it may be best to show what can be achieved in different periods and leave the comparison to the judgment of the decision-makers.

Costs and Benefits in the Goals-Achievement Matrix

In this analysis, costs and benefits are always defined in terms of goal achievement. Thus benefits represent progress toward the desired objectives while costs represent retrogression from desired objectives. Where the goal can be and is defined in terms of quantitative units, the costs and benefits are defined in terms of the same units. Where no quantitative units are applicable, benefits indicate progress toward the qualitative states that the objective describes while costs indicate retrogression from these objectives. For the same objective, costs and benefits are always defined in terms of the same units if the objective can be expressed in quantitative terms. Thus, if a benfit of x units accrues, it can be nullified by a cost of x units, provided both costs and benefits apply to the same objective. This interpretation of costs and benefits differs markedly from the traditional conception of costs and benefits. In general, costs have traditionally been defined as the value of goods and services used for the establishment, maintenance and operation of the project. Benefits are the value of immediate products, or services, resulting from the courses of action for which the costs were incurred. Thus in the proposed formulation costs may or may not be resources of land, labor or capital (as project costs are usually thought of)—this is dependent on the definition of the goal. The same applies to benefits.

The following, then, is the final product for every plan. The set of goals is known and the relative value to be attached to each goal is established. The objectives are defined operationally rather than in abstract terms. The consequences of each alternative course of action are determined for each objective. The incidence of the benefits and costs of each course of action measured in terms of the achievement of the goal is established for each goal. The relative weight to be attached to each group is also established.

The conceptual product of the analysis is given in Table 1. In the table, α, β, γ... are the descriptions of the goals. Each goal has a weight 1, 2, 3 ... as previously determined. Various groups a, b, c, d, e ... are identified as affected by the course of action. These groups may be combined in any meaningful manner in order to indicate the differential incidence of costs and benefits. A relative weight is determined for each group, either for each goal individually or all goals together.

The letters A, B ... are the costs and benefits which may be defined in monetary or nonmonetary units or in terms of qualitative states.

Costs and benefits are recorded for each objective according to the parties that are affected. A dash (–) in a cell implies that no cost or benefit that is related to that objective would accrue to that party if that plan were effectuated. A particular party may suffer both costs and benefits with respect to a particular objective. Thus, the reduction of noise may be a relevant objective of a plan for improved transportation facilities. A particular location may simultaneously experience a decrease of noise from one

TABLE 1

CONCEPTUAL PRODUCT OF ANALYSIS

Goal description		α		β		γ		δ	
Relative value		2		3		5		4	
Incidence		Costs	Ben.	Costs	Ben.	Costs	Ben.	Costs	Ben.
Groups Affected	Relative Weight								
Group a	1	A	D	E	–		N	Q	R
Group b	3	H		–	R		–	S	T
Group c	1	L	J	–	S	M	–	V	W
Group d	2	–		T	–		–	–	–
Group e	1	–	K		U		P	–	–
		Σ	Σ			Σ	Σ		

source, e.g., as a result of the proposed diversion of heavy automobile traffic from that location, and an increase of noise from another source, e.g., from a new transit route proposed for that area.

For certain of the goals Σ indicates that summation of the costs and benefits is meaningful and useful. The total costs and benefits with respect to that goal can then be compared. This will be the case when all the costs and benefits are expressed in quantitative units. When this is not the case, i.e., for the intangibles, the costs and benefits and their incidence are best stated as explicitly as possible and then left to the judgment of the decision-makers. It is most unlikely that all the costs and benefits of all the goals can be expressed in the same units. In this rare case—which may occur when only one or two goals are valued by the community—it may be possible to arrive at a grand cost-benefit summation. However, this is highly unlikely.

For each plan, the product of the analysis is a table similar to Table 1. As was mentioned earlier, in the face of uncertainty, a range of costs and benefits is preferable to the prediction of unique outcome. Thus the letters A, B ... should not be considered as a single value but rather as a range of values.

Relative Weights in the Goals-Achievement Matrix

The key to decision-making by means of goals-achievement analysis is the weighting of objectives, activities, locations, groups or sectors in urban areas. It is possible to arrive at a unique conclusion by applying relative weights. How might these weights be determined? One or another of the following methods might be employed:

1. The decision-makers may be asked to weigh objectives and their relative importance for particular activities, locations, or groups in the urban area.
2. A general referendum may be employed to elicit community valuation of objectives.
3. A sample of persons in affected groups may be interviewed concerning their relative valuation of objectives (7).
4. The community power structure may be identified and its views on the weighting of objectives and their incidence can be elicited (1).
5. Well-publicized public hearings devoted to community goal formulation and valuation can be held (9).
6. The pattern of previous allocations of public investments may be analyzed in order to determine the goal priorities implicit in previous decisions on the allocation of resources (11).

The determination of community objectives and their relative valuation by the community is no easy task and requires considerable research. However, each of the procedures mentioned above either has been successfully performed (for typical examples

see the studies referred to) or could be performed. It may be desirable to reinforce the determination and valuation of community objectives by one method with an independent determination by another technique.

Even if the relative valuation of objectives has not been empirically determined, the effect of changes in weights on the relative desirability of alternative plans may be usefully explored (4). Different sets of weights might be assumed and the effect of particular weights on the choice of the preferred plan can be determined. The effect of incremental changes in relative weights can also be examined. In this way the decision-maker can be helped if his subjective valuation approximates one of the sets of weights employed.

This, then, is the overall framework that is proposed. We now shift our attention to the evaluation of plans for improvements in urban transportation systems. The first step is the identification of the types of goals which might be furthered or might be thwarted by transportation improvements. In the next section we outline a hierarchy of goals that might be considered in planning a transportation system. The list of goals which follows is derived intuitively and is intended to be illustrative and not exhaustive.

A TRANSPORTATION GOAL HIERARCHY

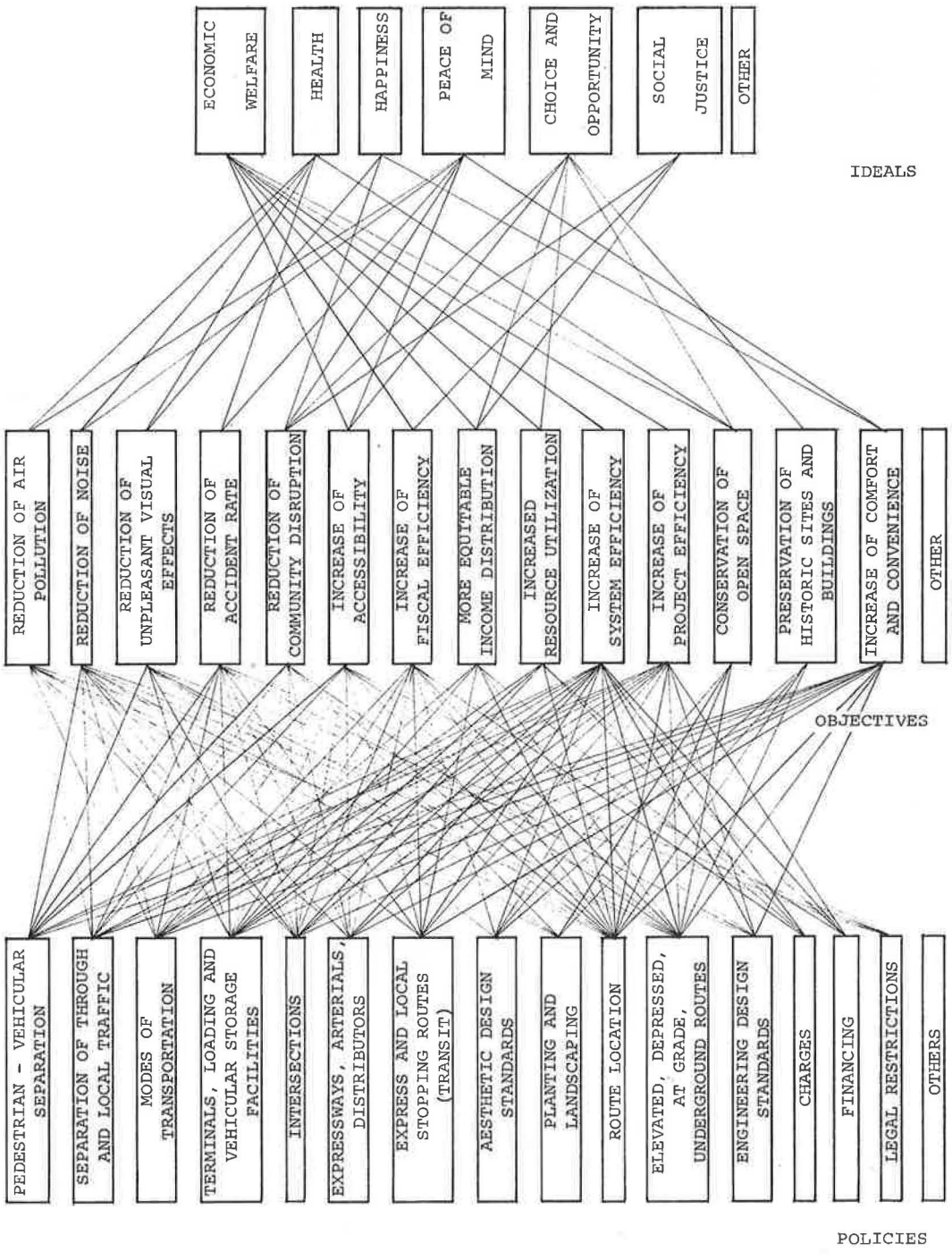
Listed here is a typical set of ideals, objectives, policies and constraints which are relevant for planning improvements in the transportation system.

1. Ideals: increase economic welfare; improve health and safety levels; increase happiness; increase peace of mind (serenity); increase choice and opportunity (freedom); increase social justice; other.
2. Objectives: reduce air pollution; reduce noise; reduce unpleasant visual effects; reduce the rate of accidents; reduce the disruption of existing communities; increase accessibilities; increase fiscal efficiency; achieve a more equitable income distribution; increase resource utilization; improve system efficiency; improve project efficiency; maintain open space; preserve historic sites and buildings; increase comfort and convenience; other.
3. Policies related to: pedestrian-vehicular separation; separation of through and local traffic; modes of transportation; terminals, loading and parking facilities; intersections; expressways, arterials and distributor streets; express and local stopping routes; aesthetic design standards; planting and landscaping; route location; elevated, depressed, at grade, or underground rail routes; engineering design standards; charges; financing; legal regulations; other factors.
4. Requisites: feasibility; immediacy; interdependence.

Diagrammatic Representation of Relationship

Figure 1 shows the relationship between the sets of policies, objectives, and ideals diagrammatically. Lines are drawn linking particular types of policies to particular ideals. At the foot of the diagram are listed the requisites which enter into consideration when the various alternative plans are generated.

The policies are represented as inputs intended to achieve the set of objectives, while the objectives are represented as a set of inputs for the achievement of a set of ideals. The relationship between each type of policy and each objective is considered in turn. Thus, a line joining a policy and an objective means that the particular policy affects the achievement of the particular objective. For instance, the modes of transportation used affect the objective of the reduction of air pollution. It must be stressed that a link between policy and objective does not represent a judgment about the degree of relationship that exists between objectives and policies. It simply states that the type of policy has an effect on the achievement of the objective, and, in turn, that the objective has an effect on the achievement of the ideal. If there is no line, no relationship exists between policy and objective. Thus pedestrian-vehicular separation has no effect on the achievement of a more equitable income distribution and the objective of increase of accessibility has no effect on peace of mind.



REQUISITES: FEASIBILITY IMMEDIACY INTERACTION

Figure 1. Transportation goal flow chart.

Analysis of Goal Achievement

Let us now turn our attention to the objectives, the intermediate level in the goal hierarchy. The extent of achievement of these objectives is analyzed in the goal-achievement matrix. We focus the analysis on the objectives because they are expressed in measurable terms. The objectives are classified in the following according to whether they primarily affect the users of transportation facilities, the immediate environment of transportation routes or the entire urbanized area. A number of these objectives could be classified in more than one category but each objective is listed under that category for which it appears to be most significant.

1. Objectives mainly affecting the users of transportation facilities: (a) increase of accessibility; (b) reduction of the accident rate; (c) increase of comfort and convenience.
2. Objectives mainly affecting the immediate environment of the transportation route: (a) reduction of noise; (b) reduction of unpleasant visual effects; (c) reduction of community disruption; (d) increase of project efficiency; (e) maintenance of open space; (f) preservation of historic sites and buildings.
3. Objectives mainly affecting the entire urbanized area: (a) increase of system efficiency; (b) increase of fiscal efficiency; (c) increase of resource utilization; (d) achieve the desired income distribution; (e) reduction of air pollution.

We now define and propose measures for measuring the extent of achievement of three of the objectives. Limits of space do not permit a detailed treatment of measures of the achievement of all the objectives listed above. For detailed treatment of all the objectives, readers are advised to see the study on which this paper is based (4). In it, the analysis is not restricted only to proposed measures and definitions. The implications of transportation improvements are also explored for each objective. Alternative transportation policies for enhancing the achievement of the objectives are postulated, and the determinants of the relative importance of particular objectives in particular environments are also discussed.

In this paper, definitions and measures are proposed for the following objectives (note that one objective from each of the categories has been chosen for this treatment): reduction of the accident rate, reduction of community disruption, and reduction of air pollution. We shall now consider each objective in turn.

Reduction of the Rate of Accidents Occurring on the Transportation System—Accidents are defined as mishaps on the transportation system causing damage to vehicles and/or to property and/or bodily injuries and/or death. The objective of reducing the accident rate might be measured by determining the probable costs that would result from accidents that would occur if various alternative transportation plans were executed. The following accident costs might be measured: property damage, damage to vehicles, temporary or permanent incapacity, administrative and legal costs, medical costs, personal cost of injury (pain and suffering), and death.

Of these costs, the following can unequivocally be expressed in monetary terms: property damage (this refers to property, other than vehicles, which may or may not be part of the transportation system); damage to vehicles; administrative and legal costs (the administrative costs refer to those accruing to the public authority as a result of the accident, legal costs are the public and private legal costs resulting from the accident); and medical costs.

The use of monetary measures to determine the cost of temporary or permanent disablement has been subject to some question. Nevertheless, the expression of the cost in monetary terms can be justified in that it reflects loss of output (and hence income) due to disability. This can be determined by estimating the future loss of output of those disabled, given a normal expectation of working life discounted to present-day values.

The use of monetary measures to determine accident costs has been severely questioned in the cases of (a) pain and suffering caused by injuries, and (b) death. The average compensation for pain and suffering of various types of injuries, from insurance

policies, or as ratified by the judgments of courts of law, can serve as a basis for determining the monetary costs of pain and suffering.

The determination of the monetary value of a human life that has been lost as a result of an accident is a much more complex problem. The cost of a human life could be measured in one of the following ways (10): (a) the cost of a life—the cost technically necessary to save a life; (b) the price of a life—the expenditure that a community is, in practice, willing to make in order to save a life; (c) compensation for death—the cash award or compensatory payments to near relatives; (d) the cost of a man—the aggregate expenditures on consumption, investment and public service which are devoted to him; (e) the product of a man—the crude value of his production (his contribution to gross national product); and (f) the loss of a man—the loss that a death imposes on the community. Any, or all, of these measures could be employed but, as with compensation for pain and suffering, it may be contended that the entire cost is not recorded since "there is no market for human life, health and grief" (6).

Furthermore, some of these measures are misleading. For instance, the monetary value of a man may be taken to be his product, i.e., his expected output over his lifetime minus his expected consumption of goods and services. Thus, a retired man would have a negative cost for the community. Yet, the community regards the death of a retired man in a road accident as a loss. This is clearly inconsistent. If compensation is used as the value of a human life, then the accident cost of an injury may be higher than the accident cost of a death. A person who is injured in an accident may claim for medical expenses, for pain and suffering, and for loss of potential earnings. If a person is killed, his next of kin may claim for their financial interest in his potential earnings, but no one claims for the lost life. The actual money that the community is ready to spend in order to save life varies widely and depends mainly on the amount of public sentiment that is aroused by the way it is lost. For instance, if 10 people are killed in an air crash, a full inquiry may take place, but if 100 people are killed on the highways, it may be accepted as a matter of course. Or, if a child is missing, no expense is spared in an effort to save its life, but the same amount of money may not be readily spent on road improvements in order to prevent accidents which may take two (unknown) children's lives every year.

In spite of these objections, it might be advisable to choose a monetary scale of value for a human life and for injuries based on one or more of the given criteria (2). However, in order that perspective not be lost, it is advisable to include a simple statement of the expected number of injuries and fatalities that will probably occur on a transportation system as a result of a proposed transportation improvement.

Probable accident costs can thus be expessed in one of three ways:

1. All costs could be expressed in money terms.
2. The following costs could be expressed in money terms—property damage, vehicle damage, medical costs, administrative and legal costs. The other costs (incapacity, pain and suffering, and death) could be expressed in terms of the number of injuries (by type) and the number of fatalities that would probably occur.
3. All costs could be expressed monetarily. However, these could be supplemented by a statement of the expected number of injuries (by type of injury) and the expected number of fatalities.

Reduction of Community Disruption—This goal refers to the direct effects on communities immediately adjacent to the proposed transportation improvements resulting from the location of the route. Two such effects are evident: (a) the displacement of residential, commerical, industrial and institutional buildings by the proposed route; and (b) the boundary effects of the transportation route. Let us consider these effects in turn.

The Displacement of Residences and Other Buildings—Inevitably, when a new transportation route is chosen in a built-up area, some activities have to be displaced. The objective might be to reduce the number of households, firms and institutions that are displaced. Even though the displaced residents and businessmen may be compensated and relocated elsewhere, the financial compensation may not be equivalent to the actual

money loss. In addition, there are psychological costs resulting from relocation which are seldom subject to compensation.

The older the resident or businessman displaced, the greater the financial and psychological difficulties are likely to be, particularly if the person displaced has been in the neighborhood for a long period. The older residents' involuntary departure from a neighborhood and adjustment to a new environment is inevitably more difficult than that of younger residents. If a business brings marginal profits, and this is likely to be the case in old neighborhoods where small businesses may supplement retirement incomes, it is likely to be wiped out if it is displaced. Similarly, the older the employee of a displaced business, the more difficulty he can expect to meet in finding new employment. Furthermore, if some of the residents, businessmen or employees belong to groups which suffer from discrimination in housing, business locations or opportunities for employment, they are likely to face more difficulties than others who are displaced. Therefore, priority should be given to those who are best able to adjust to displacement.

The Boundary Effects of a Transportation Route—These effects might be positive or negative. On the one hand, the new route might reinforce boundaries between two neighborhoods. It might separate two conflicting land uses, e.g., medium to heavy industry and residential or commerical districts. It may also set up barriers in a once-homogeneous community, thereby dividing what may be a school district, a congregational district, or an effectively integrated neighborhood (leading once more to the segregation of ethnic groups).

In the measurement of the reduction of community disruption, again let us consider (a) the displacement of households, firms and institutions; and (b) the boundary effects of the transportation route.

The Displacement of Households, Firms and Institutions—Two parallel measures are here proposed: (a) the number of displaced households, firms, institutions and employees classified according to various demographic variables; and (b) financial costs accruing to these groups as a result of relocation. The following groups of persons who would be displaced are analyzed in terms of the measures: landowners; residential occupiers, both tenants and owner-occupiers; businesses, both proprietors and employers; and institutions, both employers and employees.

The following data are gathered and considered according to the above categories:

1. Landowners
   Demographic data—(a) number of landowners displaced; (b) amount of land absorbed and type and amount of land uses displaced.
   Financial data—net loss or gain of landowners = financial compensation for property taken minus net revenues foregone.
2. Residential occupiers
   Tenants
   Demographic data—number of households classified by size of household, age of head of household, race, income, group and duration of occupancy.
   Financial data—(a) difference between existing contract rents and expected contract rents; (b) disturbance costs, i.e., compensation minus costs of moving.
   Owner-occupiers
   Demographic data—number of households classified by size of household, age of head of household, race, income group and duration of occupancy.
   Financial data—(a) difference between compensation and replacement costs; (b) disturbance costs, i.e., compensation minus costs of moving.
3. Businesses
   Proprietors
   Demographic data—number of businesses, classified by type, age of business, age of proprietor; number of businesses likely to be wiped out.
   Financial data—(a) for businesses likely to be wiped out, difference between net profit (over time) and compensation; (b) for businesses likely to continue elsewhere, difference between expected income loss while developing new clientele and compensation; (c) disturbance costs, i.e., compensation minus costs of moving.
   Employees

Demographic data—number of employees classified by occupation, age, race, number of years of employment in same occupation.
Financial data—(a) additional travel time and additional out-of-pocket expenses; (b) expected change in income (including expected drop in income of probable unemployed).

4. Institutions
Employers
Demographic data—number and types of institutions.
Financial data—disturbance costs, i.e., compensation minus costs of moving.
Employees (Data same as for employees of businesses displaced.)

The Boundary Effects of the Transportation Route—The probable boundary effects of a transportation route can be measured in the following ways.

1. Land-use analysis—The existing and proposed land uses and the alternative route locations are examined and the following questions are asked: (a) Does the proposed route cut across districts with similar land uses on both sides of the route? (b) Can the route serve as a boundary for conflicting land uses?

2. Trip origin and destination analysis—The origins and destinations of short trips from and to locations in the vicinity of the proposed route are examined in order to determine that route which crosses the least number of origin-destination lines.

3. Market and service area analysis—The market areas of businesses and service areas of various community services (schools, libraries, churches, etc.) in the vicinity of the route are determined. The question is then asked: Which of the alternative routes proposed disturbs the market areas and the service areas least?

Reduction of Air Pollution Caused by the Transportation System—Air pollution is defined as the presence of foreign matter (particulates and gases) in the air at levels of concentration which are considered objectionable, i.e., the pollutants affect man's well-being or interfere with the use and enjoyment of his environment. Although there is no universal agreement on the proportion of foreign matter which has to be present in the air for it to be considered polluted, some cities have instituted standards.[1] While a limit exists to the proportion of foreign matter in the air that man can tolerate in any environment, different environments might tolerate different levels of air pollution. For instance, higher concentrations of foreign matter may be acceptable in the air of industrial areas than in residential areas, or in areas where schools and hospitals are located.

A transportation system may cause air pollution in the following ways:

1. Emission from the exhausts and carburetors of gasoline or diesel-operated automotive vehicles.

2. The gases, smoke and soot produced by coal-burning steam locomotives. While this source is not significant in the United States, it is a major source of air pollution in Britain and other countries.

3. When transit units are driven by electric power, an additional load is put on the electric power supply. This demand gives rise to some air pollution regardless of whether power is derived from oil or coal.

The emission from automobile exhausts is by far the most significant "contribution" of the transportation system to air pollution in the United States. Estimation of the pollutants produced by automotive vehicles is based on the number and type of vehicles used, the number of vehicle miles traveled and the quantity of fuels consumed. Air pollution from automotive sources is not restricted to exhaust emissions. A considerable amount of fuel evaporates during the marketing operation and evaporation from

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[1] "The level at which Los Angeles sounds a first alert, meaning that certain air-polluting activities must cease, is 0.50 parts per million. It considers 'adverse' a reading 0.15 parts per million for 1 hour—enough to cause eye irritation, impair visibility and damage vegetation." Quoted by Sen. Abraham Ribicoff in Hearings Before a Special Subcommittee on Air and Water Pollution of the Committee of Public Works, U.S. Senate, 88th Congress, Sept. 9, 10, 11, 1963, p. 45.

fuel tanks and carburetors accounts for a considerable proportion of the fuel used by automotive vehicles.

Techniques for the measurement of air pollution have been fairly well developed. Most large cities have several strategically located sampling stations. The measurement of pollution at different locations and at different times is at least as important for considering the effects of transportation improvements as the determination of the average pollution level.

The level of air pollution may be established by determining the amount of air pollutants of various types per unit volume of air. In any area, existing air pollution levels may be measured. By means of a continuously operating system of surface wind observing stations, it is now possible to draw reasonable inferences as to the frequency of weather conditions in an "airshed" which would be conducive to high air pollution levels (3). If information is available on local air flows and their variation in time, it is possible to develop hourly maps showing existing airflow patterns over specific areas. Data on precipitation as well as data on the amount of sunshine received diurnally and seasonally are easily obtained. On this basis, it is possible to predict regional air pollution dilution capacities.

The information on existing regional air pollution and on regional air pollution dilution capacity is considered together with various land use and demographic data. By considering the existing and proposed land use plans together with predicted population growth and density, predicted automobile ownership and consequent traffic flows as well as the information on existing air pollution and regional air pollution dilution capacity, it is possible to determine whether air pollution from transportation sources is likely to be a serious problem.

Let us now consider local air pollution. At this scale the planner examines the relative importance of the reduction of air pollution in the planning of transportation projects, e.g., a new link in a street network or in a transit system. Among the environmental conditions that must be considered are the general characteristics of the airshed and both the direction of the prevailing winds in the area and local wind patterns. The topography might create local winds. It is important to know not only the direction of the prevailing winds and local windflow pattern, but also the likely direction of dispersion of stationary air masses.

The next step is the estimation of expected levels of air pollution in the vicinity of the transportation improvement. The transportation plan spells out the proposed route. The expected volume of vehicles at various times of the day, the quality of the route (i.e., whether limited access, arterials, etc.), the number and nature of intersections, transit and bus stops, etc. With this information, it is possible to compute the expected amount of pollutants emanating from the planned facilities by time of day. The estimate of expected local air pollution and regional air pollution together with the information on environmental conditions enables the analyst to plot a map of expected air pollution levels at various locations alongside the proposed transportation route.

The next step is the review of existing and proposed land uses in the areas adjacent to the transportation route. For each of these land uses, acceptable thresholds of air pollution can be established. Standards can be instituted which relate the amount of air pollutants per unit volume of air which are acceptable for various types of activities at various densities without requiring public intervention to reduce levels of air pollution. Expected levels of air pollution at various locations can then be compared with acceptable levels of air pollution for the various activities at the various locations.

CONCLUSION

We have described the general framework for the analysis of multiple objectives and we have postulated a set of transportation objectives that might be treated within the framework. While the method proposed calls for an extremely complex task, the conceptual framework is recommended as a basis for rational decision-making. The method of evaluation has been demonstrated as workable in the comparison of alternative plans for Cambridge, England (4).

By determining how various objectives will be affected by proposed plans, the goals-achievement matrix can determine the extent to which certain specified standards are

being met. Is the transportation plan likely to meet minimum accessibility requirements and minimum standards of comfort and convenience? Are levels of air pollution and noise likely to exceed specified standards? Is the fatal accident rate within prescribed acceptable limits? These are the types of questions that the goals-achievement matrix is designed to answer. It can also determine the costs of meeting specified standards in terms of the achievement of other "open-ended" objectives which would have to be forfeited. Different plans have different trade-offs between the achievement of objectives and standards, and these can be compared.

The application of the goals-achievement matrix requires the weighting of objectives and their incidence. As has been demonstrated in the comparison of the Cambridge plans (4), it is possible to arrive at a definite conclusion by the application of relative weights. The goals-achievement matrix is obviously of limited usefulness if weights cannot be objectively determined. The further development of methods for the determination of weights is thus of first priority for the successful application of the goals-achievement matrix.

We have proposed a set of measures for determining the extent of achievement of three of the objectives. Measures for the other objectives can be determined in a similar manner (4). It should be noted that while the costs and benefits relating to some of the objectives (e.g., accessibility, accident reduction, project or system efficiency) are incorporated into present-day evaluation procedures, others are usually treated as "intangibles" and omitted from consideration. We have shown how certain intangible effects such as community disruption and air pollution may be measured. By means of goals-achievement analysis and the application of relative weights, many of the intangible effects can be measured and considered simultaneously with costs and benefits relating to more tangible effects.

Because this approach to evaluation is new, much of the data necessary for the analysis is not readily available in most urban areas. The absence of data is part of a vicious circle. Because transportation planners have not focused on the types of questions here proposed, the data have not been sought. However, data for the types of measures of objectives that have been described can be obtained. The task is not easy, but if successful should prove worthwhile.

Perhaps it will never be possible or advisable to include, at least quantitatively, all of the relevant costs and benefits. However, we can hope to measure more consequences of courses of action than were considered in the past, and we can measure others more accurately than in the past, making final evaluation easier.

The task is undoubtedly complex. But the complexity of the task is no excuse for abandoning the attempt. The comparison of alternative courses of action with respect to the goals in view and the identification and measurement of the costs and benefits of these courses of action with regard to the achievement of all relevant community goals is proposed as the "rational" way to approach the evaluation of alternative transportation plans.

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