Economic Concepts of Highway Planning

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The paper discusses (a) the micro-economic treatment of highway projects, defined as the smallest units of decision-making; (b) program analyses where system effects, compatibilities and incompatibilities of various projects in time or space have to be resolved; and (c) the micro-economic reconciliation of highway claims for resources with possible other demands for them. The analysis aims at rational resource allocation and attempts to provide economic criteria for the solution of broad transportation problems; for example, in a regional or metropolitan context.

●IT IS THE purpose of this paper to inquire into the usefulness and limitations of economic concepts in the highway field. Economic abstractions under fairly rigorous assumptions are presented. Any practical examples used in the text are meant as illustrative and should therefore be regarded as incidental to the main theoretical theme. At the same time, the concepts put forward are designed for practical application to the many important highway decisions which now must be made.

There is an urgent need to employ the best possible economic tools in highway decision-making all the time. In 1959, for example, public highway expenditures alone amounted to an estimated $10.5 billion (1). The magnitude of all private and public spending on highway transportation currently may be approximately $75 billion per year. The size of this segment of the economy and the causal relationship between governmental and private action impose special responsibilities on the public decision-makers in the highway sphere.

Specifically, this paper carries the discussion into the urban transportation sphere. The 184 metropolitan areas in the United States contain 66 percent of the population and 70 percent of all industrial workers, and it is said that these regions "are being strangled by congestion." (2, p. 52) About 25 percent of all highway-user tax proceeds were spent in urban areas in 1958, whereas in 1946-47 this proportion was only about 10 percent. It is generally predicted (3) that the big conurbations will attract increasing shares of the population in the years to come; there may be 30 Standard Metropolitan Areas in 1980, as compared with 14 in 1950, with populations of more than 1 million; by 1980 the New York-Northeastern Standard Metropolitan Area alone may comprise some 20 million inhabitants.

Massive and complex metropolitan transportation problems will have to be solved in future years, especially in the passenger transportation segment. The interactions between highway transportation and many social, political, esthetic and other wider aspects of urban life are particularly powerful. Thus, there is every reason to make sure that the economic tools are equal to these tasks.

OBJECTIVES AND ASSUMPTIONS

Economic Objectives

Economic objectives in transportation are stated succinctly and authoritatively in the recent U.S. Department of Commerce report on transportation to the President:

> The Nation requires policies which will encourage maximum efficiency in the performance of the transportation function. A part of the cost of nearly all goods and services purchased by the public represents payment for transportation of one kind or another. Hence a reduction in the cost of transport enhances the national product and enlarges the opportunities of all the consumption of direct goods and services...At a given level and structure of capital investment, efficiency requires that traffic be distrubuted among (different carriers) in such a way that each type receives the traffic which it can carry with the least consumption of resources by the carrier for the service standards required by the user. It requires also that several forms of transport be used in coordination where such a combination can produce a better service-cost result than any single form working alone. (4)

Efficiency requires, the report postulates, that transport services of a given standard be performed with the least consumption of resources. Therefore, two aspects must be considered by the analyst: resource consumption, or cost; and service standards, or the right service quantity-quality admixture. If transportation of the same or higher service standards can be performed at lower cost, resources can be put to better use in fields other than transportation. The prices such resources command in the market place provide a good index for their usefulness in alternative employments. Therefore, the opportunity costs of resource use for highway or other transportation purposes must be considered.

How is it possible that "a reduction in the cost of transport enhances the national product?" Is transport not part of the national product, so that when one increases in dollar magnitude, the other does too? The staff study which accompanies the report states: "The transportation service is not, for the most part, an item of direct consumption. It is a facilitating service required in connection with virtually all production throughout the economy." (2) The transportation function is seen as a means to an end, but not as an end in itself. If it can be performed satisfactorily at lower costs, that much more resources are available for the consumption of direct goods and services. The study mentions that beneficial multiplier effects may result from transport cost reductions. The national product will be enhanced if resources can be spared from transportation (a facilitating service) without impairing its performance, and can be put into the production of direct consumption goods.

Simultaneously with costs, quantity and quality of service have to be taken into account. The constraint is "service standards required by the user." This raises questions: Who determines these requirements? Is "desired" the same as "required"? Granted that identical service performance at lower cost is an unequivocal efficiency improvement, how can one judge the merits of a higher service standard at higher cost, or of lower service standards at lower costs? The analyst's task is greatly eased when a definite requirement for a certain quantity and quality of necessary transportation services can be assumed. This may be applicable to the typical metropolitan passenger transport situation. The objective then simply becomes performance of the given task at minimum cost.

Assumptions

The following general assumptions are made:

1. Resources are scare relative to the possible uses for them. This is a basic assumption in economics and gives meaning to the efforts to economize.
2. Expenditures on highway transportation—as compared with expenditures on other things—are not presumed to have any special employment-creating or other beneficial macro-economic effects. There would have to be evidence for the superior Keynesian multiplier repercussions of investment in highways, as compared with investment in other transportation facilities, hospitals, schools, housing, private enterprises, etc.,

before these could legitimately be considered in the analyses. If there were unemployment of specific highway transportation resources, coupled with a signal lack of mobility of such resources for switching to other fields, these special conditions would normally be reflected in lower factor prices. They would thus be taken care of automatically in the analyses.

3. There is one public agency in charge of transportation matters within the metropolitan region or other area under study. This agency is sovereign within its jurisdictional boundaries. Efficiency of the appropriate administrative organs is guaranteed. In short, it is assumed that the necessary institutional and administrative arrangements can be made to carry out policies which were found desirable on analytical grounds. (These assumptions conveniently remove many intricate aspects of inter-governmental responsibilites, grant-in-aid procedures, integrity, competence and organizational efficiency of various levels of public authority, etc., from the scope of this paper. It is felt that these complex and important questions can best be dealt with by means of specific case studies.)

4. The chosen metropolitan or other transportation agency has as its objective the promotion of the public interest. Such public interest is whole and indivisible within the authority's geographic area of jurisdiction. Whenever there is conflict of interests, different functional and sectional groups (users and non-users, suppliers and consumers, private and public organizations, business and non-commercial factions) are given impartial consideration.

5. The chosen public agency will consider all important effects of possible actions No repercussions will be ignored or rejected by the engineering and economic analysts just because other disciplines are involved. This assumption is in accordance with the tenet of scientific method that all pertinent evidence must be brought to bear upon the problem on hand.

6. Reliable field data will be obtained.

7. The metropolitan decision-makers have no vested interests or prejudices in favor of public or private ownership of factors of production, nor in favor of one particular technology. There is no preconceived notion, for example, that driving in automobiles by itself is good for the economy and constitutes the proper metropolitan way of life. Proposals are considered strictly on the basis of their merits as revealed by unbiased analyses.

CONCEPTS AND DEFINITIONS

It will be convenient to divide the wide spectrum of decision-making authority of an assumed metropolitan transportation authority into definite, somewhat arbitrary, segments (Table 1). In accordance with assumption 5, all important effects of possible actions by the transportation agency will have to be considered. Therefore the broadest possible definitions of "costs" and "gains" apply. The various values that will enter into the analyses are categoried in Table 2. The terms "costs" and "gains" are self-explanatory: the former denotes all the undesirable effects one wishes to minimize; the latter, all the desirable effects one wishes to maximize.

Internal and External Values

Within the dichotomy of costs and gains, the distinction between internal and external values is made by defining the viewpoint, or planning horizon, or area of interest and responsibility, of the particular decision-maker. In accordance with assumption 4, the hypothetical metropolitan transportation agency under discussion is charged with the promotion of the entire, indivisible metropolitan public interest. Therefore, all cost and gain effects set up by its actions will be internal to the agency's viewpoint and will be taken into account for decision-making.

Why, then, make a distinction between "internal" and "external" effects at all? This distinction arises entirely from the location and delegation of authority. It is difficult for the human mind to comprehend all at once a great number of interrelationships. To do one's daily work with reference to so vague a concept as the national public interest, or even the geographically more limited metropolitan public interest seems quite impractical. Therefore, engineers, analysts, technicians working at the project level of decision-making are normally not required to worry about program, activity or general economic effects. Repercussions resulting from the construction of a particular highway and imposed upon the rest of the highway program, upon transportation as a whole and the community or region, will be regarded by the project engineer as being of no concern to him, as external to his viewpoint. But just because these effects are regarded as external from the very limited project viewpoint, does not mean that they can be ignored. They simply have to be analyzed at a higher decision-making level. Similarly, in private enterprise, the foreman or engineer in the shop will rarely be concerned with higher-level problems, such as personnel policy, investment strategy, budgeting, research, and public relations; but these vital aspects will certainly be studied and resolved at the company level.

In short, what may be external from the point of view of the project, will still be internal in some fashion to technology, or activity, or economy. As a mental image, it is perhaps useful to think of the various cost and gain effects set up by an action as being contained in various ways by boxes; these are little boxes (projects), within bigger boxes (programs or technologies), within still bigger boxes (activities), within one ultimate box (the economy). The choice of box to be examined analytically will determine the designation of effects to the external or internal categories.

By assumption, decision-making authority is put at the highest level, that of the metropolitan economy. This is a highly centralized, over-all planning approach within a limited geographical area. It is certainly possible to quarrel with this assumption. It might be argued that it is better, in the interest of efficiency, enterprise and staff incentive, to set the viewpoint at a lower level, for example at the program or technology level. Then planning carried out by a highway department, for instance, would simply ignore repercussions of actions upon other transportation media and upon the economy as a whole, as being external to the viewpoint and therefore of no concern to the decision-makers.* Some public agencies, in real life, appear to take this more restricted approach. If this is the case, it should be clearly stated that this is planning in the interest of the highway or other technology, and not necessarily in the general transportation or public interest. The author happens not to agree that this limited approach is appropriate for governmental agencies, simply because he believes that the public interest should not be broken down into narrow sections and technologies in this way. But there is room for honest differences of opinions, which would here simply affect the assumptions, but not the analyses themselves; if the planning and decision-making horizon is limited to program or technology, transportation and general economy costs and gains will simply be regarded as external to the viewpoint and therefore omitted from all subsequent considerations. In fact, in the present study,

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*There is frequently some confusion of public enterprise with the image of competitive private enterprise. In terms of Table 1, the individual firm can be seen to take a technology or program viewpoint, by carefully planning projects (internal processes, products, subsidiary operations, etc.), ignoring effects upon competitors (activity or industry repercussions) and the rest of the economy. Hence, why should, say a public highway department not act in the same way? This rather naive view of things ignores a number of crucial points: (a) private enterprise, precisely because of its competitive behavior--elaborately defined--is supposed to further the public interest; (b) violations of the "rules of the game" by private enterprise (e.g., infliction of external costs on the community, or anti-trust law infractions through "planning" by firms at the activity or industry level) are penalized by public action; the rendering of incidental beneficial effects (external gains) is frequently rewarded through public subsidies; (c) highway departments and other public enterprises simply do not operate within a competitive environment, as defined; indeed, the absence of the conditions necessary before private enterprise can flourish in the "public interest" led to assignment of these functions to public enterprise in the first place; the lack of penalties (immunity from anti-trust laws) and profusion of subsidies, tax exemption, and other favors calls for a doubly cautious approach. The author believes that the correct economic "model" for, say, a highway department is that of a powerful public monopoly.

TABLE 1

LEVELS OF DECISON-MAKING

Project: Smallest technical unit which can fulfill desired service objectives. For example, a complete highway connection, a complete overpass, a complete subway installation; but not partial project construction, such as grading, bridge abutment building, tunnel excavations, by itself.

Program or Technology: A number of projects which are interrelated by technical, functional and economic factors. For example, a highway network, or a subway system, or a series of interrelated construction projects planned over a period of time in a given area.

Activity: Projects and programs seen within the context of transportation as a whole.

Economy: Consideration of all activities within the jurisdictional boundary lines; in this case, the metropolitan economy.

TABLE 2

VALUE CATEGORIES AND DEFINITIONS

COSTS: Total costs, efforts, sacrifices, inputs, means, losses, outgoes.
- Internal: Internal to viewpoint, objectives, responsibilities of decision-maker or analyst; incurred by project (program or technology, activity) itself.
  - Market: Costs satisfactorily expressed by market prices; acceptable money costs.
  - Non-Market: Other costs.
- External: External to viewpoint, objectives, responsibilities of decision-maker or analyst; incurred outside project (program or technology, activity).
  - Market: Costs satisfactorily expressed by market prices; acceptable money costs.
  - Non-Market: Other costs.

GAINS: Total revenues, benefits, rewards, outputs, ends, proceeds, incomes.
- Internal: Internal to viewpoint, objectives, responsibilities of decision-maker or analyst; accruing to project (program or technology, activitity) itself.
  - Market: Gains satisfactorily expressed by market prices; acceptable money revenues.
  - Non-Market: Other gains.
- External: External to viewpoint, objectives, responsibilities of decision-maker or analyst; accruing outside project (program or technology, activity).
  - Market: Gains satisfactorily expressed by market prices; acceptable money revenues.
  - Non-Market: Other gains.

first a project viewpoint is adopted, which initially ignores repercussions external to that particular horizon. Only later, for convenience of exposition, are the wider interactions studied. It is thus up to analysts how far they wish to go in their studies.

Market and Non-Market Costs and Gains

The market and non-market value categories may next be scrutinized. The distinction arises from the measurability or non-measurability of effects for purposes of economic analysis. Difficult concepts are involved and some words of explanation necessarily brief are in order. Following Schumpeter's exposition (6, pp. 1060n and 1062n), a quantity or magnitude is defined as anything that is capable of being greater or smaller than some other thing; this implies only transitivity, asymmetry, and aliorelativity. Measurability, on the other hand, requires the fulfillment of two more conditions: (1) that it be possible to define a unit; and (2) that it be possible to define addition operationally, so that it can actually be carried out.

Non-measurability is acceptable if one is interested in a maximum problem. As Schumpeter points out, there are ways of telling whether one is on top of a hill without actually measuring the precise elevation of the spot. Likewise with a minimization problem. This is of some practical significance, as will be seen. Turning to measurability, it should be observed that generations of economists have given much time and thought to this aspect, especially in relation to the Theory of Utility. At first it was held that utility sensations, or the pleasantness and unpleasantness of sensations, could be measured directly, as a sort of psychic reality, in the same way perhaps as length can be measured. Later, Marshall adopted the much weaker assumption that, though "we cannot measure utility or 'motive' or pleasantness of sensations directly, we can measure them indirectly by their observable effects, a pleasure for instance by the sum of money a man is prepared to give up in order to obtain it rather than go without it." (6, p. 1060) An analogy might perhaps be the measuring of heat with a thermometer. These two approaches, direct and indirect measurability, are generally known under the name of "cardinal utility theory." Further developments resulted in various versions of the theory of ordinal utility, which embraces the indifference curve apparatus and the system of marginal rates of substitution. When employing these newer economic tools, the analyst enjoys independence from measurability of utility, inasmuch as there are just scales of preferences: (a) the consumer considers certain combinations of, say, two commodities as equally eligible; these are shown on the same indifference curve; (b) he prefers combinations on a higher indifference curve.

What is the relevance of these theoretical concepts to transportation problems in general and to the values shown in Table 2 in particular? It is submitted that the so-called "benefit"* analyses in the highway field are really cardinal utility efforts, some of them of Marshallian parentage, some of them of pre-Marshallian ancestry. Highway benefit-cost calculations now constitute one of the major intellectual links between the engineer and the economist in this field. Although the enthusiasm of the technical group for economic concepts is laudable, some of the serious shortcomings and limitations of these tools must be pointed out.

Few, if any, economists would maintain nowadays that one can directly measure (cardinal) utility and disutility. Let us consider the indirect measurement of utility, which is achieved by observing the amount of money persons are prepared to surrender in various situations. Here, it should be noted, rather stringent conditions must be fulfilled before money outlay is acceptable as an indirect measuring rod for sensations which cannot be measured directly. In particular, the notion of the market transaction has been evolved by economists. Money outlays or prices are said to be true expressions of value when the exchange of goods and services between sellers and buyers takes place under competitive market conditions; that is, when (a) there are many buyers and sellers bargaining freely, (b) each one of them has equal knowledge of what is going on, (c) the goods or services exchanged are identically similar, and (d) no single buyer or seller can influence the market price. But even if some sorts of price signals come through, there may be, as Ciriacy-Wantrup (7) points out, serious distortions at work (for example, if an equalitarian society is held to be desirable, on ethical or political grounds, price signals received from rich people would be considered to be too strong and those from poor people too weak), monopolistic, duopolistic, etc., market organizations, heavy advertising, and other imperfections, would also be the cause of warped price signals.

Consequently, market values are spoken of when reliable price signals are being received and can serve for indirect measurement. Non-market values, on the other hand, indicate that either there is no market at all, or the price signals are seriously distorted.

To be sure, the analyst will undoubtedly encounter mixtures of both market and non-market values when the merits of particular highway proposals are being studied by him. Following a cardinal utility approach, which in itself has its drawbacks the dollar magnitudes of market value items may serve as indirect measurements for the desirable and undesirable effects of contemplated action. But what about non-market value items? Quite clearly, lacking the dollar yardstick, decisions will have to be based on what is generally known as "value judgment." This term conveniently embraces various shades of meaning. It may mean that an ethical judgment is involved—some action is held to be good or bad and any further discussion has to proceed on

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*The expression "gains" is preferred here for teminological and definitional convenience. Benefits normally denote desirable effects other than money revenues, whereas gains in this study embrace all beneficial repercussions. Besides, because of loose use in the literature, benefits have acquired a somewhat doutbful reputation of late.

grounds of moral principles. It may also mean that the judgment is a subjective one, or at least questionable or debatable, as perhaps in the case of an aesthetic judgment.

How to deal with the sometimes very elusive non-market items and how to render the best possible value judgments, are matters of very grave concern in the urban transportation field. Following are some suggested practical approaches:

1. Market and non-market values are stated separately in the analysis, the former in dollars, the latter in words. For example, a freeway might set up these effects: market costs (money construction and operating costs) $1.2 million, market gains (cash user revenues) $1.4 million, quality of service gains "good," accident effects "considerable." With reference to the earlier discussion on cardinal utility, it should be noted that only the market values are employed for indirect measurability. The quality and accident effects are appropriately stated as non-measurable quantities. It is not possible to define addition operationally, therefore cash costs and gains, accidents, quality of service cannot be aggregated. A value judgment will eventually have to be rendered for decision-making purposes.

2. As an analytically fortunate variation, consider that two projects A and B are to be compared. Project A has the characteristics of the freeway previously described, project B these: market costs $1 million, market gains $1.5 million, quality of service gains "excellent," accident effects "slight." Clearly, project B is to be preferred on all counts. (Note that the search for alternative solutions is all-important here.)

3. A further variation of this is equality of some values, and superiority in one respect. For example, if B is identical to A in all respects, except that it would result in "slight" rather than "considerable" accident effects, it should be the logical choice.

Of course, as soon as there are more complex situations—one project better in some respects, worse in others—value judgments will be required for final decision-making.

4. Non-market values are translated into precise physical, but not into money terms. This is essentially the same as items 1, 2 and 3, because the separate quantities (which now have units for counting) can only be aggregated (or weighted) for decision-making by further value judgment. The advantage is that performance units are clearly stated, so attainment or performance can, ex post, be checked from time to time. This may cause the field analysts to work more conscientiously.

5. Going a step further and converting non-market values, whether stated in words or in precise physical terms, into dollar figures. Such outright translation might be condoned on occasion when non-market effects form a very small proportion of total costs and gains.

It might be argued that complete conversion into dollar values would greatly simplify the remaining analytical task. The viewpoint might further be put forward that this procedure should be employed in a money-oriented society if at all possible, because money will be the language most easily understood.

It must clearly be borne in mind, however, that any such conversion lacks support by generally acceptable economic standards (market price) and therefore definitely requires value judgment. Conversion into money figures may obscure important moral issues (highway accident deaths) and may lead to poor decisions for this reason.

6. If the above methods have been exhausted, there is no getting away from the fact that some value judgments have to be made somewhere. The practical working principle for the analyst is that complete, detailed evidence—in whatever form it is submitted—will contribute greatly to intelligent decisions. The analyst's professional information should be purged of his personal value judgments. This does not mean that in addition he, as a citizen of integrity, intelligence and knowledge, may not submit his considered ethical, social, aesthetic, or other views. Indeed, complete detachment—"this is for the politicians to decide"—in itself constitutes an extreme value judgment.

7. The value judgment and decision-making powers will finally have to be entrusted to a person or a group of persons. These powers may be given to elected or appointed officials, or to a committee. Alternatively, and outside expert may be retained and some of the value judgments will be made by him. As a further possibility, the value

judgments can be shifted to the general populace, through a referendum, a bond issue vote, or some other form of public opinion survey. There are combinations of these methods (for example, committee reports or consultants' recommendations are put before the voters). The choice of decision-maker, outside expert, committee members or officials, voting or public opinion survey method, implies value judgments.

8. Outside standards may be applied or experience over time may guide decision. This is really a variation of delegation of decision-making power, in space or over time.* The numerous standards, manuals, recommended procedures issued by national authorities and associations (Bureau of Public Roads, AASHO, Highway Research Board) belong in this class. Although any national standards of this type are riddled with value judgments, they do spare local officials the agonies of having to formulate their own. They also have solid advantages of uniformity and administrative convenience. They are frequently based on enlightened deliberations and research.

Caution must be exercised when standards are used blindly as substitutes for value judgments. If last year's or other jurisdictions' experiences are adopted as desirable norms, rather than merely as indices of past or central tendencies, this will inevitably lead to static objectives and achievements. Acting entirely on the lowest common denominators emerging from public opinion polls and the like may have similar effects. As Musgrave (9) points out, the "premise of individual preference in a democratic society" does not rule out the so-called "merit wants" which are justified by the role of leadership in a democracy; for example, "...the advantages of education are more evident to the informed than the uninformed, thus justifying compulsion in the allocation of resources to education."

These are some of the thoughts that come to mind when considering non-market values in relation to the decision-making process. In all, eight value categories are proposed here: there is first the fundamental distinction between costs and gains; within these two broad groups there is the two-fold breakdown between external and internal, and between market and non-market values. As was pointed out before, with the analytical and decison-making viewpoint set at the highest (metropolitan) level, all effects are within the planning horizon and therefore the external-internal distinction need not be made; only four value categories remain. The definitions and classifications set forth in Tables 1 and 2 may not be ultimate perfection, but they are believed to be improvements over present practice. In the current highway and general public enterprise literature the following confusing, ill-defined value categories can be encountered: pecuniary and non-pecuniary, internal and external, private and social, non-transfer, and transfer, on-site and off-site, direct and indirect, market and extra-market, economic and non-economic, measurable and non-measurable, tangible and intangible, direct and spill-over, individual and collective, primary and secondary, monetary and non-monetary. There may be still other terms. Agreement on terminology would be a definite step forward.

A Freeway Demonstration Case

To bring this discussion to immediate, practical application, Table 3 provides a list of cost and gain effects which can be expected to be set off by major highway action in urban areas; for example, by construction of a freeway through a metropolis. Some important items may be missing from the list and some unimportant ones may have

*The elegance of mathematical techniques employed notwithstanding, this—no more and no less—is also the gist of Vaswani's (8) proposals for highway planning. A highway official designates as satisfactory an existing highway, which is similar to the planned new facility. Given the administrator's decision, plus technical, cost, traffic, etc., data for the reference highway, it is then possible to work back to the "irreducible" factors, in this case the value of time savings to highway users. Choice of administrator, reference highway, technical standards, etc., of course, all imply value judgments. This does not detract from the advantages of flexibility and adaptability to local conditions which Vaswani's technique offers.

included, but Table 3 will do for demonstration purposes. Other students of the subject may be able to devise improved versions. As can be seen, whenever reliable market values are believed to exist, a dollar sign is shown; asterisks indicate non-market items and question marks doubtful ones. The designations are based on the author's judgment and there may be personal bias.

TABLE 3

POSSIBLE COST AND GAIN EFFECTS OF A FREEWAY PROJECT[a]

Costs		Gains	
Freeway Project Costs		Freeway Project Gains	
Right-of-way, construction, interchanges, approaches, feeders, landscaping, beautification. Public costs.	$	User charge revenues, fuel tax, license fees, parking revenues. Public gains. (No true market for highway use.)	$ *
Freeway, etc., operating. maintenance, overhead costs. Public costs.	$	Concession, advertising, etc., revenues. Public gains.	$
Vehicle fixed and operating costs net of user charges. Private costs.	$	Savings in door-to-door travel time. Private residual gain. (Time savings compared with what? No market for human time, except for employee drivers.)	$ * ?
"Wages" to drivers. Private costs.	?	Quality of service factors, convenience of ride, etc. Private residual gain. (Quality compared with what? No market for quality of service factors.)	* ?
Vehicle storage, curb space, garages. Public and private costs.	$	Hypothetical motor vehicle use charge — dummy item to balance vehicle fixed and operating costs. Private gains.	$
Project users' accident exposure, property damage. Private costs. (Market for property, but no market for human life and limbs.)	$ *		
All other project costs.		All other project gains.	
Project Costs, Sub-Total	___	Project Gains, Sub-Total	___
Program or Technology Costs		Program or Technology Gains	
Competitive effects on other highways, roads and streets.	$ *	Complementary effects on other highways, roads and streets.	$ *
Competitive effects on other highway users, congestion.	$ *	Complementary effects on other highway users, relief of congestion, more O's-and-D's offered.	$ *
All other program costs.		All other program gains.	
Program Costs, Sub-Total	___	Program Gains, Sub-Total	___
Transportation Activity Costs		Transportation Activity Gains	
Competitive effects on other transportation media.	$ *	Complementary effects on other media (park-and-ride, etc.)	$ *
All other activity costs.	$ *	All other activity gains.	$ *
Activity Costs, Sub-Total	___	Activity Gains, Sub-Total	___

TABLE 3 (continued)

POSSIBLE COST AND GAIN EFFECTS OF A FREEWAY PROJECT[a]

Costs		Gains	
Metropolitan Economy Costs		Metropolitan Economy Gains	
Accident exposure of non-users; noise, dirt, other detrimental health, social, aesthetic effects of freeway projects. (No market for most of these effects.)	*	Beneficial city planning, aesthetic, etc., effects; decentralization of metropolitan economy, skillful use of freeway for promoting desirable land use. (No market for most of these effects.)	*
"Imports" of metropolitan economy, possible loss of "foreign" aid.	$ *	"Exports" of metropolitan economy, possible gains in "foreign" aid.	$ *
Decreases in land values and metropolitan tax revenues, all other detrimental effects on Gross Metropolitan Product and metropolitan way of life. Many cross effects.	$ *	Increases in land values and metropolitan tax revenues, all other beneficial effects on Gross Metropolitan Product and metropolitan way of life. Many cross effects.	$ *
Metropolitan Costs, Sub-Total	____	Metropolitan Gains, Sub-Total	____
GRAND TOTAL: COSTS	____	GRAND TOTAL: GAINS	____

[a] $ = Market Values, * = Non-Market Values, $* = Mixed Values, ? = Doubtful Items.

A few general aspects should be singled out for discussion. First, an exposition such as the one shown in Table 3 does not in itself solve any problems; it will just help the analyst to marshal the various effects he has to study; he can thus make sure, in accordance with assumption 5 stated earlier, that nothing of significance is forgotten. This is an important first step to infuse into the highway planning process social, aesthetic, political considerations, in addition to engineering and economic ones. As Lang and Wohl (11) put it: "Highway planning has long since passed the stage where it can proceed in a vacuum, social, economic, or otherwise."

Second, the cost and gain array does not tell whether the incidences of the various effects (in other words, the income distribution repercussions) set up by the proposed highway action are desirable or undesirable.

Third, and this is a related point, extreme care must be taken not to double-count items. For example, the temptation is great to show very high user charge money revenues (produced, for example, by a charge-what-the-traffic-will-bear pricing regime) and yet also enter high quality of service gains, land value increases, etc. As Zettel (12) has pointed out, almost all general economic gains are basically user gains which have been transferred to other sectors of the economy. There are, therefore, residual in nature and none would theoretically remain to be transferred under a perfect charge-what-the-traffic-will-bear regime.

Finally, public and private gains and costs are shown combined in the accounts. This simply takes care of the fact that both roadway and vehicle are needed to produce highway transportation—one is quite useless without the other. The bookkeeping philosophy of Table 3 thus accommodates what might be called the "combined economics" of these two factors of production*, an important phenomenon to which Owen (13) drew attention. As was pointed out before, a metropolitan transportation authority, highway departments, or other governmental agencies, will normally be classified as powerful public monopolies. It would be quite misleading to visualize these organizations as competitively selling passenger-miles, or freight ton-miles, in the same way as a baker might be selling bread in competition with not only hundreds of other bakers in the city, but also with potatoes, cornflakes, crackers, biscuits and other substitute foods. The strong monopoly position of most public transportation agencies, plus the complementary nature of road and vehicle, make it absolutely necessary that the public and private sub-accounts be pooled and be analyzed jointly. This is, of course, in line with the best highway planning practice. Table 3 merely states this approach more formally.

Discussion of Individual Project Cost and Gain Items

Because of the somewhat unorthodox nature of the presentation in Table 3, at least a few items should be explained in greater detail.

It is a moot question whether some sort of pseudo-wages for drivers should be entered under project costs. One of the greatest economic merits of highway passenger transportation has been the apparent willingness of private drivers to perform their duties free of charge. Very likely they just enjoy driving. Of course, there might be some people who find driving to work every day a strain, in which case a cost item should appear here. This could be of some practical importance when, for example, the freeway project is compared with a subway or bus service solution. More research is needed here. Truck and taxi drivers' wages can simply be entered as money costs, of course.

Vehicle storage costs have suffered from acute neglect in most contemporary studies. A freeway solution for urban commuting traffic may simply dump thousands of vehicles in the city's inner core and the possibly very high costs of storage on valuable land are plainly an integral part of the project.

The treatment of accident costs is of crucial importance. According to a detailed Federal study (14, p. 21), 37,000 motor-vehicle accident deaths occurred in the United States in 1958, plus either 1.3 million nonfatal injuries (1 person in 134 of total U.S. population), or 4.7 million (1 in 37), depending on definitions of accident severity (14, p. 23). The cost of all highway accidents was an estimated $5.4 billion (14, p. 17). With losses of this magnitude, it is obvious that the handling of the accident cost item can make or break project proposals. The author is personally perturbed by the persistent attempts to put dollar values on highway fatalities and injuries. For example, the following fatility cost figures, for ages 15 to 55 years, have been mentioned: male $29,000; female $17,000 (15). It does not really suffice to characterize this sort of approach as undesirable "boneyard economics." It has nothing whatsoever to do with economics; there is no market for human life, health and grief, and there will never be one, it is hoped. For professionals in the transportation field themselves to translate human life into dollars and cents is not only highly misleading, it may even be regarded as amoral by some. This does not distract from the great value of reliable information on accidents per se.

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*To check understanding of this point, consider the following typical problem that has caused some confusion in the field: Compact cars reduce vehicle operating costs, but also gas tax revenues accruing to the highway department. Granted that this is a good thing for the private compact car owners, is it also in the public interest? Answer: Given the same quality, speed and convenience of travel, total gains remain the same, although user charge revenues have shrunk. Total costs have shrunk. Therefore, from the general public point of view, this is an unequivocal good. In income distribution, compact car owners have gained, the highway department has lost, but could impose higher road user charges if desired. This same reasoning is also relevant to the introduction of diesel engines and possible future fuel cell and atomic energy propulsion devices. Highway improvements resulting in fuel (and gas tax) savings, must be analyzed in similar fashion.

But in a practical way, what can be done about accidents when decisions must be made here and now? All the earlier suggestions relating to the treatment of non-market values fully apply. There has been in the United States tremendous experience with highway accidents; the statistical trends appear fairly consistent and stable. Consequently, it should be possible to develop reasonably accurate accident forecasts. The analyst should present to the decision-makers the estimated accident consequences of, say, a proposed freeway in this way: x number of fatalities over the project's lifetime, y injury cases, z property damage accidents. It is legitimate, of course, to translate the latter into dollars and cents, because acceptable market values for property exist.

It is crucial that alternative solutions be tested and information on them also be submitted. Otherwise, the planning process—with its emphasis on choice—becomes a mockery. Thus subway proposals, which are almost certain to result in considerably fewer accidents, alternative freeway designs, bus service on freeway, or perhaps novel electronic vehicle guidance arrangements, must be developed at least as paper proposals. Because it is improper for the analyst to impose his own value judgments and attempt to convert human life and health into monetary terms, the final list of choices might look something like this:

Proposal	Net Gain ($)	Accidents (No.)
Standard freeway	a	p
Subway	b	q
Alternative freeway	c	r
Etc.		

With some luck, as previously mentioned, one proposal may be superior to all others in every respect; it should then be adopted. If a more complex choice must be made, something resembling an ordinal utility or indifference curve situation must be resolved by the decision-makers (and not by the analyst). Higher money costs, or lower money net gains, may have to be weighed against predicted lower accident exposure. Obviously, ethical or other value judgment must then be rendered by the decison-makers, be they individuals, consultants, committees, or the populace at large.

But even if, by experience, similarities of individual indifference between, say, money outlay and accident exposure were discovered, aggregation of such personal indifference functions into a collective one is open to most serious objections. Experience over time, or as between jurisdictions*, also does not get to the problem's core. It is much more honest and conducive to good decisions if the agonizing choice between money or other material resources and human life is presented anew every time the occasion arises. This is simply part of the burden of office which those in command must assume. It is not a new burden in human history.

On the project gain side of the planning accounts in Table 3, user charges revenues are designated as mixed market and non-market items. Here the author differs from those in the profession who maintain that paying the gas tax always constitutes a market transaction. To be sure, the more choice there exists in each case as between highway transportation and other modes, the more the user charge receipts take on market value characteristics. In intercity freight transportation situations, for example, when there is fierce competition between air freight, railways, pipelines, private and common carrier road transport, the trucker's gasoline or diesel tax pay-

*An intrepid researcher might want to compare the values put on human life—explicitly or implicity—in benefit-cost analyses developed by public agencies in, for example, the fields of airways, air traffic control and airports; water resources (flood control) and highways. If quantitative results could be developed, the researcher might well be in for some surprises; human life might be worth $17,000 in one case and $1 million in another. But whether consistent or not, such behavioristic experiences, it is submitted, are fairly meaningless for future decision-making.

ments do represent a fairly correct "economic vote". But in much of short-range passenger transportation, especially in the cities, all the paying of the gasoline tax and license fees frequently represents, is an "economic vote" in favor of being able to get around at all, to work, to play, to shop, rather than to stay home altogether. There are thus "markets" of different degrees of perfection in this field. Economic analysts, before inputing dollar values for this item, must ponder the monopolistic nature of passenger transportation by automobile in so many American cities, the self-promoting tendencies of highway planning and suburban developments, the distorting influences of advertising, of car ownership for prestige reasons, and so on. On the other hand, the impressive reality of high road user revenues, proven over and over again in the postwar period, should carry its proper weight in the analyses.

Although concession, advertising, etc., revenues may be regarded as market value items, the detrimental esthetic and social effects which balance them at the level of the metropolitan economy are of a non-market character. Therefore, there again exists a value judgment situation; more advertising money gains versus esthetic, city planning, etc., costs. The vast differences in advertising policies, beautification, and landscaping standards that can be observed in the various parts of the United States and Canada show how diversely increased driver irritation, esthetic losses, etc., are valued by the regional decision-makers. Research on social and highway user opinions on advertising, as contrasted with sectional interests, is overdue.

Except for money wages paid to employee drivers (chauffeurs, taxi and truck drivers), it is difficult to claim that there is a market for human time. The same applies for quality of service factors. Again, whenever true economic choice is possible (as between flying, going by train, riding on a superior toll road or riding on an ordinary public road) the pleasantness or unpleasantness of sensations can be measured indirectly by the amount of money consumers are prepared to pay in each case. If there is little choice—and unfortunately this seems to be the typical situation in urban passenger transportation—it is difficult to impute dollar values here. There are also great risks of double-counting among the user charge, concession, time saving and quality gain factors. Under a rigorous market research approach, potential freeway users would be asked: given a certain quantity and quality of service, what would be the maximum amount of money you would be prepared to pay and still patronize the new freeway? Alternatively, user charge schedules based in some fashion on costs could initially be worked out. The market researchers might then take it upon themselves to tabulate time savings and other qualitative factors and translate them, taking frequent recourse to value judgment, into money terms. Once this step in the analysis is completed, user charges (which are supposed to be equal to costs of providing the service) are deducted and the residue is entered as quality and time savings items. This particular approach seems roughly to be the one used for the so-called highway cost-benefit analyses. As can be imagined, it has many drawbacks because of its largely speculative nature.*

Once again, it is essential that alternative choices be considered. The analyst has to ask: time savings and quality improvements compared with what? Usually, the present situation becomes the zero point of measurement But if an existing in-

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*Suspect may be contemporary estimates accruing from highway improvements in the form of time savings and greater comfort and convenience of travel. Winfrey (16), with the aid of representative examples, shows the critical influence of these two non-market value factors on the total magnitude of estimated benefits. Applying fairly conservative rates for time savings ($1.35, $2.10, and $2.64 for cars, trucks, and combinations, respectively), he demonstrates that time benefits account for 84.4% and comfort benefits for 11.5% of total highway benefits. Savings in motor vehicle costs, the only factor that can be worked out with a reasonable degree of refinement and accuracy, amount to only 4.1% of total benefits. Hence, subjective, non-market factors may make up 95.9% of a highway benefit estimate. If time or comfort dollar values are increased a little, the leverage of the non-market values will be greater still.

efficient highway situation becomes the basis of comparison for simply another highway solution, and it in turn for yet another, inbreeding of projects sets in. The correct approach is to work through as many alternative proposals as possible, regardless to which technology they belong.

The hypothetical motor vehicle use charge, under project gains, is simply a dummy item to balance vehicle costs on the other side of the accounts. This bookkeeping peculiarity arises because total freeway project gains accruing to users are strangely split between (a) the money motorists are prepared to hand over to the authorities for letting them use the freeway, and (b) the money users pay to themselves, as it were (in their function as vehicle owners and operators) for traveling on the new facility. It seems paradoxical to assert that expenditures for motor vehicle operations should be rated as gains. However, it is not the payment of these expenses, but the willingness to make outlays in order to obtain travel, which is a possible measure of the gains from freeway transportation.

It is obvious that opportunities for double-counting and other accounting mistakes abound in freeway project analyses. The foregoing discussion has brought out how exceedingly difficult it is to measure total project gains, especially because of the ubiquitous qualitative and non-market value sub-items. All of the approaches suggested here seem roundabout and highly contrived. Yet they are employed in practice all the time.

Under favorable circumstances however, some more, expedient shortcuts may be employed. Consider that a definite requirement for metropolitan passenger transportation exists; in economic terms, a perfectly inelastic demand for a certain volume of these services is assumed. Now let a number of projects—various freeway configurations, a subway solution, a mixed freeway-subway solution, a bus service proposal, a combination park-and-ride project, and so on—be planned on paper. Attempt initially, if possible, to hold service quality of the various schemes equal; bring the subway or bus solutions up to private car standards (e.g., through more frequent schedules, high speeds, seats for everybody, air conditioning). Make sure, perhaps through a users poll, that the paper designs are really identical in the service quality they yield. This eliminates gains, and especially quality factors from the the comparison. Now juxtapose costs: the lowest-cost proposal should logically be carried out.

Alternatively, various freeway, subway and bus schemes could be planned, on paper, in such a way that they will all entail exactly the same project costs. Now compare gains produced by the different proposals; the project yielding the superior admixture of revenues, quality and convenience of service should be chosen.

Another intriguing method of project selection, described recently by Marschak (17), is apparently used by the nationalized Electricite de France. To avoid directly comparing total future receipts or gains of two or more alternative hydro plant proposals which would entail various analytical pitfalls the EDF analysts first set up, on paper, an "equivalent" thermal plant which could do the job in question. Then, hypotehtically, the thermal plant is replaced first by one hydro plant configuration, then by the other or others. The hydro plant proposal which makes possible the greater (net discounted) gains due to the replacement, per franc of net discounted expenditure, will be selected.

This project planning method used in France appears to be based on the "requirements" approach; in the economist's jargon, a perfectly inelastic demand for the electric power services is once more assumed. To avoid the inaccuracies inherent in absolute gain measurements, merely the relative merits of alternative schemes are compared in the fashion described. It is not quite clear why the French approach could not be reduced to a simple cost minimization problem for a given output requirement; perhaps this is not possible because "requirement" for power has complex demand parameters over time, including (a) peak instantaneous output required in the course of a year, (b) total annual output required, and (c) average daytime hourly output required in the winter months (17, pp. 137-8). One is strikingly reminded of highway peak traffic problems, the 30th highest hour concept, the difficulties of absolute gain measurements in the highway field, etc. Here seem to be exceptionally fruitful areas of research and exchange of ideas between related fields, such as electric power and transportation.

None of these short-cut methods can tell, however, whether one or all of the proposed schemes is economically justified in the first place; that is, whether project gains, V, will exceed project costs, C. To do this absolute measurements of cost and gains are needed, therefore value judgments frequently must be resorted to.

Referring once more to Table 3, technology or program effects, as well as repercussions upon the transportation activity and the metroplitan economy, are discussed in the context of transportation planning and the time dimension.

PROJECT ANALYSIS

Probably more than one-half the analytical battle is won once the right data have been collected and arranged correctly, as suggested in Table 3. It now remains to show what use can be made of such information. The narrative takes the reader quickly through descriptions of the analytical techniques available for solving economic problems at the project, program or technology, activity and metropolitan economy levels of decision-making. Some of the techniques are well known, others represent novel aspects.

It must be assumed from now on, of course, that reconciliation of market and non-market values has been accomplished in some form or another and that all the effects one wishes to study can be expressed quantitatively and can be aggregated. This is a big assumption; but it is hard to see how one could go much further in the discussion on non-market values than was done in the preceding section. The natural limitations from which the intellectual tools of the engineer, economist, or analyst suffer in the public decision-making field, should be recognized.

Project Identification

A brief defintion of "project" was given in Table 1. It was stated that the smallest unit of production which can fulfill the desired production objectives would be designated as a project. This definitional device conveniently removes compatibilities, incompatibilities and other cross-system or network effects which several projects may exercise upon each other, from the scope of project evaluation proper. The consequences of interdependence of projects can be handled with greater ease by means of program or activity analyses, to be explained later.

It is apparent that the absolute dollar size of a project to be evaluated is of no significance for project identification. At the one extreme, a complete multi-million dollar highway would be regarded as a single project, if no traffic at all would move if something less than the entire highway were built. At the other extreme, the addition of one traffic lane to an existing highway would be regarded as a project in its own right, if it adds capacity over the whole of the connection between only two traffic origin and destination points. Even maintenance and other operational activities can be defined as projects (19) and subjected to analysis, if desired. One can imagine that practically every highway process, however trivial, could be subjected to project evaluation if defintions are made sufficiently fine. Similarly in private enterprise. As Angell (18) puts it, from the micro-economic point of view, all business expenditure can be described as "investment" regardless whether it is expansion of plant, purchase of raw materials, or labor services. Conversely, very coarse definitions of "projects" can be employed. Because planning costs something, and because good highway analysts are scarce, initially the rather more important highway projects probably should be scrutinized first.

Project Life

As a simple rule, it is proposed that either physical life or economic life of the project, whichever is considered to be the shorter, should be chosen as the correct project planning period.

Typically, highway projects may have very long physical lives; a bridge may last 50 years, some structural components 100 years, the real estate tied up in highway right-of-way may have unlimited life. The temptation is great to impute very long service lives for highway and freeway projects, although there is no evidence that economic and functional obsolescence will not set in long before the facility physically expires. Of course, the more costs can be stretched out over time, the more favorable the project will appear in the economic analysis. But artificial stretching out of project life is quite inadmissible from the economic and analytical point of view.* Only the period for which project usefulness can honestly be foreseen should be employed for analytical purposes.

It should be noted that Winfrey (16) has suggested the adoption of shorter lifespans for highways than many analysts are currently using. It might further be argued that urban freeways should be allowed somewhat shorter lives than intercity ones. Freeways in cities represent technically very specialized solutions, are under heavy criticism from people outside the highway field, and may conceivably be supplemented, if not superseded, by superior urban transportation technologies in future years. Intercity highways, on the other hand, are of long standing and will probably be useful for many more years to come. Adoption of shorter urban freeway lifespans for analytical purposes would simply make for a more cautious planning approach, but would still allow the better proposals to qualify. It is believed by some that a case exists for introducing greater prudency into the metropolitan freeway planning processes.

Project Costs

All costs attributable to the project over its lifetime, as they are expected to occur over the years, should be recorded. Amortization thus does not have to be considered separately. Interest demands special attention and therefore is discussed later; it is not included with the other costs. No distinctions between direct and variable costs, or between capital and operating costs, need be made at this stage. These cost concepts only assume a specific meaning when relatively limited time horizons pertain, usually the calendar year or the fiscal year of the accountant. In ex ante project planning, the time horizon is that of the lifespan of the project. Ex ante, all costs whether capital or not, are still avoidable. They can be treated in the same way, subject to time analysis to be covered later. The unnecessary breakdown of costs into subcategories complicates analysis greatly, when for example benefit-cost criteria are used. McKean (5, p. 76) correctly states: "...investment occurs whenever more is being put into a project than is being received from it." Therefore, operating costs not at first covered by receipts are just as much "investment cost" as are construction outlays.

It is important that allowances be made for liquidation of the project at the end of its useful life. There may be positive scrap values (sales of salvagable materials), which should be creditied as final gains to the project, or there may be negative ones (for example, removal of structures) and these must be treated as costs. Once more in support of prudency in urban freeway planning, it can be argued that concrete structures, interchanges, etc., are difficult and costly to demolish; therefore, there should be analytical evidence that freeway projects show sufficient economic returns over

*Examples for such malpractices can be found frequently in the highway field: traffic (i.e., functional, economic usefulness) may be predicted over 20 years to 1980, but the annual costs of, say, a freeway are computed on the basis of 40-yr amortization. The resulting benefit-cost ratios are quite distroted in economic terms, it can be argued, of course, that "freeways will surely be useful after 1980;" if so, the analyst should go out on a limb and predict traffic to the year 2000 as well. A better method would be to calculate differential scrap values for the components of a freeway as of 1980: high scrap value for real estate, low for pavement, etc.

It appears that the AASHO approach (20) favors the use of physcial project life for amortization purposes, although traffic (and therefore benefit) forecasts apply to shorter periods. The AASHO procedures have had, and still have, tremendous practical influence upon highway planning in the United States, Canada, and elsewhere. Perhaps the time has come to draw up improved planning guidelines, more in line with the theoretical and practical advances that have been made since 1952.

and above project costs to cover final site clearance costs. Although it is true that many highway projects will retain or even enhance their usefulness in future years, no one should be so presumptuous as to believe that all of the current creations will meet the approval of future generations.

Accepting the propostion that the analysis must cover all costs of initiating a project, running it during its lifetime, and liquidating it, one is now interested in total project costs which are incurred at different levels of output. This output-cost relationship may be represented as in Figure 1. Marginal cost curve MC is a truly long-range one, indicating the costs incurred when producing one more unit (or bundle) of output. Why long-range? This implies that true total costs are incorporated and that no planners are, ex ante, able to make any changes in design and construction which are economically desirable and technologically possible. Average costs are not shown in order not to clutter up the diagram, but can easily be derived from the given information. The area under the MC curve (i. e., OBDA for output OA) represents total costs over the long run.

The smoothness of the MC curve, as drawn, suggests that factors of production can be varied continuously. But it is well known that indivisibilities of factors exist and that costs are likely to show sudden jumps; for example, from four lanes to six lanes of highway. How can one resolve the problem created when, in effect, a calculus of continuous variation is to be applied to a lumpy material? If one is satisfied that he

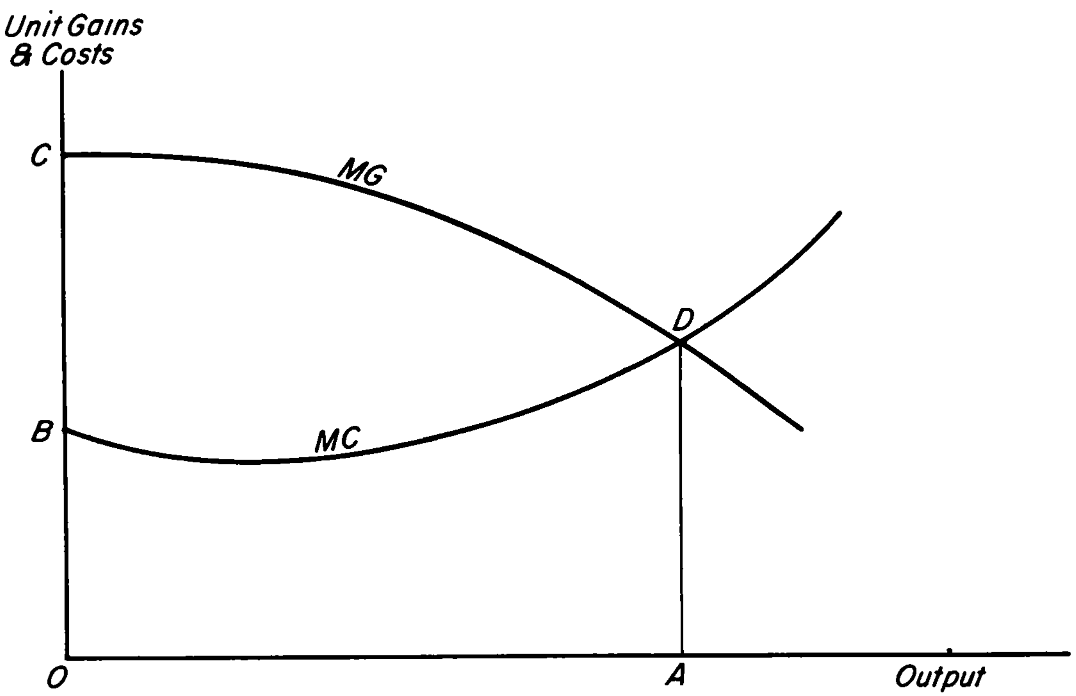

Figure 1.

is really dealing with the smallest possible quanta of decision-making, then two distinct incompatible projects exist—a four-lane highway and a six-lane highway. With intermediate output solutions ruled out, the two possibilities must separately be subjected to gain-cost analyses and then be compared to findthe better compromise. If there are side effects, with the choice of four or six lanes setting up further reactions through the highway network, the two project proposals must be subjected to program analysis, as described later herein under "Program or Technology Analysis."

Gains

It will be recalled that gains are taken to mean all ascertainable desirable effects caused by carrying out the project. It is evident that the "with and without" principle (21, pp. 51-5) applies to both costs and gains. With its aid a distinction can be made between the relevant true project effects and irrelevant ones brought about by the passage of time and other extraneous circumstances. Once more it must be assumed that market and non-market values have somehow been aggregated into total gains.

Magnitudes of gains realized from disposing of various output quantities are recorded on the marginal gain curve MG in Figure 1. The properties of this second curve also deserve scrutiny. Curve MG is the locus of points denoting the gains accruing to the project when disposing of one more unit of output. The area under the MG curve (i.e., OCDA for output OA) represent maximum total gains that would accrue to the project.

Once more the familiar objections to such a smoothly drawn curve can be raised; but if a step-like MG curve is the one found to represent reality, this information should simply be employed for analytical purposes. In case of output conflicts, compromise solutions, as mentioned before, may then have to be worked out.

Output Determination

Briefly, the desired output for a highway project will be determined by the intersection of the marginal gain and cost curves. In Figure 1, curves MG and MC meet at point D, designating OA as the optimal output. At this point net gains accruing to the project (OCDA-OBDA=CBD) are maximized.* No other output position can better the net gain yield. Provided all other goods and services elsewhere in the economy are also produced in such quantities that marginal gains (or more conventionally, marginal revenues in the absence of non-market items), equal marginal costs, at this level of project output both most efficient use of productive factors will be made and consumers' welfare will be maximized. (For a more detailed discussion, with special reference to water resource economics, see Eckstein (21, pp. 19-46) or Krutilla and Eckstein (23, Chap. II). For brevity, one may refer to this method of output determination, which thus results in maximization of net gains for the project, optimum allocation of resources and maximization of consumers' satisfactions, as the marginal rule.

Critical Comments

Some special difficulties arising in highway project analyses should be examined critically. Only highlights of these problems can be presented as follows:

1. Shape of Marginal Gain Curve. It was stated that the size of the surplus of

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*It should be noted that this is not the same as maximizing the benefit-cost ratio. If such a ratio were to be maximized, it might be better to produce just the first few, highly profitable, output units. In private business terms, if maximization of revenue-cost ratios were the right criterion, bakers would sell only a few, highly profitable loaves of bread, investment brokers would perhaps invest only a few dollars of their clients' millions in exceptional opportunities, etc. Other sales or ventures, which are still profitable but would depress the average revenue-cost ratio, would be ignored. This is, of course, absurd. This is one of a number of reasons why benefit-cost ratios, unless hedged around with many assumptions and conditions, offer poor guidance for highway planning and investment decisions. (See also Grant and Ogelsby (22), and McKean (5) for criticisms of the benefit-cost ratio method of planning.)

gains over costs (area BCD) will determine project acceptance or rejection. If two alternative project proposals are compared, the one promising to yield the larger surplus should be chosen.

It is clear that the configuration of the MG curve is crucial here. If it is a rather steep curve—this will be the case if the service offered is essential and no good alternative choices exist—the surplus area BCD will be large. The project then has an excellent chance of being chosen. Conversely, in a rather competitive situation, the MG curve will be flat and the surplus area will be small. The project will have a hard time to get accepted. Hence, the way in which the individual points on the MG curve are arrived at is most critical. How should the market studies and demand analyses for projects be carried out in practice?

Consider the example of a river crossing. Potential travelers may be desperate to get from one side to the other. Possible solutions include a ferry, a subway, a low-quality bridge, or a high-quality bridge. Under present highway planning rules-of-the-game, other technologies (ferries, subways, etc.) do not even come within the effective decision-making horizon. Using a crude benefit-cost approach, the time, fuel, etc., sayings for the low-quality and the high-quality bridge approach only would be assessed, would be given some more or less arbitrary money weights, and then compared with each other through the benefit-cost ratio mechanism.

More sophisticated approaches would follow Marshall's prescription and ascertain what amounts of money users would be prepared to pay, at the most, for being able to cross the river by bridge. But if the market researchers were to ask prospective customers "how much toll would you pay for a bridge?", or ".....for the bridge we have in mind?", very inelastic (steep) MG curves would result. No good comparisons between alternative project proposals are possible; everybody knows, in this age of rapid traffic growth, that a bridge is better than none. But this still misses the whole essence of economic planning, which is comparison of alternatives.

Under the circumstances depicted, the correct approach of the market researchers to prospective users should be something like this: "We will definitely accomodate river crossings; the following solutions are possible: (a) ferry, (b) subway, (c) a low-quality bridge, (d) a high-quality bridge, etc., etc. Given this choice, and given certain qualities of service, speed, etc., for each, how much would you be prepared to pay for solution (a), for (b), (c), or (d)?"

Under this market research approach, there would be separate collective demand curves for each alternative; in fact, there would be four or more separate diagrams here. The demand curves for each, since alternatives exist in the users' minds, would be far more elastic (horizontal), the formerly large surplus areas would shrink and much more sensitive comparisons between the project proposals could be made.

It is clear that we are still far removed from such theoretical market research perfection in actual highway planning. There is little, if any, choice now between alternative proposals. (Laudable exceptions are the recent Chicago (24) Detroit (25), and Washington, D.C. (26), transportation plans. These studies represent important milestones in the evolution of urban transportation planning in the United States. Therefore, there is also little, if any, choice now between the non-market designation of the category "project user revenues" in Table 3. The essential interactions between different projects, programs or technologies are also brought out once again by the preceding cussion.

2. Incidence of Costs and Gains. Project investment analysis as such does not tell anything about the distributive effects of the proposal: Who will reap the gains? Will everybody pay a fair share of costs? Will not one class of users subsidize another? Should services be sold exactly at cost? Or at a loss? Or should the transportation agency be allowed to make a profit?

If an isolated project, such as the one depicted in Figure 1, is considered, freedom of pricing policies may be assumed. If so, there is an almost infinite variety of distributive effects that can be brought about by the right charging schemes. These might range from a completely discriminatory pricing regine, through various monopolistic devices, the uniform charge case, to the long-range marginal cost pricing solution.

Some of the possible solutions, which still satisfy the marginal rule, have been described elsewhere (27). This particular area has been written about excessively in recent years, and may perhaps have been researched almost to death in the highway field. The interest in distributive effects, which was presumably sparked by rail-truck competitive struggles, has greatly declined lately, perhaps because of piggyback, the consolidation of the positions of the media, the shift in emphasis to urban problems, etc.

Because of the prevalence of joint costs (as between heavy and light vehicles, peak users and off-peak users, and even highway users and non-users), little more than convenient, or equitable, or fair—whatever these terms may mean—pricing schemes can emerge from economic analysis.

3. Influence of Uniform Charges. It is fundamental in the highway field that there are, within broad user groups such as passenger cars, fairly uniform charges. Uniform charges are convenient, easy and cheap to collect, have great administrative advantages and appear fair to the public.

Figure 2 shows what uniform charging does to highway project operation. Suppose a tax is struck according to the principle that the highway function as a whole must break even—also called the "no deficit" constraint. Let it be assumed that $0.01 per vehicle-mile is just right. The highway department runs separate roads, A, B, and C, which differ in their cost curve configurations as shown.

As can be seen, the uniform charge plays havoc with the "right" outputs according to the marginal rule:

Highway A: Actual output is OF, which is correct according to the marginal rule; there is a large surplus which is diverted to Highway C; if Highway A were autonomous, it could be run at output OG and still break even. This is the typical urban-to-rural highway money transfer case.

Highway B: Actual output is OI; according to the marginal rule, correct output should be OH, using different charges; as things are, some users, who generate a surplus, subsidize other users who are being accommodated at a loss at the given highway price. The highway by itself just breaks even nicely. This is the typical case, where it is usually alleged that trucks do not pay their fair share of costs and are cross-subsidized by automobiles, or vice versa.

Highway C: Actual output is OK; according to the marginal rule, with a different pricing regime, it should be OJ: the highway by itself is a dead loss and, under the no deficit rule, should never have been built at all. As things are, the facility is being subsidized heavily by Highway A. This is the typical case of the low-travel, high-cost rural road, or possibly of an exceptionally expensive urban freeway.*

Comment. Under the circumstances depicted, something has to give; it is not possible to satisfy simultaneously (a) the marginal rule, (b) individual and aggregate break-even, and (c) uniform charges. The situation shown in Figure 2 probably truthfully represents many a highway department's current experience.

It should be noted that Highways A, B and C are assumed to be independent of each other. Feeder, network, etc., effects are discussed in the next section of this paper.

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*The controversial Embarcadero Freeway in San Francisco, at current traffic volumes, costs the highway authorities about $0.25 to $0.30 per vehicle-mile to own, operate and maintain; at maximum projected traffic volumes, to be reached 20 years from now, its total costs would still be as high as $0.10 to $0.12 per vehicle-mile. By contrast, highway user charges in California are about $0.0075 per vehicle-mile for automobiles, and about $0.01 per vehicle-mile on the average for all vehicles combined. There are other complex features of the Embarcadero project which should be taken into account, in particular the beneficial system effects (as described in the next section of this paper) which the facility may confer upon the Bay Bridge and possibly upon parts of San Francisco's network of streets. With rising urban land costs and the gradual exhaustion of the obviously more worthwhile freeway projects, it is evident that much improved planning analyses are urgently needed to show whether facilities of the Embarcadero type should be undertaken at all.

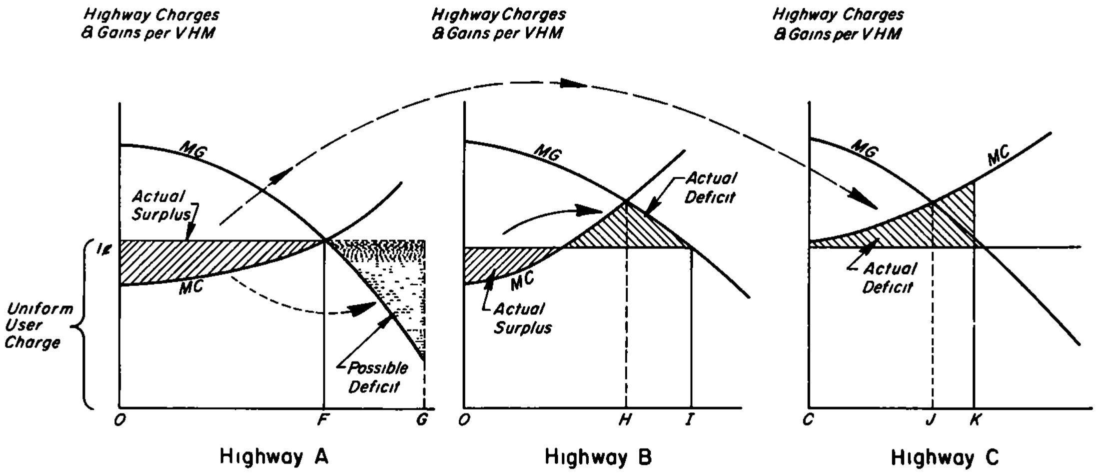

Figure 2. A highway department situation including uniform user charges, pooling of revenues, and break-even for the highway department as a whole.

4. Superior Analytical Treatment. As the foregoing discussion suggests, given uniform user charges it is not possible to always satisfy the marginal rule output requirements. But a superior analytical treatment suggests itself, which may lead to better solutions. As was pointed out, highway and vehicle are singly merely factors of production, which are needed jointly to produce the desired output—highway transportation. A joint gain-cost approach was therefore incorporated in Table 3.

To follow it up, one must show unit gains and costs for the combined product, highway transportation, as demonstrated in Figure 3. The gain curve, as was explained, denotes the total amount of money people would be prepared to surrender, at most, for facility use. The cost curve then shows correspondingly what total expenditures are necessary to satisfy these user desires. The artificial distinctions between private and public, highway and vehicle outlays, disappear. A correct marginal rule output solution (output OL) will follow. As vehicle costs and highway costs are, within limits, substitutes for each other, one can be raised to lower the other; similarly, with highway user charges and time savings, etc., on the gain side. Therefore, with some internal adjustments, highway costs can be made to equal highway user charges by biting into residual time, etc., gains. Gains from motor vehicle use and motor vehicle costs are identical, by definition (Table 3).

The great advantage of this analytical treatment is that adaptation to the correct output does not rely exclusively on raising and lowering highway user charges; this is difficult to implement administratively and the leverage effect of these imposts is very weak, in any event. Here, the adaptation to correct output relies on variations in total gains and costs. In other words, the highway department, with reference to a correctly planned highway, now says: If it is underutilized, it will offer very low total highway transportation costs and will therefore attract users up to the correct output; if it is overutilized, congestion will set in, this will increase total highway transportation costs and therefore cut down on usage.

Rationing by congestion, as it were, provided there are alternative transportation choices, appears to be the only possible economic approach, when differential road user charges (toll gates) are ruled out. Many beneficial consequences arise for highway planning, too, which should be explored.

The joint highway-vehicle planning concept becomes a little easier to understand, if it is imagined that Figure 3 represents, say, a subway case. Total marginal gains constitute simply the maximum fares which might be exacted from users. There is no need to specify how much users "gain" from the rolling stock and how much from the tracks, tunnels, stations, etc. Similarly on the cost side; the breakdown between

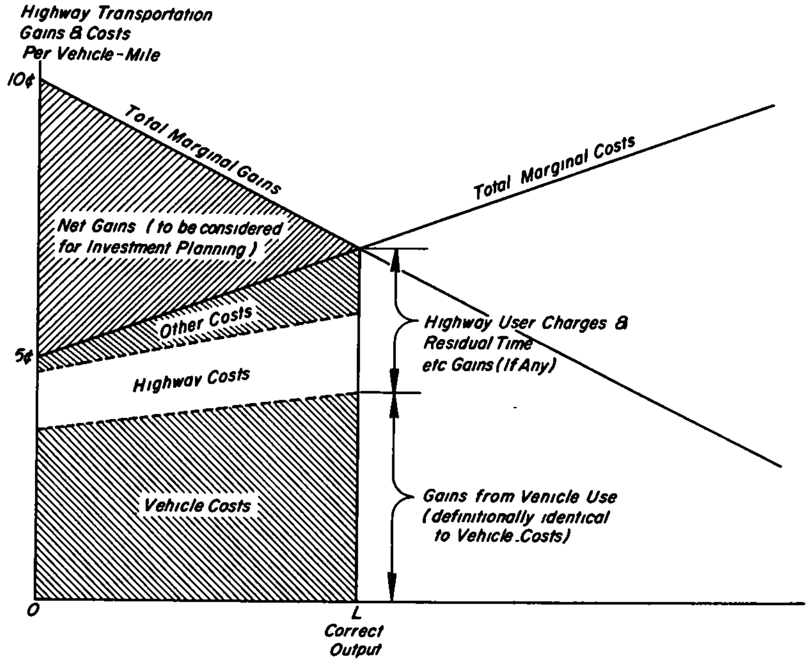

Figure 3. Superior analytical treatment; analysis of complete highway transportation operation.

vehicle and track, plant, etc., costs are quite irrelevant for subway investment planning as such; it is a subsidiary problem, in the same way as "more capital costs, less maintenance costs, or vice versa" is one.

PROGRAM OR TECHNOLOGY ANALYSIS

The preceding investigations will result in a list of possible projects, such as freeways, feeders, interchanges, for a metropolitan area, complete with information on gains and costs for each. Decision-making responsibility is now raised to the program or technology level, and the planning horizon expands correspondingly. Consequently, many relationships which are external to individual projects, but internal to the metroplitan freeway program or highway technology, can be recognized. These relationships are brought about by technical, functional and economic factors; they may be referred to as systems, or network effects. The following forms of project interrelationships may be encountered:

Perfect Incompatibility. A number of mutually exclusive uses for a single site are proposed (for example, a freeway location, or a parking lot, or residential streets). Or different design configurations for the same purpose are considered, such as low-level bridge, or a high-level one, or a tunnel, for the crossing of a river. Or, various levels of peak and off-peak demand have to be satisfied by a single facility which can only be constructed to one definite capacity. Or solutions with peculiar rival economic characteristics (toll road versus public road) must be compared.

Perfect Dependence. At the other extreme, projects may be completely dependent upon each other. Of course, if all of several projects cannot exist without each other, then according to the earlier definitions they must be treated as one single project. But there will be cases where a subsidiary activity is completely dependent upon the main activity for survival, but the latter can, if necessary, stand on its own feet. Examples are primary highways with their feeders, or toll roads with their toll road restaurants and similar ancillary activities.

Neutrality, Partial Dependence, or Incompatibility. Between these two extremes, there may be cases of projects helping or hindering each other to greater or lesser degrees, or having no effects upon each other at all. In other words, there may be partial dependence and complementarity, or partial incompatibility and competition, or neutrality, between the several projects.

It is the objective of program or technology analysis to identify these system effects created by the interaction of several projects upon each other and then, from the stated conditions, find optimal solutions. How this might be done will be demonstrated with the aid of a greatly simplified metropolitan road planning example.

A Metropolitan Road Planning Case

Assume that there are four distinct road projects, designated as A, B, C and D, which are being considered simultaneously by the metropolitan transportation authority. Costs and gains predicted for each project treated individually have been worked out by means of preceding project analyses. Assume that there are no budget limitations imposed upon any possible project grouping and that therefore the objective is maximization of net gains for the four projects considered as a whole.

Consider, for purposes of demonstration of the analytical techniques, that perhaps the following conditions pertain (see Figure 4 and Table 4):

Project A might be a planned freeway, which takes a more circuitous route than toll road B, its incompatible rival. Either A or B, but not both projects, can be built. Route C is a pure feeder to A and is thus completely dependent for its own survival upon the main freeway project, A. The latter, in turn, gains somewhat from the services provided by C, but these are not essential to A's survival. Project B, the toll road solution, stands by itself, and no special feeders are considered. Routes C and B are perfectly neutral in their effects upon each other. Route D, finally, is a complementary feeder to C to some extent, is neutral to A, and mildly competitive to B.

Other program or technology interrelationships can, of course, be readily devised. The present example is designed to demonstrate all possibilities, from complete incompatibility, through rivalry, neutrality, to complementarity and complete dependence. Instead of feeders, interchanges, downtown parking garage projects, etc., can also readily be visualized. Relationships get exceedingly complex and hard to trace when more elaborate models, with more projects, are constructed.

Putting values on the various effects, the interrelationships can for convenience be represented by a quadratic matrix, as shown in Table 4. The values conform to the descriptions given in the preceding paragraphs. Some examples will explain this representation. Project A by itself (by A on A) yields 500 gross gains or, at 300 project costs, 200 net gains. Toll road solution B, by itself (by B on B), with 350 costs being the bigger undertaking, yields 600 gross gains. If there was a straightforward comparison, ignoring all systems or network effects, between the two rival projects, B should be selected because it results in the larger net gains; namely, 250. As can be seen from Table 4, A and B are incompatible and both their gains are cancelled out when they are undertaken simultaneously (A on B, and B on A). This was a basic condition of the model.

Looking now at feeder road C, by itself; with gross gains of only 20 and project costs of 140, it results in a net loss of 120. But C, regarded in conjunction with A, becomes profitable. Freeway A confers 120 systems gains upon C and C confers 90 gains upon A. Both taken together therefore yield 730 gross gains at 440 costs and hence 290 net gains. This, incidentally, is the substance of the famous "branch line" problem in railroad economics, the "loss leader" phenome-

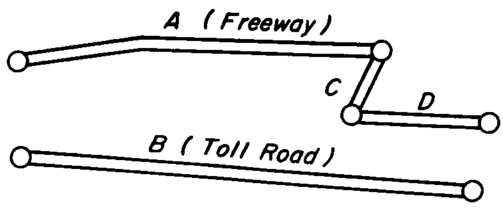

Figure 4. Metropolitan road project proposals (circles are access and egress points).

non in retailing, and numerous other system or cross subsidization situations found in the real world.

All other interrelationships can readily be observed in this way in Table 4.

TABLE 4

PROJECT OR TECHNOLOGY EFFECTS*

By \ On	A	B	C	D	Individual Project Costs	
A	500	-600	120	0	A	-300
B	-500	600	0	-30	B	-350
C	90	0	20	50	C	-140
D	0	- 30	40	100	D	-100

*Positive values are gains, negative values are costs.

To find the optimal solution under the assumption that there are no budget constraints (i. e., the one which maximizes net gains), all possible combinations of the four projects must be tried out. This has been done in Table 5. It will be seen that combination ACD is the optimal one, leading to net gains of 380, which cannot be exceeded in any other way. It should be noted in the last column of the table that toll road project B, by itself, would result in a higher rate of return than the ACD project combination (net gains divided by costs for B = 71.4 percent, and for ACD = 70.4 percent). Similarly, the benefit-cost ratio of B (600/350 = 1.714) would be higher than that of the ACD combination (920/540 = 1.704). This once again shows the possibly misleading effects of such planning tools.

It is easy to see from Table 5 that the profitability performances of individual projects take on quite different complexions when segments are placed into the program or network context. Take, for example, project D. By itself it would yield 100 gross gains at 100 cost and therefore zero net gains. Individually, it would be the classic example of the marginal project which might or might not be undertaken. But when D is withdrawn from the optimal combination ACD, net gains decline from 380 to 290 as a result. Hence, in the context of the given network ACD, project D makes a net gain contribution of 90. Even more extreme is the case of feeder road C. By itself it results in a net loss of 120. If, however, C is withdrawn from the optimal combination ACD it can be seen that C makes in fact a net gain contribution of 180 in this context.

It follows that profitability of a project by itself is not a decisive criterion if system effects are present. As a rule, even proposals showing negative returns during the project analysis must still be processed through the program analysis if there is any reason to believe that they might result in positive system effects. This has great practical significance in the highway field, where network effects are prominent. The correct procedure is to test whether withdrawal of a network segment results in a decline of net gains for the system as a whole. If yes, the network addition is worthwhile and should be retained. If, however, withdrawal leads to increase in net gains (i.e., cost savings) abandonment is indicated. (As McKean (5, pp. 54-55) puts it, one has to test "...whether or not uneconomic features or uneconomic additions in size are riding on the coattails of the truly profitable parts of a proposal.") This procedure is obviously already incorporated in the trial-and-error selection method depicted in Table 5. Hence, optimal solutions obtained in this way are also correct with respect to deletions or additions of network segments.

Another interesting observation can be made by referring to Figure 4. As it is drawn, road C is a feeder to main freeway A, and D is really a feeder to C (or C to D). It follows that through the positive intervention of C, if C is also built, D becomes a feeder to A and A, in turn, will likely stimulate D. But these cross effects between A and D depend entirely on the existence of the link C between them. Consequently, although A and D, if analyzed by themselves, may be neutral in their reaction upon each other, they will show positive effect upon each other if A is confronted with the combination CD, or D with the combination AC. A quick check reveals that such possible tertiary system effects are not incorporated in Table 4; that is, A's effects on D, and vice versa, are shown to be zero whether C is there or not. Indeed, these further effects cannot be handled by one representation, such as Table 4, alone. To trace and exhaust all possible network combinations, further tables need be drawn up which would confront, for example, the AC combination with network additions B and D. Further tertiary, etc., effects and combination can be visualized, but the nature of the actual problem in hand and the availability of data will determine whether it is worthwhile to carry the analyses to such high degrees of refinement.

Program analyses will also be the appropriate vehicle for testing different design configurations when indivisibilities of factors exist and system effects are present. Highways provide a good illustration. Assume that either a two-lane or a four-lane design may be built. By itself the two-lane highway may maximize net gains, but it may have an inhibiting effect on associated parts of the network. The four-lane highway, although somewhat extravagant by itself, may bring about large net gains in other segments. If confirmed by program analysis, the four-lane might be preferred.

Some Practical Observations

To really get the best results from program analysis, all possible combinations of projects should be played through. As can be seen from Table 5, where only four projects are considered, fifteen combinations must be tested. As further projects are introduced for more elaborate models, the computational work rises to horrendous proportions. (The number of combinations is: $\sum_{K=1}^{n} \binom{n}{k} = 2^n - 1$. If, for example, 20 projects are considered, there will be 1,048,575 possible combinations.) This would be the case with everyday highway problems; for example, in freeway planning where different locations, number of lanes, spacing and design of interchanges, feeders roads, etc., must be considered.

What can be done to keep the computational work within reasonable bounds? First, the empirical data can be checked to see whether simpler relationships prevail. Projects may have identical cross effects upon each other (for example) when traffic is balanced in both directions and as much is passed on to the other project as is received from it. Similarly with traffic abstraction. In Table 4, projects B and D hinder each other equally by inflicting 30 costs both ways. It can be said that a symmetrical relationship exists under these circumstances. If such symmetry prevails throughout the network, the relationships and calculations are rendered much simpler. Triangular traffic patterns and external values will, however, deny such simplification. Turning once more to Table 4, it can be observed that C confers 90 gains upon A, but A confers 120 gains upon C. The explanation might be that there is a mutual, symmetrical traffic stimulus of 90 gains between the two roads, but that in addition property values along C rise (or other external gains specific to C are realized) to an amount equivalent to 30 gains, whereas no corresponding effects are bestowed upon properties along A by virtue of the new connection with C. Second, problems of this type lend themselves to linear programming techniques, which would constitute a great improvement over crude trial-and-error approaches. For the purpose, to give an illustration, the values in Table 4 can readily be expressed net of costs. All that is necessary is to subtract individual project costs from individual project gains. The diagonal values then are: AA = 200, BB = 250, CC = -120, DD = 0. From then on the objective is straightforward gain maximization. Modifications of the assignment technique or other linear programming methods might possibly be used and might cut down the computational load considerably. Third, failing less expensive shortcuts, resort can, of course, be had to electronic data processing, the panacea when large numbers of computations must be carried out.

On a very practical level, it is likely that the availability and quality of the basic data themselves will impose more stringent limitations on the volume of calculations than the matehmatical techniques that can be devised. Nothing is gained by building a towering analytical pagoda upon the clay feet of poor empirical data. Further, in many cases the more remote system effects will be difficult to measure, let alone forecast, and lack of such information by itself will make for simplifications. Also, frequently one particular project will be certain to yield large net gains compared to the net gains of the other possible network components and additions. This could be the case of a main highway connection, the economic justification of which has been established beyond doubt; only minor modifications need be tested. Under those circumstances the dominant project can be taken as given and all the minor projects can be tested in relation to it. This will also make for less complex analyses.

TABLE 5

POSSIBLE PROJECT COMBINATIONS
(Derived from Table 3)

Project Combination	(1) Gross Gains (units)	(2) Costs (units)	(3) Net Gains, (1)-(2) (units)	(4) Rate of Return, (%) $\frac{(3)}{(2)} \times 100$
A	500	300	200	66.7
B	600	350	250	71.4
C	20	140	-120	-
D	100	100	0	-
AB	0	650	-650	-
AC	730	440	290	65.9
AD	600	400	200	50.0
BC	620	490	130	26.5
BD	640	450	190	42.2
CD	210	240	- 30	-
ABC	230	790	-560	-
ABD	40	750	-710	-
ACD	920	540	380	70.4
BCD	750	590	160	27.1
ABCD	360	890	-530	-

Transportation Activity Analysis

Decision-making responsibility is once more raised, this time to the transportation activity level. The planning horizon expands correspondingly and embraces anything concerning transportation within the metropolitan area. Further relationships, formerly external to projects, or to the highway technology, now are internal to the metropolitan transporation deliberations and must be analyzed.

The economic and analytical techniques are precisely the same as the ones described earlier for program planning. On reflection, it stands to reason that the rivalry between, say, a freeway and a parallel toll road, is equivalent to rivalry between a freeway and a subway. Similarly, the complementarity of the main freeway and its feeder is analogous to the dependence between bus and subway, or parking lot and subway, or freeway and express bus, or airport and the supporting ground transportation facilities.

From the purely computational point of view, transportation analysis is therefore carried out in exactly the same fashion as program analysis. No special difficulties should arise on this score. Lacking a metropolitan region authority, it may take some persuasion to convince highway authorities, transit agencies and other technological decision-makers in the area that they should voluntarily adopt broad transportation viewpoints. What organizational steps might be taken in such a situation, is a fascinating research topic in its own right. It will not be pursued here, however, because it was assumed at the beginning that the appropriate political and administrative arrangements can be made to implement the policies found desirable on analytical grounds.

A Mathematical Statement of the Program or Activity Problem

Let p_i $(i = 1, \ldots, n)$ be a proposed list of projects having known costs of construction $c_i \geq 0$. Then the total cost of a program, P, may be written as

$$C = \sum_{i=1}^{n} c_i \, \delta_i \tag{1}$$

in which

$$\delta = \begin{cases} 1 \text{ if } i^{th} \text{ project is included in P} \\ 0 \text{ otherwise} \end{cases}$$

Let the first order effects of p_i on p_j $(j = 1, \ldots, n)$ be given by the matrix (G_{ij}) where the diagonal elements $G_{kk} \geq 0$ for $1 \leq k \leq n$ represent the worth of p_k taken individually. The gross worth of P may be calculated by

$$G = \sum_{i=1}^{n} \left(\sum_{j=1}^{n} G_{ij} \, \delta_j \right) \delta_i \tag{2}$$

and the net worth of P calculated by

$$W = \sum_{i=1}^{n} \left(\sum_{j=1}^{n} A_{ij} \, \delta_j \right) \delta_i \tag{3}$$

in which

$$(A_{ij}) = (G_{ij}) - (C_{kk}) \tag{4}$$

and

$$(C_{kk}) = \text{a diagonal matrix.}$$

It is desired to maximize W over the set of column vectors $\delta = (\delta_1, \ldots, \delta_n)$, or, in vector notation,

$$\max_{\delta} W = \max_{\delta} \, \delta' A \, \delta \tag{5}$$

It should be noted that the G_{ij}, and hence the A_{ij}, may take negative values, otherwise the problem would be trivial. The discrete finite nature of the problem guarantees the existence of an optimum selection of the p_i.

THE TIME DIMENSION

So far the discussion has referred to a timeless decision-making universe. Now it is convenient to introduce the time dimension into the analysis. Answers must be found to questions such as these: Should projects be carried out all at once, or should one proceed in stages? Should one prefer a facility with a long physical life, or one which is less durable and necessitates frequent repairs and renewals? Should projects be constructed now, or would it be better to postpone them?

Discounting for Present Value

Such problems call for comparisons of projects with different life spans, and different paths (or profiles) of gain and cost streams over time. Solutions can be found by giving an economic meaning to time. Discounting is an exceedingly convenient procedure for comparing projects with different lifespans and value streams, by reducing the complex time-space structures of the projects into flat images, as it were.

(It also produces unambiguous results. McKean (5, pp. 92-93) demonstrates how alternative "fuzzy" annual gain and cost concepts can give rise to different interpretations and may produce a variety of profit rates.) Steiner (28, p. 897) calls discounting "a metric for comparing unlike time profiles".

Standard procedures can be used to obtain solutions. The present value V of a series of gains from a project is

$$V = \frac{G_1}{(1 + r)} + \frac{G_2}{(1 + r)^2} + \ldots + \frac{G_T}{(1 + r)^T} + \frac{S}{(1 + r)^T} \qquad (6)$$

in which G is the gain accruing at the end of any unit period t, usually year (t = 1, 2 ... T); r is the rate of interest or discount (here assumed to be constant); and S is the scrap value at the end of the project's lifespan (T).

McKean makes the subtle point (p. 75) that estimating salvage or scrap value means really that costs and gains beyond the project lifespan can be foreseen; this "may be tantamount to peering into the indefinite future". However, there may be a contract or obligation to raze a structure at the end of its life, in which case a definite scrap cost can be put in for the terminal period. As was indicated earlier in the present study, highway investment analyses should allow for site clearing costs, in order not to burden the future with unwanted costs of the past.

What is the appropriate general project selection criterion when time is taken into account? Let it be assumed that there are no budget limitations and that the interest rate is given. Following from the preceding exposition, the objective will then be to maximize the difference between the present value of future gain streams and the present value of future cost streams. In other words, the objective is maximization of the present values of net gain streams over time. This intertemporal objective of net gain maximization is analogous to the timeless net gain maximization procedures applied to projects and groups of projects as depicted by Figure 1 and Tables 4 and 5.

Some Examples of Different Time Profiles

This brief first statement of general principles makes it possible now to look at some typical project planning examples. There are no budget limitations and the interest or discount rate is alternatively given at 5 percent and 30 percent. The cases are greatly simplified for purposes of exposition. To render the computations not too cumbersome, fairly limited planning horizons (i. e., short project lifespans) are stipulated.

In Figure 5 and Table 6 different versions of the same project, which may be visualized as a toll highway or a freeway, are contrasted with each other. These are mutually exclusive project possibilities and the planning agency must select one of them. The information on the design and construction variations will have come from engineering studies and the gain data from traffic, economic and market research.

In Case A the highway is immediately, during the first year, constructed to full capacity, say to four-lane standards, at a cost of 100. Operating costs of only 10 units per annum must be carried for the remaining four years. This represents high capital intensity.* This is a model of gain and cost streams as they actually occur in time; therefore, the question of the placement of depreciation or amortization charges in time does not arise. Gains build up over the years, from 20 during the first year to 100 during the last. In the real world, gains would probably decline toward the terminal period, but this point is not essential to the present exposition. As depicted, in all four cases gains drop to zero in year 6 and project continuation would therefore mean a loss.

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*Capital intensity can conveniently be measured by the ratio of initial costs to the present value of the future stream of costs. The higher the ratio the more capital intensive is the project.

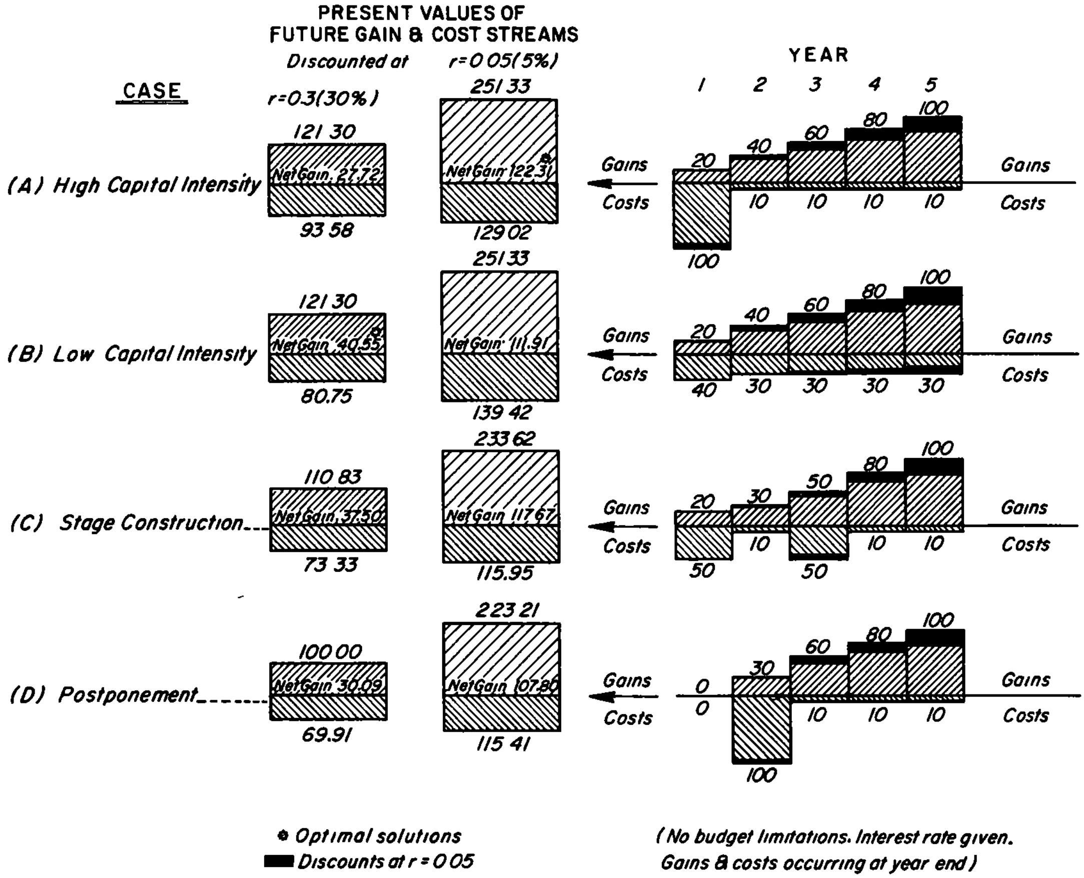

Figure 5. Project comparisons.

Case B represents a less capital intensive solution than Case A. The highway is from the outset constructed to lighter standards at an initial cost of 40, but thereafter much heavier reconstruction and maintenance expenses of 30 units per annum are incurred through to the end. Assuming that there is no deterioration of service standards despite lighter original construction and the necessity for frequent repair work on the road—a somewhat doubtful proposition—gains over the years will be the same as in Case A. If desired, reduced gain values can easily be put in as a concession to reality, but again this does not invalidate the general method.

Case C involves stage construction and is, as it were, a variation of B. During year 1 only two lanes are constructed at a cost of 50 and the highway is expanded to four-lane standards during year 3. Moderate operating expenses of 10 units per annum are incurred during the other years. As a consequence of stage construction, traffic growth is a little slower compared with the first two cases and only 30 and 50 gains, rather than 40 and 60, accrue during the second and third years, respectively. Case C can, if desired, be changed around at will (for example, by letting construction of the additional lanes occur during year 2 or year 4). Operating costs during year 2, since only two lanes have to be looked after, could also more realistically be assumed to be 5 rather than 10 units.

Case D, finally, considers postponement of four-lane construction by one year, to let demand build up more. It is an extreme variation of Case C. Penalties are incurred that way, with first-year gains lost irretrievably, of course, and second-year gains running at 30 units only, rather than 40 as in Case A. On the other hand, there are savings in operating costs during the first year.

TABLE 6

PROJECT COMPARISONS OVER TIME
(No Budget Limitations, Interest Rate Given, Gains and Costs at Year End)

	Present Values of Future Gains and Costs		Yearly Discounted (Not Discounted) Values, r = 5%				
Items	r = 30%	r = 5%	1st	2nd	3rd	4th	5th
		Case A, High Capital Intensity					
Gains	121.30	251.33	19.05 (20)	36.28 (40)	51.83 (60)	65.82 (80)	78.35 (100)
Costs	93.58	129.02	95.24 (100)	9.07 (10)	8.64 (10)	8.23 (10)	7.84 (10)
Net Gains	27.72	122.31[a]	-	-	-	-	-
		Case B, Low Capital Intensity					
Gains	121.30	251.33	19.05 (20)	36.28 (40)	51.83 (60)	65.82 (80)	78.35 (100)
Costs	80.75	139.42	38.10 (40)	27.21 (30)	25.92 (30)	24.68 (30)	23.51 (30)
Net Gains	40.55[a]	111.91	-	-	-	-	-
		Case C, Stage Construction					
Gains	110.83	233.62	19.05 (20)	27.21 (30)	43.19 (50)	65.82 (80)	78.35 (100)
Costs	73.33	115.95	47.62 (50)	9.07 (10)	43.19 (50)	8.23 (10)	7.84 (10)
Net Gains	37.50	117.67	-	-	-	-	-
		Case D, Project Postponement					
Gains	100.00	223.21	-	27.21 (30)	51.83 (60)	65.82 (80)	78.35 (100)
Costs	69.91	115.41	-	90.70 (100)	8.64 (10)	8.23 (10)	7.84 (10)
Net Gains	30.09	107.80	-	-	-	-	-

[a]Optimal solutions.

From mere inspection of the gain and cost streams over the five years and without knowledge of the economic value of time, it is impossible to say which case represents the optimal solution. However, by discounting the streams to arrive at present values, a rational choice can be made. The final results of discounting are shown in the first two columns of Table 6 and Figure 5, while the detailed discounted values year by year are given in the last five columns of the table (undiscounted actual values shown in parentheses). Gains and costs are assumed to accrue at year end.

Which project proposal is the best? If an interest rate of 30 percent is assumed (first column), Case B represents the optimal solution. Net gains are maximized at 40.55 and cannot be bettered any other way. On the other hand, if an interest rate of 50 percent prevails, the capital intensive Case A maximizes the present value of net gains at 122.31 units. Stage construction is the second best solution under both interest rates and project postponement comes third at 30 percent interest and last at 5 percent.

By the right choice of interest rates and gain and cost streams over time, any one of these four broad project cases might be made to come out best. It is difficult to phrase rules which will cover all complex situations. Generally, very high interest rates will penalize projects of high capital intensity, or high initial investment. Or, there is an inverse correlation between durability and the rate of interest. Very low interest rates will normally work in favor of future generations, as it were. Why? It is always assumed that there will be some positive payoff, some net gain from projects, otherwise they would not be carried out at all. At very low interest rates this net gain can accrue at some distant date and still count quite substantially in present terms. At the extreme, with no interest assumed at all, consideration would even be given to investing 100 cost units into a project now, although gains of 110 units would not accrue until 100 years from now and there is no payoff at all in the interim period. It can also be observed that the influence of variations in the interest rate will be very powerful when long project periods are involved. When 50-year projects are considered, as is sometimes the case in highway or transportation planning, the leverage effect upon gains and costs of moving the interest rate up or down slightly, will be quite tremendous. (Grant and Oglesby (22) chide highway planners and analysts in the United States for frequently using unjustifiably low interest rates—3½% or less—or even zero ones.) An original investment of $1 million will be $5.6 million at 3½% compound interest, but will be more than double that, with $11.5 million at 5 percent at the end of 50 years.

Intertemporal Program or Transportation Activity Analyses

Complications arise when interdependent projects must be dealt with. Consider network or systems effects, such as those depicted in Figure 4 and Tables 4 and 5. Given one particular discount rates, such as $r = 0.05$, the project bundle ACD might maximize net gains, as shown in Table 5. But when, for example, $r = 0.30$ applies, some quite different project combination might be the optimal solution. That this may happen can easily be shown with the aid of numerical examples. Indeed, given sufficiently varied gain and cost stream profiles over time, any project bundle can be made optimal at the "right" discount rate.

It can be seen, therefore, that the composition of the set of projects which maximizes net gains will change with fluctuations in the discount rate. One can imagine 16 columns representing the profiles of all values over time to rise vertically from the flat matrix used to describe the system (see Table 4). Discounting, then, can be visualized as a device to project the values represented by the vertical columns downwards onto the flat plane. But the projected values, or flat images, will be affected by the focussing of the projection apparatus itself; that is, by changes in the discount rate.

If the rules of the transportation planning game demand that several discount rates must be considered, the corresponding number of flat projections of gain and cost values must be prepared. In other words, separate lists of optimal project bundles must be drawn up for the various discount rates. It is clear that numerous "side calculations", as they are termed in the literature, then become necessary.

The complexity of the iterative processes necessary to find optimal solutions under these circumstances may alarm some. But it is well to remember that such complexity is caused by the system effects and fluctuating interest rates (i.e., by the circumstances which the analyst may encounter in the field) rather than by the analysis itself. It should also be emphasized that the phenomena discussed here are not restricted to highways or transportation, or to the public sector, but may also, of course, be found in private enterprise investment planning.

HIGHWAYS IN THE ECONOMY

There are two facets of major transportation investments in urban areas which must be studied: First, the cost and gain effects in the metropolitan region which are directly traceable to the introduction of the freeway or other project. Second, the general economic consequences of resource allocation for highway transportation, rather than for other purposes. These two aspects will be considered in turn.

Effects on the Metropolitan Economy

Decision-making responsibility is now raised to the level of the metropolitan economy and the analytical and planning horizon expands correspondingly. All remaining cost and gain effects become internal to the deliberations. It is submitted that public agencies, by virture of the statues governing them and the mandate given to them by legislatures, are obliged to adopt this broadest possible viewpoint.

Turning once more to Table 3, the first group of metropolitan economy cost items requires little explanation. Accident exposure of non-users on a controlled access freeway itself will be very slight, but will be considerable on the feeder routes, etc., leading to and from the ramps; these segments are part and parcel of the project, because the freeway itself represents neither origin nor final destination for travelers. Accident costs, as well as noise, dirt, air pollution*, etc., costs, are predominantly non-market items and the familiar problems discussed earlier apply. Similarly with most of the possible beneficial city planning, aesthetic, etc., effects of a freeway project.

The designations "imports", "exports", and "foreign aid" are somewhat unorthodox, but become reasonable on closer scrutiny. If the viewpoint of the metropolitan economy is adopted, there will be cost and gain effects which are external to it, but internal to senior levels of government, to the national economy, or, more fancifully, to the world as a whole. Exports, or gains, set up by a freeway project might be increased profitable tourist spending within the metropolis. Imports, or costs, might be accommodation of traffic from outside the metropolitan region which does not contribute to the costs it causes. The "corridor state" problem is an example for this in the intercity field. Peak-hour commuters into the central city core, who reside in dormitory suburbs outside the city boundaries where they cannot be taxed for freeway support, are another manifestation of such pseudo-imports. Metropolitan government is designed, among other things, to overcome these unwanted import aspects.

From the metropolitan viewpoint, grants-in-aid rendered by federal, state or provincial governments constitute foreign aid, as it were. Relevant to the transport analyst are highway aid, city renewal and urban transit support. The history of these intergovernmental transfers is long and the allocation formulas are most involved. The rationale for highway fund transfers seems to be based on the following considerations:

1. The senior government is the more efficient revenue or tax collector; hence, after deduction of expenses, the collection agency simply hands moneys back to the source jurisdictions.
2. The senior government has bona fide jurisdictional and functional interests in highway facilities in metropolitan areas (e.g., the urban portions of the interstate or statewide highway system), presumably as required by genuine interstate or statewide traffic. However, for reasons of administrative efficiency, close local supervision, etc., the work is actually carried out or contracted out by junior governments, hence fund transfers become necessary.
3. The senior government performs an income redistribution role; for example it takes more from automobile-rich regions (cities, densely settled states) and gives more to automobile-poor areas (rural districts, sparsely settled states).
4. The senior government takes over certain functions, because the junior governments are not fit, willing or able to carry them out efficiently.

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*Care must be taken to avoid double-counting and other social bookkeeping errors: accidents can be minimized by higher freeway project expenditures; noise, dirt, etc., can be held down by more landscaping and maintenance; air pollution health hazards can be converted, as intended by a recent California law, into motorists' private costs by making exhaust fume cleaning devices compulsory.

5. The senior government acts as a consultant, or renders technical aid, without interfering with the actual decision-making of the junior jurisdictions.

It appears that all of these five major elements are present in varying degrees in current inter-governmental highway money transfers.

What is the effect of this upon planning of, say, a metropolitan transportation facility? The distortions introduced, wittingly or unwittingly, into decision-making can be considerable: "foreign aid", if it requires little local matching effort, is almost costless—one might as well obtain it, before it is lost to another city or region. There is little doubt, that at the present time "foreign aid" works in favor of highway solutions in big cities and to the detriment of other technological proposals. If there is confidence in the quality of metropolitan decision-making it is desirable that "foreign aid" be neutral in its effects upon urban transportation planning. Although no attempt can be made here to do this topic justice, it is clear that precise definitions and distinctions of the senior governments' roles —as collection agents, bona fide decision-makers in urban areas, income redistributors, trustees, or technical consultants—would be an important first step toward removal of "foreign aid" distortions in urban transportation planning.

Land value changes and other broad effects on Gross Metropolitan Product and the general urban way of life, finally, represent one of the greatest challenges to the analyst. Opportunities for double-counting or for neglect of important effects, usually detrimental ones, abound. This perhaps explains why the results of many highway benefit and economic impact studies carried out in recent years have not always lived up to advance expectations. True, a highway or freeway project may set up faster land value increases in an adjacent zone, as compared with real estate price trends in a remoter control area. But, as a result, simultaneously a relative decline of property values elsewhere in the metropolitan area may have taken place, which may go unrecorded. Hence, from a metropolitan viewpoint, the relative gain at one locality may be offset by a relative loss at another. The true picture is further distorted by the secular land price increases (due to growth of population, incomes, etc.), by many cross effects, and by property acquisition for freeway purposes itself. It must not be forgotten that highway departments these days are important real estate customers themselves. It is further not clear whether maximization of land values (or of property assessment and tax revenues) should be the overriding human objective in urban areas. The assumptions which must be made before real estate trends can be accepted as the sole success indicators for the metropolis, certainly deserve close scrutiny.

Finally, those who regard big cities as something more than just convenient locations for producing the maximum number of vehicle-miles, would wish to draw further aesthetic, social, political, cultural cost and gain effects to the attention of the metropolitan decision-makers. The quantification of the relevant personal or collective value judgments and their aggregation with all the other effects listed in Table 3, will obviously pose tough practical problems.

Highway Investment Planning in the Macroeconomic Setting

So far it has been assumed that resources for the initiation and operation of freeways and other highway projects will somehow be forthcoming. How does resource allocation at the higest level take place? To say that funds are assigned in accordance with given budgets really begs the question, because then one must inquire how the budgets were arrived at in the first place. The budget assumption, furthermore, can be dangerous in its consequences: in economic terms, funds once budgeted are regarded as costless by the spending agency, because no alternative uses for the moneys are contemplated. If the budget is too small, profitable investment opportunities will go begging; if it is too big, uneconomical projects will be undertaken.

In the highway field, a more refined budget approach is being used. Financial self-sufficiency, or the no-deficit rule, coupled with so-called "user tax dedication", are the chief constraints, so that revenues expected to be collected from motorists will determine the spending budget. This economic regime implies, in order to function properly, that the following conditions prevail:

1. The level of user charges must be set rationally, i.e., in response to proven

highway investment opportunities and not vice versa. With inelastic demand for the usually highly monopolistic road transportation function, it is evident that mere willingness of users to pay, say $0.02, or $0.05, or $0.10, or $0.20 per gallon gasoline tax, does not constitute proper guidance for spending the moneys.

2. The highway function must be a going concern, which is neither in a sharp expansionary phase, nor in the process of contraction. If expansion was expected, credit financing should be resorted to (why should the present generation of motorists pay excessively high charges to finance facilities which will mainly be used by future generations of motorists?) If contraction of highway demand was anticipated, charges should be reduced or the money be redirected to other purposes.

3. Highway revenues, once collected as such, do not have more profitable application anywhere else in the economy. To emphasize this crucial condition, visualize the highway department as one technological division of a large concern (namely, public interprise, or "the public interest") in the same way that, say, Chevrolet is one of many divisions of General Motors. The financial autonomy rule for highways (user tax dedication, earmarking of funds), in terms of General Motors, then implies that Chevrolet profits always must go back to the Chevrolet plant, although no expansion may be needed there and although dozens of far more worthwhile G. M. projects (fuel cell development, diesel locomotives, refrigerators, VTOL vehicle, rocket ship, etc.) may go begging for lack of funds. It will be recognized at once that one of the great advantages of a big concern like General Motors is the ability to switch funds freely within its economic empire to the most profitable applications. Should this freedom of investment fund dispostion, a priori, be denied to the custodians of the general public interest?

The preceding, necessarily brief, discussion of one of the key issues of contemporary highway finance brings out the point that both the ordinary and the user-revenue determined budget alike must be regarded as subordinate means to a superior aim. This aim is clearly the disposition of funds, throughout the economy, in such a way that aggregate net gains are maximized. It is, therefore, the anticipated investment opportunities which should determine the allocation of money for investment.

One can imagine that within the economy an aggregate public-private demand schedule for investments exists. Suppose a mixed list of private and public projects, including highway ones, are hierarchically arranged by rates of return. At the top of the list there will be a few very profitable ventures. As projects with lesser profitability are included, cumulatively the total demand for investment funds will grow. When such a mixed public-private investment demand list is confronted with a given interest rate, the following results will be obtained: At the margin, there will be a public project, or a private one, or both, which just barely qualify for investment. This means that the marginal projects, when their future cost and gain streams are discounted at the given interest rate, will just promise to break even; in other words, at the given discount rate, their V's exactly equal their C's. In this position, total net gains for the economy will be maximized and no further shifting of resources, into and out of projects, or from public to private and vice versa, could enhance net gains expected from all ventures as a whole.

Clearly, all supermarginal projects (i.e., all those which show $V \geq C$ at the given discount rate) should be carried out. Adding up the investment costs of qualifying projects for each sector, such as highways or transportation, will reveal the correct individual investment budges; the grand total of all will represent the correct total investment budget for the national economy for the given period. Any other budgets will yield lesser aggregate net gains.

Consequences for Highway Investment Analysis

It is evident that the interest of discount rate thus plays a key part in investment analysis. But all the chains of causation determining the crucial interest rate factor—incomes, savings, taxation, central bank policy, attitudes to risk, dividend policies, profit expectations, technical knowledge and discoveries, etc.,—cannot possibly be described in a few simple sentences. Nor is it necessary for the present purpose to do so. The preceding discussion was designed to demonstrate that any searching inquiry into highway and other public investment planning inevitably merges into general equilibrium analysis.

Where does this leave the highway analyst who has a very immediate and practical job to do? It seems that he has to carry out calculations within a framework of assumptions and data which he and many other public and private decision-makers and analysts themselves determine in some unpredictable fashion. Would he not be forced to say: "Since everything depends on everything else, nothing can be determined"?

In this situation it is best to assume the interest rate as given. This approach has a number of attractive features. It might be visualized as a predicted general market interest rate, worked out by federal financial experts or central bank specialists. With a given interest rate, allowing somehow for risk, length of investment period, etc., projects financed on a pay-as-you-go basis, by budget allocation, or through bond issue, could be mutually compared. Furthermore, if the right interest rate range is selected, performance comparisons between various public (highways, subways, water resources, city redevelopment, etc.) and private projects become possible and optimal performance of the investment process over the whole economy can be brought about.

How should the right interest rate be chosen, if it cannot be assumed as given? Different interest rate concepts have been proposed for adoption by public agencies. Krutilla and Eckstein (24), for example, have empirically calculated the social cost of federal capital at between 5 and 6 percent. Grant and Oglesby (22), correctly proposing an opportunity cost concept for investment opportunities foregone elsewhere, mention rates of 5 to 7 percent for highway planning purposes.

Little of general value can be said here about the choice of the interest rate, or what may be called more broadly the social rate of time preference. If it is not given or forecast by some central authority, the analyst in each case must select a rate and defend his choice as well as he can. In any event, there is no excuse for using no interest at all; i.e., adopting a zero rate of discounting. Sometimes, as McKean, (5) suggests, it will be convenient to prepare analyses based on several "likely" interest rates. As Marschak (17) points out, the "études de rentabilité" of the French nationalized coal, gas, electric power and railway undertakings likewise show predicted cost and gain streams discounted at one or more "interesting" rates.

If designation or choice of the interest rate as the rationing device is completely ruled out, what is the alternative? The only other course of action seems to be to set the budget more or less arbitrarily. If so, the analytical and planning objective is still maximization of net gains over time (i.e., maximization of the present value of V - C). It can be shown mathematically that arrangement of projects in order of their benefit/cost ratios (V/C), or by internal or other rates of returns, going down the lists until the given budget is exhausted, does not necessarily lead to net gain maximization and may, indeed, result in sub-optimal decisions. Because even with a given budget maximiztion of V-C is still the correct criterion, one must find the discount rate which just exhausts the amount available. It will be convenient perhaps, as McKean (5) explains, to work out project lists based on reasonable ranges of discount rates and then determine the correct budget cut-off point by interpolation.

Project and program interrelationships (systems or network effects), make for "jumpy" project bundle choices when the interest rate is varied, as has been seen: at 5 percent the project selection ACD may be optimal, at 7 percent perhaps CDEF, at 10 percent possibly B, and so on. Or, to put it differently, there is no unique list of "ranked" projects which is correct at all discount rates. This once more shows that project selection by means of benefit-cost ratios may not lead to optimal results. Therefore, full project search procedures must be carried out for each likely discount rate. Electronic computers or improved mathematical techniques for the iterative processes may reduce the work load. This is a most promising field for research.

Even with given budget limitations as the chief constraint, all is not lost for the analyst: if he can point out to the decision-makers that an extreme discount rate of, say, 30 percent (or of 1 percent) just exhausts the budget, such information in itself may greatly influence future action. In view of such exceptionally good (or bad) investment opportunities prevailing in the sector in question, more (or less) funds might be allocated next time.

CONCLUSIONS

Summary

This paper has attempted to sketch the economic principles which might guide highway planning. Beginning at the lowest level of decision-making, it was shown how projects might be identified and how the prospective cost and gain effects over their lifetime might be analyzed. It was pointed out that maximization of net gains would determine the optimal output solution, which incidentally would also represent the best position for consumers, for contributing productive factors and for the economy at large.

Next, the interrelationships between projects and programs or technologies were traced. It was seen that such so-called systems or network effects might react back upon the selection of the optimal project bundle. Changes in the discount rate—a convenient device to reduce complex gain and cost streams over time into flat, comparable images, as it were—may further change the composition of the desired optimal project investment combination. There is no unique ranking of projects at different interest rates. Iterative techniques become necessary to obtain the optimal investment planning results.

Finally, highway investment planning was discussed in the broadest economic context. It was pointed out that adoption of the "right" interest rate (which might be a market rate or range of rates) for project selection and discounting purposes, would guarantee not only maximization of prospective net gains from all public and private investments, but also allocation of the right magnitude of funds for the various purposes (private and public; highways, rapid transit, city redevelopment, etc.). If at all possible, it would be convenient if the planning interest rate, as the crucial analytical tool, were given or forecast by some higher authority (federal financial experts, central bank specialists). But if necessary the analyst himself may have to select an appropriate rate and then defend his choice. Neglect of interest in highway or other transportation planning (i.e., adoption of a zero rate of interest) is inappropriate. Due to institutional circumstances, either arbitrary or revenue-determined (earmarking of highway user taxes) budgets may be the chief analytical constraint. If so, proposed project selections must be subjected to discounting at several "likely" rates, until the budget is just exhausted. It should then be pointed out to the decision-makers, that a certain rate, which may be rather high (or low), applies to the program selection; this in itself would strikingly indicate the need for increased (decreased) budget allocations in future.

Throughout, it was pointed out that many market and non-market cost and gain effects will be caused by highway actions. These different value species pose treacherous problems of identification, quantification and aggregation. Although they may have to be presented separately, in dollars, in words, in physical or other terms, it is not permissible to ignore any effects for which evidence exists and which are relevant to the problem at hand. Some cost and gain effects will appear to be internal, others external, to the analyst's area of responsibility. It was argued that any public agency, by virtue of its legislative mandate, must adopt the broadest possible viewpoint—that of the national, state, regional, or metropolitan economy. This means that any project effects occurring within this broadest of horizons—repercussions inflicted upon other projects, technologies, transportation or the economy as a whole—are internal to the decision-making viewpoint, and therefore of analytical interest and concern.

Some Practical Consequences

This paper has been largely presented in condensed, highly abstract form. It was felt that this was the best way in which to discuss the enormously complex problems of highway and other public investment planning.

It may well be asked that indications be given as to what all this means in immediate, practical terms. In conclusion, an attempt is therefore made to highlight some of the more important aspects of direct concern to highway planners and decision-makers. The convenient question and answer form of presentation is used. Personal judgment will have to be employed for some of the answers, with the attendant risk of bias.

1. Are the analytical techniques outlined here correct beyond doubt? Can they be relied upon by the practitioner?

It would be misleading to say that no controversy about their validity in all circumstances remains among economists themselves. Capital and investment planning theory has been built up rapidly in recent years, and there are bound to be further developments ahead. Application of some of the newer concepts to the public sector—which lacks the usual private enterprise competitive price, normal profit, survival-of-the-fittest, profit maximization motivation, etc., constraints—is regarded by most students of the subject sphere as pioneer work. Even recent books on one public sector—water resources—reveal differences of opinion on which economic yardsticks are the correct ones. However, under certain circumstances some of the more popular economic criteria (internal rate of return, maximization of benefit-cost ratios, maximization of investor's present worth) yield the same answers. At present, the maximization of investor's present worth, also called maximization of the present value of net gains technique, which was incorporated in this study, appears to be by far the most satisfactory one. It is, incidentally, also the economic criterion recommended by McKean (5) for the water resource field and other public activities. With some modifications and some additional features grafted on to it, the present worth apparatus can handle a great range of practical planning problems very well.

It is interesting to note what the Staff Study Appendix to the Commerce Department Report on Transportation (2) has to say on public investment planning concepts:

> Unfortunately, adequate tools and methods of analysis are not presently available. The use of economic analysis in public investment decision-making in recent years has received increasing attention, but the only tool that has had significant application is the benefit-cost ratio...There is need for analytical procedures for both justification and ranking. Only justified projects and programs should be undertaken at all and the best projects should be undertaken first.
>
> Although critics have pointed out several weaknesses in the benefit-cost ratio as a decision-making device, it seems to be the best tool of analysis that has been widely used. It should receive wider use in the highway field and should be applied in airways and airport investment decisions. But it needs to be studied and improved. (p. 42)

The foregoing statements and others contained in the two Commerce Reports, which may well have stirred other transportation economists and analysts into thought and action, certainly reflect the motives behind the present study.

2. Are analyses of the type described here worth bothering about? Supposing the theories shown are found to be correct, is it likely that they will be adopted in practice?

Of course, planning of this or any other type is not costless. But no planning at all would probably lead to incomparably greater costs for the community. The tangible and intangible returns from better investment planning in the highway and general transportation sphere are likely to be very large indeed. Present highway budgets and other transportation expenditures are so enormous at present, and expected future problems in this area are so great, that even slight analytical advances will yield great community returns.

The highway profession has a particualrly good tradition in planning. It is most likely that the newer economic or other analytical tools, provided they can be shown to be sound and practicable, will be received enthusistically by the decision-makers and planners in the highway field.

There is keen official interest in improved economic planning in the transportation sphere. The Commerce Department Report (4) repeatedly calls for the adoption of investment analyses as a guide to policy; examples are:

> The national transportation role will be carried out most effectively if decisions on necessary public investments are based on analytical procedures using objective criteria comparable to those which govern the economy at large. (p.21)
>
> The Government should evolve and keep current a comprehensive plan for its investment in all types of transport facilities. Within each type of facility, it should continue to develop adequate standards of analysis to compare costs with benefits for each project. It should also devise standards by which to compare each primary area of investment (highways, rivers, and harbors, airways and airports) with the others and with private transportation investment, so that investment decisions can be made upon similar tests of need and public advantage. (p.6)
>
> The Government should establish a transport investment planning staff to use objective analytical methods in making unified, long-range Federal investment plans to be published and included in the annual budget document... (p.22)
>
> (The Federal Government) should encourage urban long-range community planning, including total transportation planning to make full use of highway, transit, rail communication, and all other capacity to minimize total transportation cost and congestion... (p.25)

3. What is the best way to gain acceptance for improved analytical procedures?

Probably in the usual way: through research papers, workshop conferences, through the spearhead of consultants' work, through pilot projects which can be publicized to explain the methodology. The Chicago, Detroit and Washington, D.C. studies, among others, in some respects already represent significant practical advances.

Once some acceptance and experience has been gained, it seems important to review the influential AASHO, BPR, etc., manuals. Simultaneously, planners and researchers will take a growing interest anyway. That this has already happened, is attested by the growing number of relevant papers on highway planning, economics and finance presented at recent Highway Research Board meetings.

4. Applying subjective judgment, which problem areas in transportation might at present be regarded as the most critical ones?

First, in the highway field, accidents probably constitute the most serious and intractable of all problems. As was pointed out, purely economic considerations cannot and should not be the sole guides to decision-making in this respect. It may well be that the present accident toll, on purely functional grounds, cannot be drastically improved upon. After all, there seem to be limits to improvements in the average operating performance of large segments of the population put behind the steering wheel. To maintain or officially inspect the mechanical reliability of huge fleets of old and new vehicles, individually owned, also seems to be inherently difficult. Furthermore, a fair amount of risk seems to be inherent in the two-dimensionally independent movement, at high speeds, of many vehicles traveling along narrow routes at much the same time. Perhaps the inevitability, within statistically defined limits, of highway accidents should be recognized realistically. Possibly the correct high-level decision would then be to reduce the amount of highway travel (for example, by offering attractive, safe rapid transit services in cities) as the most direct and effective way to obtain improvements in transportation accident trends.

Second, highway planners, especially when their actions affect urban areas, have on occasion been accused of being insensitive to broader transportation issues and general community values. Although there may be some truth to this, for the following reason this is rather superficial criticism:

(a) As was pointed out, the determination of the decision-making level, or planning horizon, is crucial. It cannot be expected that highway planners, hired and paid to perform a highway job, will suddenly and without instructions, adopt a general transportation or community planning viewpoint.
(b) It is really the responsibility of the ultimate decision-makers (legislatures and their executive arms), either to reconcile conflicts between projects, technologies and broad economic and social activities at the highest level of authority, or to issue appropriate instructions to the lower echelons of officials.
(c) Until recently, it seems, rural highway development predominated and there traffic, technical, economic and community objectives usually coincided. The most acute conflicts of interest have only been experienced with the pushing of large-scale highway projects in purely urban areas. From the point of view of the highway profession, clashes between their objectives and city planning, esthetic, social, etc., considerations are new, rather unexpected phenomena.
(d) In all fairness it might be pointed out that highway planners have definite, everyday jobs to do. So far, it seems, the necessary precise guidance for their work has sometimes not really been forthcoming in usable form from local governments and city planners.

One can be most hopeful that with more precise definitions of objectives and governmental responsibilities in urban areas, coupled with advances in anlaytical techniques, satisfactory transportation and community planning results will be achieved in future.

Third, as practical observation in any large city during the "crush" hour will bear out, the transportation industry as a whole surely cannot be particularly proud of its contemporary urban peak passenger service performance. Here further economic research might be of very great help. The peak problem might be somewhat susceptible to pricing policies—people traveling during certain hours of the day could be economically penalized. Some flattening of the peak traffic volume curve segments might be achieved in this way. But there is serious doubt whether it is indeed desirable to suppress peak traffic: Do not certain activities have to coincide in time? Do not the foreman, the worker, the secretary and the executive depend upon each other's presence during the same hours at the same location? Would not such enforced savings in peak transportation costs result in much reduced efficiencies for the rest of the economic system? Perhaps urban peak transportation requirements should be accepted as a given fact of economic and social urban life. If so, further refinements of the investment analyses outlined here might tell how the given task might be performed most efficiently. In any event, research on urban peak problems promises to be one of the most fruitful spheres in transportation research.

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