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Before and After Benefit-Cost Analysis in Urban Transportation

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BEFORE AND AFTER BENEFIT-COST ANALYSIS IN URBAN TRANSPORTATION

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The accuracy and utility of benefit-cost analysis in urban transportation was investigated. The purpose of this report was to examine expected benefits and costs associated with particular transportation projects and to compare them with actual results. Benefit-cost analysis is described in detail along with conceptual and practical problems. The Santa Ana Freeway in Los Angeles was a selected case study to compare ex ante-ex post benefits and costs with reference to time value savings for freeway users and highway commodity savings. The analysis revealed significant differences between the benefits and costs anticipated and those which were observed. Assumptions in the ex-ante analysis are discussed in detail. The report concludes with recommendations to improve the effectiveness of benefit-cost studies in urban transportation decision-making.

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I. Introduction

Benefit-cost analysis has played a central role as a tool in decision making or evaluation of public transportation programs and projects. This role developed largely in response to the need to understand the relationship between economic outcomes and particular social investments. Since revenues often could not be generated from social investments, or prices which were charged for products or services often were set below market levels, means had to be developed to determine whether or not these social investments were desirable, worthy and/or optimal. The costs of public capital investments and of continuing operations were often calculable and fairly well predictable. However, the same was not true for the value of benefits received. Decision makers, lacking the usual market-determined information, had no good criteria for choosing between investments which might have had equal costs but different benefit streams. Even more complex problems arose when investments had both unequal costs and dissimilar benefits.

The absence of carefully designed decision rules based on economic analysis are not of great import in a society where public investments generally are small scale. In such cases, the public or political opinions might have been sufficient grounds for decision making. However, as the scale and complexity of programs and projects increased, involving a wide variety of different costs and benefits with varying time streams, purely _ad hoc_ and verbal qualitative approaches to public project analyses were no longer considered sufficient. A need was felt for organizing benefits and costs on a carefully structured basis so that projects of different or similar types could be compared. Processes of imputation had to be devised to replicate markets which offered only indifferent clues to the value of private and social benefits and costs. These processes of imputation remain at the heart of the benefit-cost analysis even today.

The application of the benefit-cost method became a subject of considerable discussion among both academicians and practitioners of the art. Questions were raised on the nature and types of private and social benefits and costs to be included in the analysis and the bounds of impact areas where projects were lodged in specified regions. A further debate revolved around the methods of valuing benefits and costs. A typical example here might be the appropriate value to be imputed to, say, travel time savings associated with a highway development program or project--e.g. the opportunity cost at places of work or some other value.

Several other problems arose in executing benefit-cost studies. The intangible nature of many benefits and costs (particularly the latter) often meant that they were treated cursorily. Air and water pollution are obvious examples of complex effects which were ignored in the early highway programs. The potential damage to human health and the perturbation of the eco-system associated with air and noise pollution in urban freeway developments offer instances of disbenefits that were often brushed away. Similarly, the intangible character of benefits flowing from investments in environmental protection programs usually meant that they were set aside and not treated in an analytical fashion. Even currently with environmental impact studies required, as part of public investment programs, these studies are usually distinct from benefit-cost analysis. An obvious reaction has set in, and earlier exuberance about imputing dollar values to costs and benefits has been dampened. Many analysts have become cautious about placing benefits and costs on a common scale, and they are sensitive that efforts in this direction may involve making highly unrealistic assumptions. Benefit-cost analysis became only one of a variety of methods providing inputs into the decision-making process. In part the shift was attributable to several factors already mentioned. First, the approach placed undue emphasis on tangible economic benefits and costs, to the exclusion of intangibles. Second, the need to quantify benefits and costs often necessitated weak assumptions. Third, its reliability as a predictive tool rarely was tested or, when tested, the projections of benefits and costs were found to depart sharply from the actual. Fourth, benefit-cost analysis frequently was undertaken to justify predetermined conclusions. Simply put, the tool was manipulated to support or reject previously established postures rather than used to assist decision makers in determining whether or not social investments should be undertaken or how to establish priorities among alternatives. The opportunities for manipulation are manifold, and even those who are familiar with the approach are not always in a good position to determine whether the analysis as carried out produces reasonable results. The outcomes can be influenced by including or excluding selected direct and indirect benefits.

To illustrate, some benefits may be double counted as would be the case if both reductions in accidents and potential savings in insurance costs are included in an analysis of highway developments. Treating future benefits or costs at the same value as current benefits or costs implies the unrealistic assumption that the public is indifferent between current or future expenditures and returns. Similarly, the use of unrealistically high or low discount rates for valuation of benefits and costs will result in favorable or unfavorable benefit-cost ratios or net benefits. The worth of particular benefits or costs also may be subject to manipulation. Finally, benefits or costs may be imputed although these are in the nature of transfers rather than being real gains or losses from the standpoint of society.

Even as the tool was being refined to deal with these problems, questions still were being raised on the general efficacy of the overall approach. Particularly when projects were parts of complex systems, with massive interdependencies between the projects and the rest of the systems, the benefit-cost analysis was considered by many as an inappropriate tool. It became apparent that a group of independent project-oriented benefit-cost analyses could not take cognizance of such interdependencies as complementary relationships and substitutability. Thus, independent analyses could not provide reasonable or reliable results.

Yet, benefit-cost analysis continues to hold an important place in public investment programming. It is a familiar tool to the engineering economist especially, and as a matter of policy many agencies undertake such analyses, although other inputs will also be required. As more system-wide information was required to evaluate public investment impact, there was a tendency to shift away from using benefit-cost analysis as a primary test of economic feasibility. This led in recent years to the development of large-scale systems studies focussing especially on urban transportation. The perturbing effect of small changes in the system could be more readily understood in the context of such models. Obviously, the approach did not lend itself immediately to answering questions such as which parts of the system in the development phase had the highest priority for investment. However, the information which was generated did provide inputs for more detailed analysis.

II. Prospective Use of Benefit-Cost Analysis

Whether used alone or as part of larger studies, benefit-cost analysis usually has been applied in situations where prospective projects are evaluated. A benefit-cost analysis is prepared before investment decisions have been firmed up. The findings may then be included as part of the deliberations by decision makers. The benefit-cost in these circumstances influences a "go" or "no go" decision. Alternatively, the findings may suggest scaling down or up of a project, deferral for the time being, or for that matter rapid implementation. Similarly, the selection of the "best" alternative from variants of essentially the same project may be enhanced. To illustrate, benefit-cost analyses may support the selection of one route from several alternative urban transportation links.

Prospective use of benefit-cost analyses was initiated in the United States in the early 1930's and 1940's by the Army Corps of Engineers. These "economic analyses" actually were engineering surveys and inventories prepared as planning aids for independent projects. Early use of the prospective benefit-cost methodology was dominated by the nation's need for and promotion of dam construction and other work projects, especially of the multiple purpose types. Policy objectives emphasized productivity of projects more than economic efficiency in general. Use of the independent benefit-cost analyses tended to be limited to questions of financial and physical feasibility and the budgetary consequences of projects.

Roland McKean, in a classic study, evaluated the benefit-cost approaches incorporated in various government manuals.[1] His work appeared

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1. Roland McKean, Efficiency in Government Through Systems Analysis, with Emphasis on Water Resource Development (New York: John Wiley and Sons, Inc. for the RAND Corp., 1958).

just after a period of sharp criticism of federal water-resource development subsidies and project evaluation procedures. McKean did not discuss specifically the benefit-cost procedures adapted by government agencies evaluating transportation projects.[2] Nevertheless, his critique of the methodology and his suggested systems analysis approach are relevant to all public project investment decision making. His approach emphasized that benefit-cost analyses served a very limited function: it provided a means by which to "array" governmental investment possibilities, and it permitted meaningful comparisons only when used system-wide (i.e., for all budgetary problems).

McKean classified the methodological problems into three general areas: criteria, time streams, and uncertainty. McKean suggested that most investment analyses should be content with "proximate criteria" or project objectives. Perfect optima are impossible in the real world. An attempt to maximize gain while simultaneously minimizing cost is an unworkable goal. Benefit-cost is a tool for "piecemeal analysis" of small incremental investments which, theoretically at least, should be consistent with whatever general welfare optimum society would like to attain.[3]

McKean argued that the benefit-cost is meaningful for decision makers only if it describes the maximized present value of alternatives: "present value of gains minus present value of costs" using the marginal internal rate of return as the discount rate.[4] Applying the investor's rationale,

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2. Bureau of Public Roads, The Highway Research Board and The American Association of State Highway Officials. See, especially AASHO, Road-User Benefit Analysis for Highway Improvements (Washington, D.C.: 1950).

3. McKean, *op. cit.*, pp. 21-34.

4. *Ibid.*, p. 76.

decision makers should undertake only those projects which have the highest present worth when their respective benefit-cost streams are discounted at a rate representing the yield available in the next best opportunity. The analysis should rank or array alternative projects according to the present value of their gain-cost streams under a variety of different discount rates, for a variety of different project sizes and for combinations of interrelated projects.[5]

McKean argued that uncertainty as well as intangible and spillover effects should be specified or at least the likelihood of their existence recognized. Rather than hide risk in the time stream calculations, McKean would establish a "frequency distribution of outcomes," giving the decision maker some idea about the uncertainty associated with gains and costs; with system constraints; and with political, technological, or random changes.[6]

Intangibles are consequences--of the options being compared--which cannot be expressed in the common denominator being used for gains and costs. While intangibles should not be added to the benefit-cost streams, they can be identified in their own value terms as consequences, specifically, of either side.

Spillover effects are external economies or diseconomies. They are "uncompensated effects" on the revenue or expenses of any group outside of the project itself, but they are caused by the project. McKean argued that if spillovers are "technological" (i.e., "affect the physical outputs that other producers can get from their physical inputs"), then the effects

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5. Ibid., pp. 82-88.

6. Ibid., pp. 58-68.

should be included as a separate component of the analysis. "Pecuniary" spillovers are reflected in changing prices resulting from a project. These effects represent redistribution of resources and transfers of rent. Since they are part of the process of reaching a new output equilibrium with a project investment, such effects should be included only as supporting data describing assumptions underlying each project's analysis.[7]

In sum, benefit-cost cannot be used to divide projects into efficient versus inefficient categories in the pure sense. It can be used to array project alternatives and to specify the underlying assumptions.[8]

McKean tested his projection results against actual prospective benefit-cost analyses which were undertaken by the Department of Interior and Corps of Engineers. The purpose of his comparisons was to understand the problems of prospective analysis and to deal with each in an orderly manner, without permitting the benefit-cost calculus to hide the critical issues.

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7. Ibid., pp. 134-140.

8. Ibid., p. 175.

III. Retrospective Use of Benefit-Cost Analysis

Another use of benefit-cost studies is the after the fact evaluation of projects or programs which are totally or substantially completed. An excellent illustration of analysis in retrospect is Ann Fetter Friedlaender's study, The Interstate Highway System.[9] In part based on actual experiences, this analysis asks a different question: given that society has committed substantial capital resources to the development of a highway system, how does the system perform and what improvements might be made in the future? A sketchy review of Friedlaender's conclusions draws attention to some of the points raised above:

> ". . . The Interstate Highway System is a desirable public investment project, for the substantial savings that it creates in the resources required for transportation outweigh its considerable cost. . . .[it]is far from optimal and could be, in fact, improved to increase the future stream of income to society . . . ."

It was also found that in the rural Interstate System " . . . the overall levels of economically justified traffic in the rural areas are too small to support an entire network of highways with the capital intensity of the proposed rural Interstate System." One reason is that since the bulk of the costs are borne by the Federal government "state highway departments have little incentive to make sure their proposed Interstate projects are as economical and efficient as possible." This is exemplified by the building of four-lane highways where similar benefits would be generated with a two-lane highway. The general level of benefits on the urban Interstate System is estimated to be high in relation to the costs. However, the major

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9. Ann Fetter Friedlaender, The Interstate Highway System (Amsterdam: North-Holland Publishing Company, 1965).

criticisms are leveled at pricing policies, since commuters are not made to pay the marginal social cost of trips. Friedlaender also finds it impossible to compare mass transit facilities to urban superhighways. In other words, the optimal distribution of investment between mass transit and superhighways could not be determined due to incompatible data.

This brings us to the purpose of the current investigation, namely, to join the prospective and retrospective benefit-cost analyses. The research question is: What benefits and costs were anticipated in selected transportation projects, and how do the expectations compare to the actual experiences? A related question is as follows: If expected and actual benefits and costs sharply diverge from each other, then what explains the divergence?

In part the reasons for divergence may lie in the general or specific weaknesses of prospective benefit-cost analyses. Alternatively, the divergence may result from methods of implementing programs and projects. Friedlaender's finding on the failure to properly price trips on urban superhighways is of some importance in this last question. Pricing below marginal social cost, for example, is likely to increase the effective demand for trips on superhighways. As a consequence congestion may result which substantially reduces realized benefits in relation to expectations. Another view might be that the heavy utilization of the systems in retrospect is really a sign of success, and steps should be taken to expand and improve the systems. The reasoning here is that realized benefits to individual users are lower because of congestion. Nevertheless, the aggregate benefits exceed by a substantial margin the costs incurred, even though the benefits are diffused among many more users than anticipated. This last view may find popular support among those who have an interest in expanding particular transport systems. This reasoning may require re-evaluation.

We shall proceed by first reviewing briefly the conceptual and practical aspects of benefit-cost analyses. This will be followed by study of a Los Angeles freeway where before and after benefit-cost data became available.

IV. Conceptual and Practical Problems in Benefit-Cost Analysis

In the previous section we distinguished between ex ante and ex post benefit-cost studies which examine social investments in a with-or-without framework. It was noted, however, that the framework does not deal with certain problems. The approach may suggest that particular investments under consideration may move society in the direction it desires. The problem of whether alternate paths are inferior or superior will not necessarily be clarified in the process. This problem can be considered by examining the level of analysis involved.

A benefit-cost study may involve, for example, the practical problem of determining the best route for a contemplated urban transportation project within a larger transportation system. This may be considered a fairly straightforward kind of problem, where benefit-cost analysis usually is applied. A preliminary decision may have been made that it is desirable to connect two points in space. If the alternative routes produce the same level of benefits, determined according to some criteria, the problem reduces itself to one of cost minimization. However, if benefits vary, and this will usually apply as long as trip generators are distributed unequally throughout space, then both the benefits and the costs will need to be calculated for different routes being considered. The assumption is that at best the most economical and at worst the least uneconomical route will be selected. As has been shown, no matter whether the analyst makes his calculations using one or more of several available methods, if properly executed, the same conclusion should result.[10]

The implications of technical proficiency are

10. On this point see Robley Winfrey, Economic Analysis for Highways (Scranton: International Textbook Company, 1969), Chapter 7.

not without some importance. A great deal of discussion has addressed the choice of methods including benefit-cost ratios, internal rate of return, net present value and other approaches. All the methods, assuming they were applied correctly, will yield the most economical route in the case of the mutually exclusive projects considered above. Of course, one might also reach the conclusion that none of the alternative routes should be selected because in all cases the benefits relative to the costs are low in comparison to other investment opportunities. A benefit-cost ratio above, say, 1.25 or an internal rate of return which is above some minimum desired level might be set as a threshold before accepting a project. But in any event the decision of what the threshold should be is not strictly a matter of economic interpretation. Since we are dealing with social rather than private investments, it is entirely possible for society to declare that with respect to one type of investment being considered a benefit-cost ratio of 1.25 is acceptable, whereas in other types of investment it should be much higher. Particularly, if the project is designed to accomplish redistributive as well as efficiency goals the differences in the thresholds may be justified.

If we now move to another level of analysis, the applicability of benefit-cost analysis is much less clear. A problem might be to determine say whether a highway should be built to connect communities A and B, A and C,or both. The question of priorities enters into the decision making process when considering those projects which are not necessarily mutually exclusive. If both projects are considered worthy, which should be developed first? If the problem concerns building one or both projects at different points in time, what are some of the dynamic systems interdependencies which need to be considered? Improved accessibility between A and B or A and C directly or indirectly influences relative and/or absolute accessibility between B and C. If only one project is built, then a process of relocation may be induced which could reduce anticipated user benefits from a highway and eventually could occasion substantial congestion costs. Building one or the other highway or both may have synergistic consequences of uncertain magnitude. Assume for a moment that A, B and C are three communities of a subregion within a larger region. Reductions in transport costs are realized initially and improve the efficiency of interdependent economic activities located within the subregion. This would improve the comparative advantage of the area relative to others, inducing increases in employment, associated housing construction and trip generation. If trips are priced at marginal private costs as contrasted to marginal social costs, then the long run outcome might well be more congestion than existed prior to the highway development. In addition, significant environmental pollution may appear, whereas formerly it was trivial. Aside from the potentially dire consequences described, realized highway user benefits may be greater, equal to, or less than those anticipated. The result depends on the totality of synergistic effects which were not or could not be incorporated into the initial benefit-cost calculus.

Conceptually, of course, the problem as outlined above is not dramatically different from the previous problem of selecting one route to connect two points. They both presented unequal benefits and costs for different routes. However, the impact area is readily identifiable in the case of a mutually exclusive set of alternatives. User benefits and costs will vary depending on which of several possible routes is selected to connect the two communities. Nevertheless, a highly circuitous route alternative is not going to receive serious consideration in the analysis. Moreover, and this is critically important, it is reasonable to hold constant the dynamic and interacting effects which economic activities have on location when one is evaluating mutually exclusive projects along a particular route. In the case of non-mutually exclusive projects the implications for spatial dynamics are much more complex, and simplified assumptions are less likely to be reliable.

A third level of study involves projects or programs which in part are substitutable and in part complementary. The weaknesses of benefit-cost studies become most apparent at this level. An example might be the with-and-without consequences of combinations of mass transit and highway alternatives in a partial or total systems approach. Even more complex situations might be postulated, such as choosing between investments in transportation versus or in combination with other social investments including health facilities, education, etc.

As indicated in the introductory section, Friedlaender's comprehensive study of the Interstate Highway System was inhibited by data constraints from making benefit-cost comparisons between urban highways and mass transit investments. The information required for such comparisons involve segmentation of users by mode; evaluation of user benefits from alternative or combined modes with frequent modal splits; and consideration of varying environmental implications and of the consequences of differing pricing systems for parts of the system, to cite a few examples. This is not to say that benefit-cost data could not be developed in a mechanical fashion. However, it is another question to determine how meaningful they are when highly aggregated and when presented without a comprehensive study of the systems' dynamics.

Several problems arise in the development of comparisons. The assumptions introduced are critical and unless carefully specified may yield unreasonable results. This issue is examined in a recent discussion by Mishan.[11] He shows how "the circumstances under which consumer's surplus, when used as an index of the benefits to be derived from private automobile travel, may give perverse results--a rise in the index being accompanied by a reduction in the benefits experienced by motorists."[12] The Mishan case is a highly simplified model of the real world, but nevertheless of considerable heuristic value. He proceeds from the assumption of an efficient public transit system (buses) with no cars. At this point one and eventually more consumers perceive a gain with private automobile ownership and travel. Congestion increases and perceived travel time savings diminish or disappear as the demand for auto travel increases. However, a return to the original state provides no advantage to the auto traveller because increasing congestion and out-of-pocket costs also affect bus travel and inhibit returning to this alternative. Journeys by car maintain an absolute travel time advantage over the bus, but travel on both modes is more costly than at the initial

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11. E. J. Mishan, "Interpretation of the Benefits of Private Transport," Journal of Transport Economics and Policy, Vol. 1, 1967; also reprinted in Welfare Economics by the same author (New York: Random House, 1969), Second Edition.

12. E. J. Mishan, Welfare Economics, p. 275. For further elaboration on the controversial issue of consumers' surplus as a measure of benefits, see Jules Dupuit, "Public Works and the Consumer," in Denys Munby, ed., Transport (Baltimore: Penguin Books, Inc., 1968), pp. 19-57; Martin Wohl and Brian V. Martin, Traffic System Analysis for Engineers and Planners (New York: McGraw-Hill, Inc., 1967), Chapter 7; Paul Samuelson, Foundations of Economic Analysis (Cambridge, Mass.: Harvard University Press, 1947), pp. 189-202; James Henderson and Richard Quandt, Microeconomic Theory (New York: McGraw-Hill, Inc., 1958), Chapter 2; and references cited therein.

stage. Finally, due to low profitability, service on the bus system is abandoned. Only a collective decision can return the community to the initial socially preferred state. The problem arises because of improper pricing of private auto travel. Pareto optimality requires that a shift such as to auto travel is only appropriate if the welfare of some or all is improved and no one loses. Pareto optimality is assured where price equals social marginal costs.[13] Alternatively, those who experience an improvement in welfare, but who impose costs on others, may be able to compensate the latter.[14] In the problem under consideration private car users should compensate bus drivers and passengers and intra-marginal automobiles for the congestion generated by the use of cars.

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13. For an introduction to the debate concerning the issue of marginal cost pricing, see Nancy Ruggles, "The Welfare Basis of the Marginal Cost Pricing Principle," The Review of Economic Studies, Vol. XVII (1), No. 42, 1949-50, pp. 29-46 and "Recent Developments in The Theory of Marginal Cost Pricing," The Review of Economic Studies, Vol. XVII (2), No. 43, 1949-50, pp. 107-126; Edwin Mansfield, Microeconomics: Theory and Application (New York: W.W. Norton & Co., 1970), pp. 149-163; A.A. Walters, "Road Pricing," in Denys Munby, ed., op. cit., pp. 184-211; R.H. Coase, "Price and Output Policy of State Enterprises: A Comment," Economic Journal, Vol. LV (1945), pp. 112 ff. "The Marginal Cost Controversy," Economica, New Series, Vol. XIII (1946), pp. 169-182; and "The Theory of Public Utility Pricing and Its Application," The Bell Journal of Economics and Management Science, Vol. 1, No. 1 (Spring 1970), pp. 113-128; and Edna Loehman and Andrew Whinston, "A New Theory of Pricing and Decision-Making for Public Investment," The Bell Journal of Economics and Management Science, Vol. 2, No. 2 (Autumn 1971), pp. 606-625.

14. The compensation dilemma is discussed in Harold Hotelling's, "The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates," Econometrica, Vol. 6 (1938), pp. 242-69. See also Nicholas Kaldor, "Welfare Propositions of Economics and Interpersonal Comparisons of Utility," Economic Journal, Vol. LXIX (1939), pp. 549-52; J. R. Hicks, "The Foundations of Welfare Economics," Economic Journal, Vol. LXIX (1939), pp. 696-712; and Henderson and Quandt, op. cit., Chapter 7, for a survey of the Arrow ranking and Scitovszky "second best" variations.

In any event, Mishan argues in favor of first establishing an optimal traffic flow and then imputing returns to the transport investments. A part of his conclusion is as follows:

> "It is possible, therefore, that an initial optimal traffic flow might reveal no economic case for traffic investment whereas failure to establish this optimal flow would allow traffic to pile up congestion costs and would consequently enable investment to appear profitable, in effect, by reducing excess traffic costs that were not warranted in the first place."[15]

A similar argument was presented earlier, in 1960, by Hirshleifer, et al.[16] There, too, it was argued that market processes establish the criteria necessary to determine whether existing resources are being used efficiently. The market process criterion is that "the marginal value in use (price willingly paid) for the products of an enterprise [must equal] the marginal cost," (representing the value which customers and producers place on the resources used in producing one more unit of output in the enterprise).[17] Hirshleifer maintained that public construction of uneconomic projects was encouraged by using artificial allocation processes. The arguments used to justify uneconomic public investments are rationalizations which really only acknowledge the existence of structural artificialities. These structural defects are perpetuated by the allocation processes which ignore the "price = marginal cost" market criterion. Cursory treatment of such problems as market imperfections, divergences between private and social costs, private market undervaluation of collective goods, and the impact of

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15. Mishan, op. cit., p. 280.

16. Jack Hirshleifer, et al., Water Supply: Economics, Technology and Policy (Chicago: University of Chicago Press for the RAND Corp., 1960).

17. Ibid., pp. 56-58.

employment policies are representative of failures to apply appropriate criteria, which go far beyond defects in the pricing mechanism per se.[18]

Mishan and Hirshleifer together imply that it is not possible to make any judgment about economic feasibility of a project (i.e., increase in supply) unless existing resources are allocated according to market criteria. Thus, the first task of an analysis is to determine the efficient allocation of existing supply. If "economic shortages" are found to exist, then increased capacity is warranted:

> " . . . an increment to capacity is justified if marginal value in use (the value consumers would pay for an additional unit) exceeds long-run marginal cost (the cost incurred, per unit, on account of the incremental expansion)."[19]

Hirshleifer's treatment of spillovers is similar to McKean's, although he argues that intangible effects should be ignored because their valuation and interpretation are arbitrarily deceptive. The array of benefit-cost analyses would show alternative present worth conclusions depending on varying the interest rates as well as the assumptions about the project's life, initial and continuing costs of alternative projects, and patterns of interdependent projects. By measuring only incremental and relevant monetary benefits and costs, Hirshleifer argues that the analysis can provide the basis for efficient resource allocation.

Several possible conclusions may be drawn from these arguments. First, if in the analysis one chooses to use benefit-cost methods prospectively, then it is required by economic logic to establish or impute optimal conditions (price = marginal costs) at the start and for the total realm of whatever level of project analysis is involved. Alternatively, if one chooses

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18. Ibid., pp. 78 ff.

19. Ibid., p. 115.

to use benefit-cost as one of many analytical inputs into a larger systemic or modeled study, then it should be recognized that a descriptive (rather than normative or optimality-seeking) approach is being used. The model(s) would be used to simulate, as much as possible, the many interrelated and redistributional effects which are operating on all aspects of a given project's realm--simultaneously, often irregularly, and perhaps on a scale which may be estimated only roughly. Benefit-cost analysis then is used incrementally, to evaluate each assumption or component of the model on its own merits and to advise the analyst of how and where effects are impacting on the system's operations.

This retrospective use of benefit-cost analysis, as an adjunct to more comprehensive prospective analyses, is the alternate approach tested here.

V. Ex Ante--Ex Post Study of Benefits and Costs

The discussion in the previous section serves to introduce our comparisons of expected benefits and costs, associated with a particular project, to actual benefits and costs after completion. The analysis is designed to provide inputs for continuing re-evaluation of the changing effects associated with a project. It will assist in explaining divergences which may exist between ex ante estimated and ex post actual benefits and costs. In the process, we are also developing findings which may assist transportation analysts and others in the planning process.

A section of the Santa Ana Freeway in Los Angeles County was selected as a test site for the following reasons:

a. The Los Angeles to Santa Ana route covers an area of dramatic growth, such that there seemed little doubt initially that significant benefits would accrue to users and contiguous areas. The question to be examined is whether our alternative approach is sensitive to the many range of effects of and associated with freeway construction.

b. The freeway itself is a diagonal connector for two major communities (Los Angeles and Santa Ana), while the overall transportation system is a general rectilinear grid connecting many nodes. The approach thus can be applied to a project where benefits and costs were expected to exist in a relatively well-defined market area.

c. The early planning and development data are extensive. The project report has been described as "one of the most comprehensive," providing "a complete picture of the present status of this freeway and . . . future plans for the full development."[20] Several special task force reports and corridor impact studies are available for the period projected. Thus, there is the opportunity to compare anticipation and outcomes.

d. The freeway has reached a watershed in terms of standard benefit-cost comparisons. Currently, plans are being developed for expansion, "double-decking," and other service and capacity improvements. Thus, our evaluation may provide some insights for present planning efforts.

The Santa Ana Freeway, at its full length of 31.7 miles, extended from the Los Angeles Civic Center to a route junction directly south of Santa Ana. The freeway project was planned to replace the 2, 3, and 4 lane parkway route which covered 33.77 miles along Los Angeles and Orange County Routes 2, 166, and 174. The new link was included in the 1946 Expressway System report recommendations ("Interregional, Regional, Metropolitan Parkways") presented to the Collier Committee by the Los Angeles Parkway Engineering Committee. Project planning was completed by 1948, with 1947-1967 the benefit-cost projection period. Freeway agreements with traversed communities were finalized during the late 1930's and early-1940's. Initial construction was estimated to be completed by 1952, and most construction completed by 1954.

The territory into which the project entered was varied along its northwest to southeast axis, as described in the planning report.[21]

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20. District VII Project Report, Santa Ana Parkway (PR-VII-11) (Los Angeles: California Department of Public Works, Division of Highways, January 1948), hereafter SAP Report, cover letter from J. W. Vickrey, California Department of Public Works Engineer (March 2, 1948).

21. SAP Report, pp. 3-5.

--East Los Angeles: "an area of substandard dwellings, small industries and several housing projects" and "congested residential" property;

--Commerce, including edges of Bell Gardens (on the south) and Montebello (on the north side of the freeway): "a partially developed but potential industrial area";

--Downey and Norwalk (south) and Pico Rivera and Sante Fe Springs (north) as far as Rosecrans Avenue: "largely devoted to citrus oranges and general agriculture";

--Cerritos (south) and La Mirada (north) as far as the Orange County line: "partially developed rural farm land."

The pre-existing arteries were described as deficient in terms of highway capacity, safety and alignment standards. The primary benefits to be garnered from the freeway project were the anticipated reductions in the existing parkway's congestion, traffic delay, accidents and fatality experiences.

Preservation of the then-existing parkway investment provided savings by permitting some of the old highway to be used as frontage road and the existing right-of-way and pavement resources to be incorporated in various development phases. Increased maintenance costs of the larger freeway facilities were anticipated.

Additionally, benefits were expected to accrue in the form of encouraging the development of the area. This development included "the urban and suburban residential developments for persons working in and commuting to and from the Los Angeles Metropolitan area."[22] In addition, the planning

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22. Ibid., p. 24.

anticipated "increased industrial growth . . . accompanied by large residential developments in adjacent and desirable areas [to the southeast of the City]."[23] The assumption that residential and industrial growth along a contemplated route are a form of benefit goes to the center of our earlier discussion. The location along a new highway may represent merely a shift of establishments or activities from other less favored areas. The effect of the urban transportation investment then would be to redistribute activities spatially (e.g. from central cities to suburbs). In part, such shifts in location may be amplified by the existence of a pricing system which fails to incorporate social costs of congestion associated with relocation. Of course, even with pricing including private plus social costs, some residents or producers may relocate and obtain a comparative advantage. In retrospect it will be somewhat difficult to distinguish between these two types of situations.

The expectations of benefits and costs of the Santa Ana Freeway investment are adaptable to the three components of our alternative approach: users' travel time, highway commodity savings and costs, and investment/development "benefits and costs." In reconstructing a full ex ante benefit-cost analysis, all assumptions of the original need to be incorporated. One form of an incremental, recursive benefit-cost methodology is described below, using the Santa Ana Freeway as an experimental laboratory.

1.A. Time Value Savings for Users

Users of the freeway were expected to benefit from reduced distance, congestion, and delay once the new route was available. Their valuation of time savings can be described generally by the following formula:

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23. Loc. cit.

$Y = \alpha \cdot \frac{D_s}{S_s} \cdot T \cdot W$ where total user benefits accruing from savings in time are equal to the annualized time savings in vehicle miles, per average vehicle trip, for an average wage earner based on given assumptions about the wage rate and occupancy of vehicles. Specifically,

Y = value of time savings benefits

D_s = distances saved with versus without freeway project

S_s = miles per hour saved with versus without freeway project

T = average daily trips or peak hour volume

W = hourly wage rate value of time

α = conversion factor for annualized basis (e.g., 8 hour average work day, 250 average workdays per year).

Over the total projection period (n), savings for users will equal

$$\sum_{i=1}^{n}\left[Y_i\right] = \sum_{i=1}^{n}\left[\alpha_i \cdot \frac{D_{s_i}}{S_{s_i}} \cdot T_i \cdot W_i\right]$$

where the annual conversion factor (α) includes alternate discount rates to transform savings into their 1947 present values (based on alternate interest rate assumptions). Data on the value to highway users provide the basis for determining what is happening in the post-development stage and how the experiences compare with what was expected. When divergences occur, several explanations can be investigated. The range of variables whose parameters might change over time include at least the following:

1. alternate interest rate assumptions for present value calculations;

2. greater than anticipated induced traffic, resulting in declines in speed and increases in congestion delay;

3. different speed and traffic volume characteristics for areas where bottlenecks are expected or where ramp metering is applied;

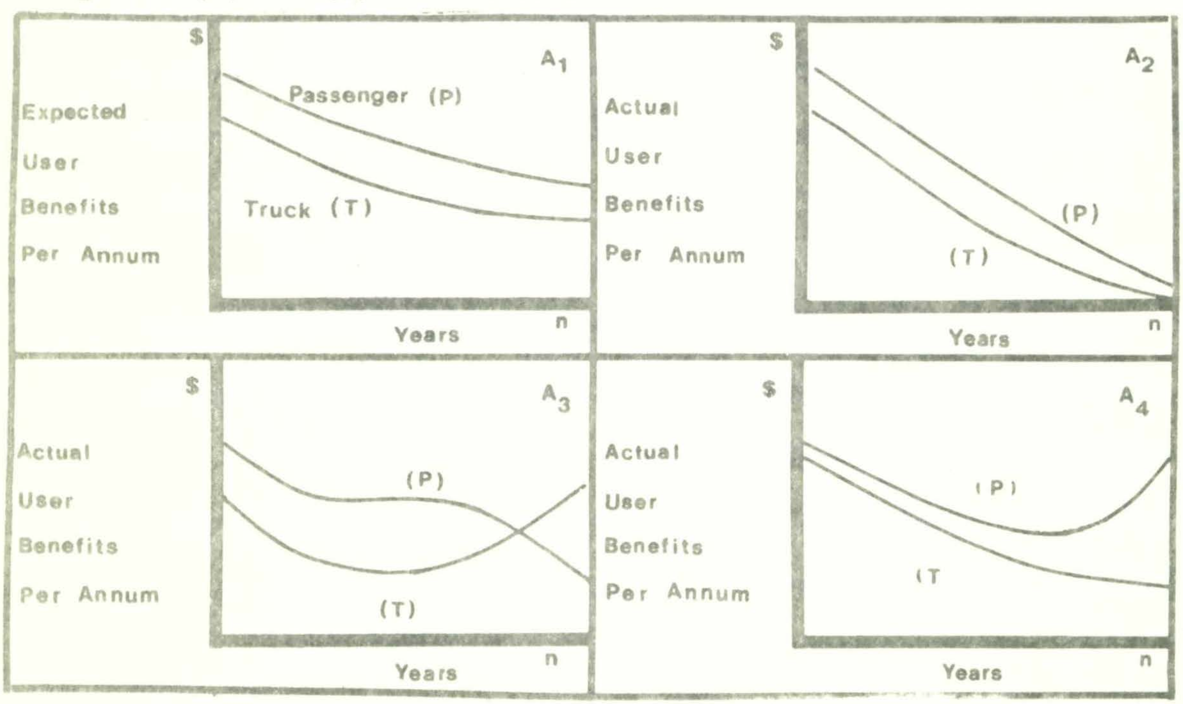
4. different peak hour volume estimates, such as when staggered work hour experiments are undertaken;

5. greater or lower estimates of the number of wage earners per vehicle, such as when car pooling experiments are tested or when the purchase of single-commuter-occupied vehicles increases with increased area incomes;

6. changes in passenger versus truck proportionate shares and the special user savings available with higher occupancy bus utilization; and

7. different projected wage rates and specific variable wage rates for freeway sections where user profiles can be constructed in more detail.

Graphically, Figure A_1 represents the anticipated passenger and truck savings projections tending towards a stable relationship over the project period. Figure A_2 **indicates** uniform overestimates actually occurred which might indicate assumptions (1) and (2) no longer reflect users' experiences. Figure A_3 indicates irregular effects pointing to possible miscalculations suggested by assumptions (3) through (5). Figure A_4 would imply special effects on passenger vehicle users only, rather than on all traffic, and that assumptions (6) and (7) need re-evaluation.



In this form, the benefit-cost analysis becomes a device for projecting the scale of errors or savings losses which can result from misestimating the project's impact on highway users' time values. The interrelated impact of several assumptions can be measured internally by reference to some optimal traffic flow (e.g. A_1), leaving aside comparisons with construction and maintenance costs. Further, this format requires that the analysis incorporate sections of a freeway link in terms of the users' economic values. The analysis must consider whether the area's income is sufficient to permit users to choose freely among alternate routes. The analysis must specify the range of assumptions about population and traffic growth and where they are expected to occur. Aversion to bottlenecks, ramp metering or heavy truck traffic areas or diversion from alternate routes or bus lines present a more meaningful introduction to the population being serviced, when defined in time savings terms, than when lumped into vehicle mile aggregates.

1.B. Time Value Savings for Users: Santa Ana Freeway Test

The test results for expected and actual users' benefits on the Santa Ana Freeway relate to an exceptionally dynamic area. The approach makes no apologies for the fact that hindsight usually is clearer than foresight. The 1947 projection efforts cannot be criticized on the basis of these results alone. However, the tests do indicate that continuing, recursive use of the benefit-cost analysis throughout a project's life may show when and where changes occur. By using the three separate presentations of quantifiable benefit-cost streams, decision makers can examine likely reasons why deviations from projected trends occur, and they may take corrective action if this is advisable.

The tests compared the projected assumptions with actual data, using the same methodology for the before and after period. The ex ante value of time savings were calculated using assumptions adapted from the SAP Report and 1947-base data. Figure B summarizes the user-value stream (for passenger vehicles only) generated by the initial expectations:

a. Traffic volumes were projected to increase at a normal rate of 15% over the first five years, 10% over the next ten years, and 15% over the next five years.

b. Speed savings would increase from 10 to 15 miles per hour over the first six years, peak at 15 mph for the next eight years, decline to 10 mph over the next six years, and hold at 10 mph for the remainder.

c. For the 88.5% share of traffic apportioned to passenger vehicles, value of time was estimated at 70% of the prevailing hourly wage rate for manufacturing employees.

d. For the 11.5% truck share, value was 100% of the prevailing hourly wage rate for drivers.

e. Real wages were projected to increase at two percent per year.

f. Adjustments for time preference and risk were made using present value factors for 2%, 3%, and 4% to represent a low, medium, and high range, respectively.

Figure C presents the test results which would have occurred had the analysis used the same approach, but modified the calculations each year using updated information. (Passenger-vehicle data are presented. See Technical Appendix for supporting data on all tests.)

The six listed items can be varied independently. Additionally, alternative base year assumptions can be used to introduce variations in

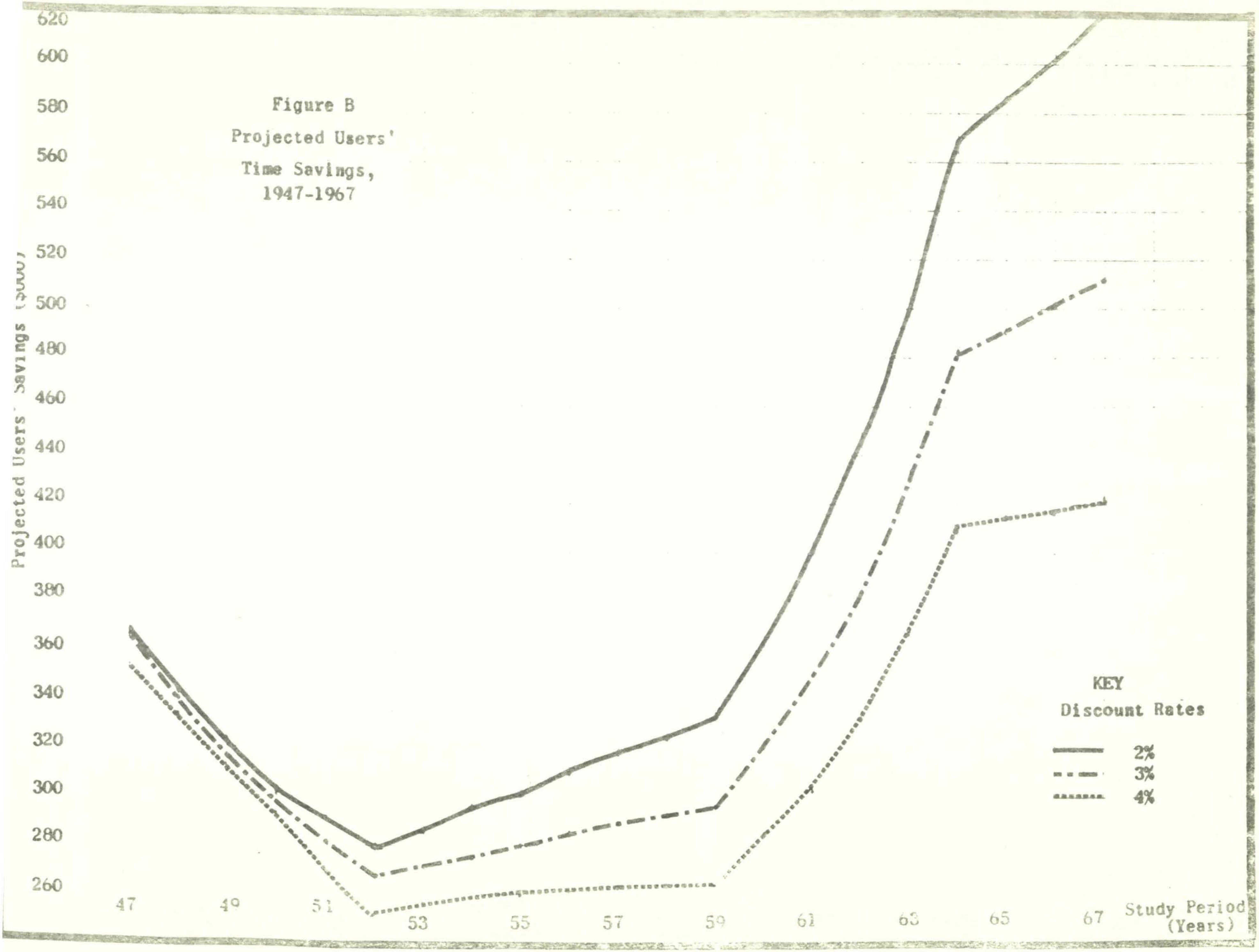
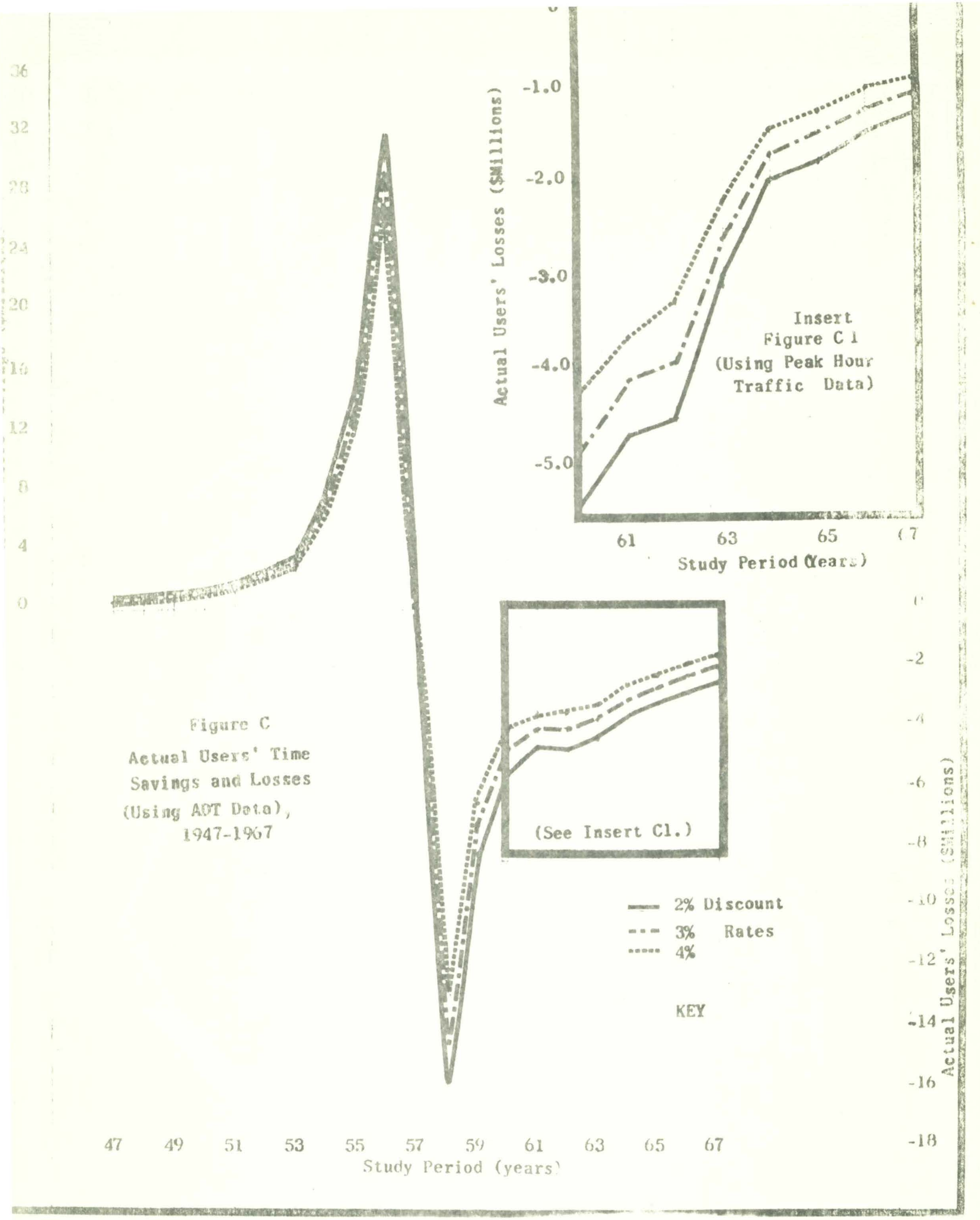


Figure B
Projected Users'
Time Savings,
1947-1967
Projected Users' Savings ($000)
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
47
49
51
53
55
57
59
61
63
65
67
Study Period
(Years)
KEY
Discount Rates
2%
3%
4%



36
32
28
24
20
16
12
8
4
0
Figure C
Actual Users' Time
Savings and Losses
(Using AOT Data),
1947-1967
-1.0
-2.0
-3.0
-4.0
-5.0
Actual Users' Losses ($Millions)
Insert
Figure C 1
(Using Peak Hour
Traffic Data)
61
63
65
Study Period (Years)
(See Insert Cl.)
2% Discount
3% Rates
4%
KEY
-2
-4
-6
-8
-10
-12
-14
-16
-18
Actual Users' Losses ($Millions)
47
49
51
53
55
57
59
61
63
65
67
Study Period (years)

different traffic categories or patterns. Peak hour base traffic could be projected, rather than using average daily traffic volumes, to determine the relative importance of twice daily commutation vis-a-vis gross utilization. Vacation and recreational traffic relative to home-to-work traffic could be projected to compare the importance of each for the impact areas' interconnecting community of interest. Bi-directional and uni-directional flows could be evaluated separately to emphasize either the special access points available for northwest- versus southeast-bound users or to help anticipate particular directional bottlenecks. The passenger-truck shares and the discount rate assumptions were left unchanged in the ex post analysis, since they appeared reasonable over the full period. Actual traffic and area wage rate changes produced significant divergences each year. The resulting passenger valuation data indicate it is possible to anticipate and analyze development along a project route by examining the changing value which the area's resident-commuters associate with the route.

The critical variable affecting users' valuation is the high volume of traffic growth in excess of anticipated levels--traffic was induced by the development of the area which in turn was related to the freeway's existence and a price which took no account of congestion costs. Actual users' values peaked six years before anticipated, at only two-thirds of the total expected level of savings. The 1951-1953 plateau represents the "interruptive" influence of construction on the progression of time and speed savings. The 1955 peak marks the freeway's completion to the Orange County line. Throughout the late 1950's the freeway's "first generation" impact was occurring. By 1957 actual speed "savings" disappeared, due to increased traffic and congestion. By mid-1960 the user savings that were "accumulations" over the early years were lost, as "losses" began to be incurred at an ever-increasing rate. Each increase meant users were starting to "pay" more in time-price equivalents than they had "received," cumulatively, up to that point in time. The 1959-1961 period showed a slightly lower rate of increase in the time-price equivalents users were paying. This evidently reflects the impact of some widening on selected links of the project just prior to full extension to Santa Ana in 1958. (Data presented in the insert, Figure C_1 shows similar slackening effects when an off-peak-hour travel program was initiated mid-1960.)

It is not intended, here, to assert or deny that users' time value savings "cover" any costs--construction or maintenance--since we examine only the divergence between anticipated and actual results. Essentially, the tests indicate only that the actual growth, income and price increases are significantly greater than anticipated. Further, the methodology does provide a degree of sensitivity to these developments and encourages analysis of factors underlying the induced traffic volume levels as well as incorporating such exogenous factors as income and aggregate population growth in the region.

1.C. Evaluation of Ex Ante-Ex Post Divergences in Users' Time Savings

There are several plausible reasons for these developments which may be examined. We shall look at four effects in particular: (1) Income effect; (2) Price effect; (3) Population growth effects; and (4) Redistribution effects. These effects, of course, are intertwined, but for purposes of exposition we can separate them.

Assume for the moment that some general increase in income was experienced in southern California independent of changes in the quality of the transport system. One would expect the following effects to occur. Rising incomes translate into a strong appetite to consume more land and housing. Suburbs are opportunity areas for translating this appetite into effective demand. Together with the consumption of more land and housing one finds that vehicle ownership rises, and the number and length of trips increase. Thus, some portion of the unanticipated increase in traffic on the Santa Ana Freeway appears to be associated with income expansion. Simply put, consumers were willing to trade higher costs of travel in order to enjoy the benefits of more land and housing in the suburbs. It is a general problem that this effect might have been forecasted improperly. Heavier utilization of the highway and road transport system would have been experienced as a result of higher incomes with or without the freeways. Trip costs probably would have risen even more sharply without the freeways, but consumers might have curtailed somewhat their exuberance for residential locations in the suburbs. However, the ownership and use of automobiles were enhanced substantially with rising incomes.

The urban growth of southern California which was associated primarily with migration may be assumed to be independent of the development of freeways. Mass migration into the region, well before limited access highways left their mark, may be evidence in support of this assumption. However, migration did respond to the opportunity for earning higher income, and thus it is confounded with the income effects. Assuming income constant for the moment, it seems reasonable to say that a more compact form of urban development and population growth would have taken place in the region without the improvements in the transport system. Nevertheless, some indeterminate amount of growth at the urban fringe would have occurred in any event, and trips to central areas would have increased. A portion of this growth probably was included in the original assumption of an erosion in travel time savings over the years after the Santa Ana Freeway development was completed. The question that arises is whether sufficient allowances were made for increases in travel demand as population grew, given some rate of auto ownership and utilization above a certain level of income.

The price effect results from the initial decline in trip costs. Apart from any redistribution in the location of people and activities, such a decline would occur when any nonubiquitous investments are made in a single major freeway. Assuming an elastic demand, the reduced trip costs will induce an increase in the number of trips. Breadwinners will be willing to take jobs at greater distances from their homes; public transit users will be induced to shift from this mode to automobiles; workers who formerly shared rides will now use their own vehicles; and so on. Especially if trips are not priced at marginal social costs, the induced demand will be considerable, and congestion costs will rise.

The population redistribution effect of higher incomes, discussed above, can now be examined in terms of price changes. Since freeway investment reduces trip costs, it will induce some consumers and producers to shift their location into the corridor which the freeway serves. This will occur even if incomes remain constant and the population does not grow. Assume two locations are equidistant from some central place and that only one is served by a freeway. Some consumers and producers will move to the area served by the freeway. Also, of course, the margin of development will be pushed outward in the process, and land will be transferred to urban uses. Eventually, the lowered trip costs may be eroded and partially translated into higher property values. A new price-quantity equilibrium is established which is different from the initial stage. However, in the process, the actual number of trips on the freeway will have risen substantially and possibly far above expectations if this effect was not modeled initially. Again, socially subsidized reductions in trip costs will tend to reinforce the tendency to relocate. The possibility cannot be ignored that consumers and producers maintain excessively high expectations of travel cost savings in areas served by the freeway and may continue to relocate in the corridor beyond some equilibrium point. In the long run, however, this will not be a stable solution.

The various effects examined briefly can be placed in the context of our finding of rapidly eroding user "benefits" on the Santa Ana Freeway. The combination of rising income and population contributed to an increasing demand for trips on all segments of the Los Angeles transport system. The implications of these developments were increasing ownership and utilization of the automobile. The pre-existing highway system would have been taxed more heavily if no freeways had been built. However, the rate of car ownership and use probably would have been checked, because the margin of urban development would not have moved outward at the speed it did. Presumably, the physical distance between places of work, residence and related facilities also would have been decreased.

In the case of the price effect, the situation is somewhat clearer. In the first instance, the Santa Ana Freeway reduced the price of trips along the travel corridor. As a result, traffic volume increased for the populations already living in the area because additional traffic was drawn to the corridor by the initial relative advantage in travel costs. The substantial gap between expected and realized travel time savings partly has its origins in the redistribution of people and job-creating facilities around the freeway on formerly open land. Underpricing of trips in comparison to alternative modes stimulated demand for trips and eventually precluded the alternatives. This is very similar to the Mishan phenomenon described earlier where it was not feasible to return to the status quo.

To argue only that travel time savings on the Santa Ana Freeway soon were translated into travel time losses ignores the question of what travel time in the long run might have been on the pre-existing highways. Answers to this question are pure conjecture. Conceptually, however, it is one thing to say that transportation investments by themselves are worthwhile because they contribute positively to economic development by reducing real travel costs. It is quite another thing to say that such investments are designed to relieve sharply increasing congestion costs on a transport system which will exist whether or not incremental investments are made. In public debates transportation planners and decision makers often stress the latter point and predict disasters unless the costs of investments are incurred. Yet, the analytical tool emphasizes positive benefits to economic and social development rather than the maintenance of some level of benefits in the transport system.

The lack of reliable data in our test area made it impossible to examine in isolation the impact of each of the effects described. However, the discussion may be relevant to transport decision making. In preparing analyses of prospective transportation systems investments, it may be well to distinguish between those elements which are designed to serve a growing population with higher anticipated incomes and more trip generation as contrasted to those elements which are directly related to prices on existing and prospective systems.

2.A. Highway Commodity Savings and Costs

The second element to be tested is referred to, here, as the "highway commodity component." Unlike more familiar approaches, which combine vehicle operating costs or savings with time savings, our tests seek to determine whether the disaggregated operating costs can provide analytical insights when used in an ex post-ex ante comparison. The time savings component, as discussed above, is related directly to the subject project and the traffic generated by its market area population. However, variable and fixed costs required to operate a vehicle depend on a variety of factors or commodities which are purchased in market places distinct from the single freeway project considered. Operating costs are the out-of-pocket unit costs related to the performance of a vehicle. As such, they vary with the quality of highway maintenance operations. A portion of the fixed and variable costs may go directly to cover some highway maintenance costs, such as through taxes, insurance and registration fees.

When the savings in operating costs of vehicles exceed the costs of operating the route, the resulting net benefit would consist of several elements:

a. the owner's reduction in the purchase of ancillary services required by a transportation system's organization and operation (e.g. gas, tires, etc.);

b. a lower rate of depreciation on vehicles; and/or

c. a higher rate of return on invested capital to the owner.

However, available unit operating cost data reflect, jointly and indistinguishably, the power performance of hypothetical average vehicles, the variable quality of all routes traveled, and the varying driving habits of a population of users (which may not be the users within the project's region). In addition, it is not possible to determine whether an individual's tax dollars are returned to him in the highway services he uses or whether they are returned elsewhere in the overall transportation program's services. Finally, there is little evidence to indicate that users purchase vehicles with the expectation of recovering a fixed percentage each year on their capital invested.

The allocation of available net benefits to these elements is, therefore, of necessity, an arbitrary conclusion of the analysis. Likewise, when route maintenance operations and costs exceed vehicle operating cost savings, the net losses can be allocated only on the basis of assumptions about ancillary service accounts or the vehicle as a capital or depreciating investment.

However, the expected relationship between vehicle and project operating costs and benefits can be used as a standard to which actual experience can be compared.

The relationship between estimated highway commodity benefits (vehicle operating savings) and costs (roadway maintenance expenses) can be described by the following formula:

$$\frac{\Delta\left(U_i \cdot V_i \cdot m\right)}{\left(U_o \cdot V_o \cdot m\right)} = \beta \frac{\Delta\left(M_i \cdot m\right)}{\left(M_o \cdot m\right)}$$

Each year (i) after the base year (o), the incremental unit savings per vehicle mile (U, expanded by the total vehicle-miles of the project; i.e., V, traffic volume, times m, the project length in miles) holds some fixed relationship (β) to the incremental cost to maintain the highway (where M = maintenance cost per mile expanded by m, the project length in miles). If $\beta > 1$ net vehicle operating savings exceed highway maintenance costs, while if $\beta < 1$ the reverse is true. The value of β is given by virtue of the decision maker's selection of the route (i.e., the "go" decision) and acceptance of the relationship between maintenance costs and traffic volumes. If one includes the construction costs required, over the project life, to widen and/or alter the freeway, different relationships result (i.e., lower β -values). Thus, it is possible to compare the change in users' vehicle operating savings resulting from maintenance expenditures and other physical investments made at the margin to improve the quality of the route. Adding this second variable (and dividing through by m, since the miles over the study project are unchanged), the new formula is:

$$\sum_{i=1}^{n} \frac{\Delta (U_i \cdot V_i)}{(U_o \cdot V_o)} = \beta \sum_{i=1}^{n} \frac{(\Delta M_i + \Delta I_i)}{(M_o + I_o)}$$

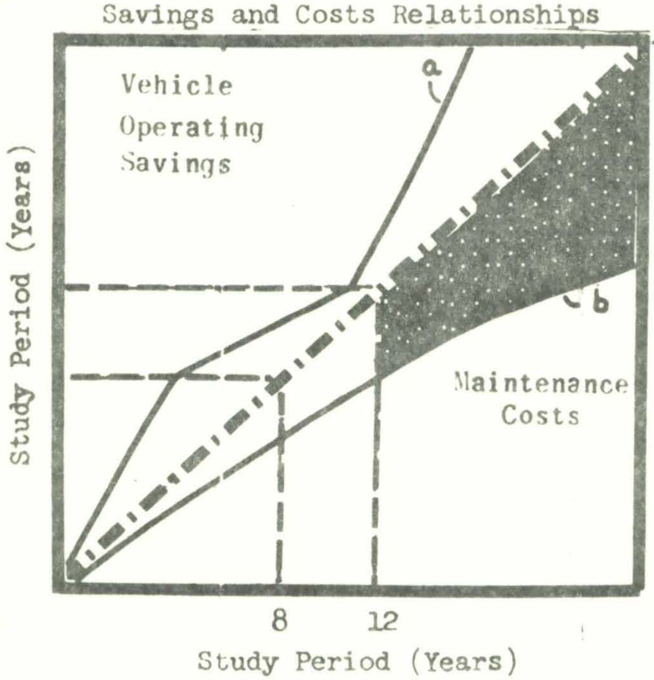
where I = the additional construction, widening, signalization, or other investments required over time.

The ratio of vehicle operating to maintenance plus additional costs per mile will depend on the traffic volumes (V). The format which we follow allows the analyst to project expected volumes and their associated vehicle running savings and incremental investment levels over the total period. Higher or lower actual induced traffic volumes will alter maintenance and other expenditures requirements. The relationship indicates at what point divergences begin to occur.

Graphically, Curve "a" in Figure D would indicate that more users were reaping vehicle operating cost savings at a less than proportionate increase in incremental costs. Curve "b" would represent excessive expenses occasioned by increased traffic with no proportionate sharing in operating cost savings.

Figure D

Expected and Actual Highway Commodity Savings and Costs Relationships



The timing (e.g., at year 8 or at year 12), direction ("a" or "b"), and degree (shaded area below projected normal trend) of divergence from the expected trend line provide measures useful in evaluating the freeway's dynamic effects. It permits one to anticipate likely divergences by compelling examination of the causes of variances from the projection.

2.B. Highway Commodity Savings and Costs: Santa Ana Freeway Test.

Since the highway commodity component was not used in 1947, Figure E is a hypothetical presentation of the SAP assumptions, with the following adjustments:

a. Maintenance costs in 1947 dollars were estimated initially at $2500 per mile.

b. Savings were projected to increase from $0.097 to $0.100 per vehicle-mile eventually returning to $0.097 over the period, reflecting a peaking and leveling-off of auto efficiency and highway quality. (Operating cost savings may be an underestimation of actual 1947 vehicle commodity savings potential, since estimates as high as $0.125 have been made for California in 1951. However, the same base was used for both ex ante and ex post tests.)

c. Traffic volumes and price indices were the same as used in the users' valuation calculations.

Figure F shows the results of using actual information incrementally. The ex post comparisons of vehicle savings and highway expenditures indicate trends similar to the users' valuation results. Again, the savings peaked soon after construction was completed, with a decline following thereafter and extensive investment being incurred by the early 1960's. Beginning in late-1966 users began to "pay out," in annual operating loss equivalents, sums which were greater than that required to cover annual maintenance costs. These "losses" are attributable to greater fuel and oil consumption, more frequent maintenance and repair costs and faster depreciation rates associated with stop-and-go congested highway use. These in turn are caused in part by induced traffic--increased demand over and above "normal" anticipated

Figure E. Projected Highway Commodity Savings and Costs Relationship, 1947-1967

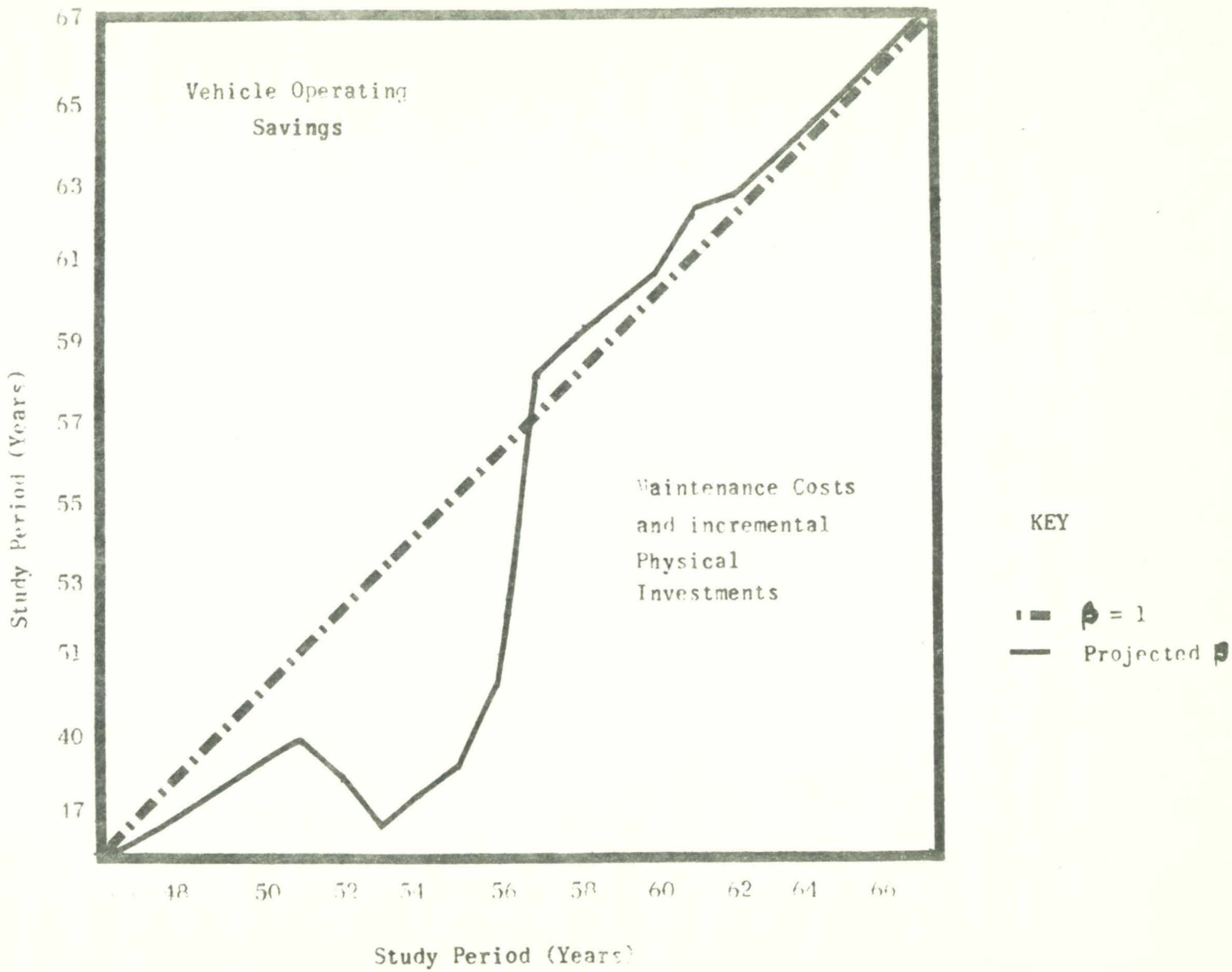
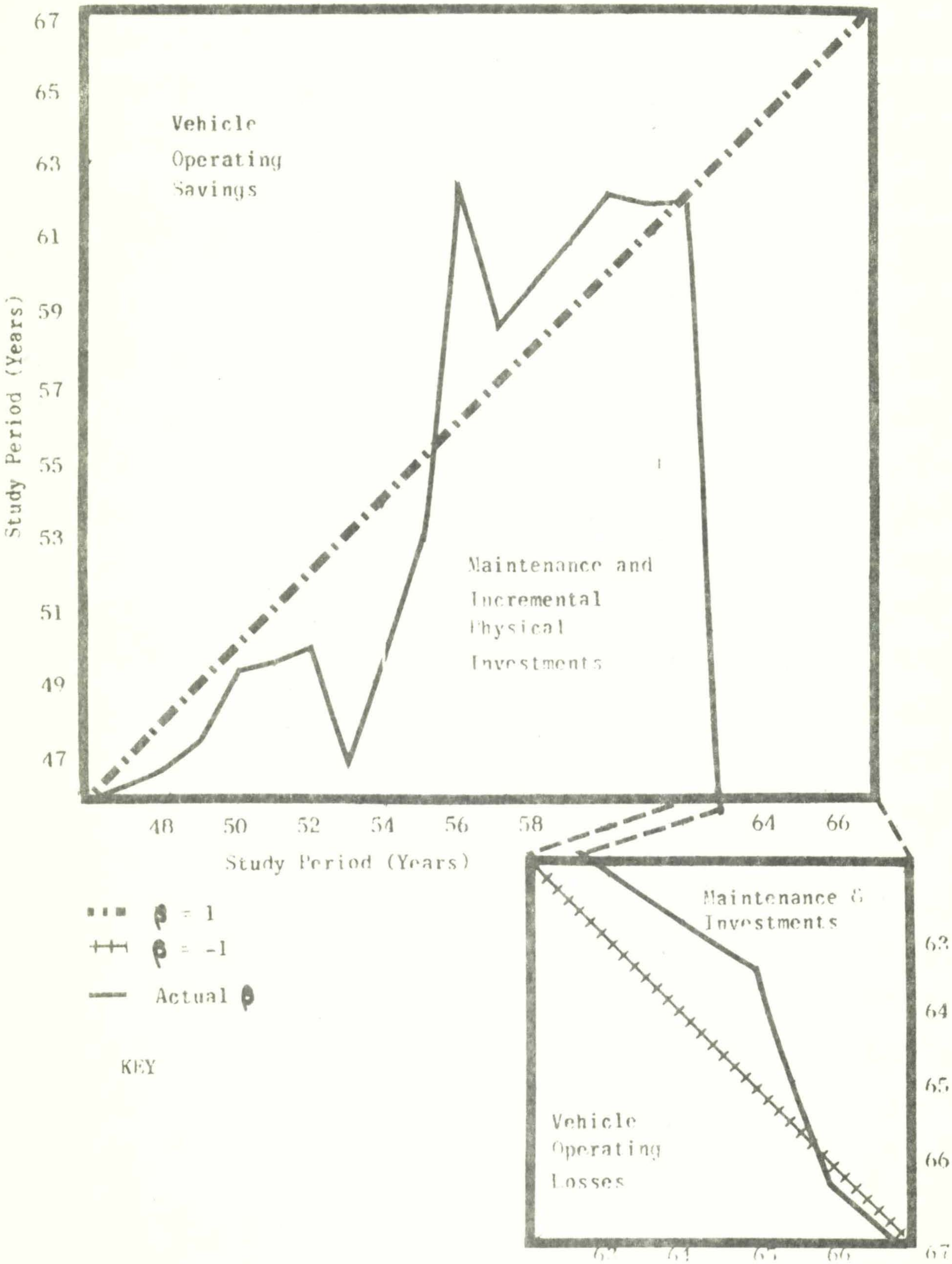


Figure F. Actual Highway Commodity Savings and Costs Relationship, 1947-1967



traffic volumes--resulting from the rapid development in surrounding areas. Also these "losses" result from the aggregate growth in the region of income and population as well as absolute and relative increases in vehicle ownership, operation and congestion. Again, the "losses" must be placed in juxtaposition to the situation without the freeways where vehicle operating costs most probably would have risen in any case. However, the system of pricing which occasions inordinate utilization of freeways also is of major importance in this context.

2.C. Evaluation of Ex Ante-Ex Post Divergences in the Highway Commodity Relationships

Two important issues arise in evaluating the changes in highway commodity relationships. The first is the diversity of factors affecting the three variables themselves (i.e., vehicle operating costs/savings, maintenance costs, and incremental investments). The second is the question of whether the latter two expenditures serve only the current users (i.e., the users reaping vehicle operating savings).

Examination of the growth, redistribution, income and price effects helped explain what differentiated the ex ante projection and ex post revised analyses of users' time valuation. Many elements of the earlier discussion are relevant to this second test because the highway commodity relationships represent an alternative way of conceptualizing the diverse impacts occurring about any freeway. While the first test provided insight into population settlement and income effects especially, the second test provides more information on the price effects involved. Specifically, the relationship depends upon the prices of factors which determine vehicle operating costs and highway operating and physical investment costs. Even more important, the factor inputs have their prices determined in marketplaces outside of the corridor being studied. In effect, the measurements represent influences outside of any one particular freeway. This especially is true of vehicle operating costs, and conditionally true of maintenance and investment costs.

Average unit costs for vehicle operations have been derived from nationwide or statewide experimental studies. These were applied to the average daily traffic volumes on the Santa Ana Freeway between 1947 and 1967. One apparent conclusion from the ex post analysis is that reductions in operating efficiencies resulted, i.e., "losses" were incurred. Part of the explanation may be in the growth effects since the freeway's congestion probably produced higher average gas and oil consumption and greater auto maintenance expenditures for vehicle owners. Additionally, the changing design of vehicles over the period must be considered: increasingly larger engines require higher octane fuel; lighter body materials incur greater damage at the same or lower impact speeds; rapid rates of new car purchases imply faster rates of depreciation; and greater average trip distances per person mean more wear and tear for the same ownership period. These factors represent the price of overall vehicle operations on all highways, rather than simply of travel on the Santa Ana Freeway.

If rising vehicle operating costs were the sole explanation for the "losses," it might be possible to say that consumers were paying--willingly and simply--the appropriate price for all they desire from vehicle ownership: speed, power, frills, mobility, etc. However, another important effect in this test resulted from the rapid increase in maintenance cost trends. Maintenance costs, including labor, materials, equipment and overhead, nearly doubled over the 20 year period. This is the part of the "losses" over which consumers had no control.

There is a question of whether rising maintenance costs were controllable at all. The late 1960's did evidence a reduction in the rate of increase of the cost trend. This possibly may reflect budget tightening, or a stabilized level of maintenance for the Santa Ana Freeway, or a propensity to invest in small improvements which did not generate proportionate increases in maintenance requirements (or which may have economized on maintenance expenditures).

Over the life of the project, however, maintenance and improvement costs together represent the supply-demand relationships in the factor input marketplaces. Highway construction and operations require relatively specialized factor inputs (trained labor, special materials and equipment). The prices in the factor marketplaces thus reflect the competition among suppliers to meet the demand of highway development. The prices in these marketplaces may reflect the generative influence of the particular freeway since nearby suppliers and workers are subject to the same growth and income effects that users incurred in their time valuation. It is more likely that a program of freeway system construction and operations will be the significant force--increasing the demand for factor inputs, encouraging a rising supply, and resulting in higher factor prices. In a regional or statewide context the "total environment" of a developing transportation system implies a significant incentive for expansion of these supporting or factor markets.

A great deal of work needs to be done in this area of program demand-inducement of supply. The more specific question is how might transportation systems be inducing volume and price expansion in factor supply markets? Usually, it is assumed that public investment in highways or transportation systems are a form of subsidy for a decreasing cost "industry." That is, private enterprise normally would be deterred from undertaking such investments or would be willing to do so only under monopoly pricing circumstances--neither option being desirable from society's point of view. However, once public auspices sponsor such investments, indirectly a subsidy results for all those marketplaces which provide the factor inputs required to sustain transportation system production.

This becomes more important when considering the rate of incremental investment in physical construction. Traditionally, benefit-cost analyses compare projected savings to a fixed initial investment sum and assume no other expenditures will be required. Widenings or alterations are inevitable, even under the best projections of traffic growth and development. If individual benefit-cost analyses are made for each alteration, they usually are made on the assumption that all prior investments are sunk costs. Thus, the incremental efficiency of the total system's investment seldom is examined. It is possible that the added investments made between 1958 and 1962 were of the sort which--because factor or supply marketplaces were being subsidized--tended to increase the prices of labor, materials and equipment required for highway construction. Thus, subsequent physical investments (in 1965-1967) were made at the higher prices which were generated by earlier, subsidized demand for the factor inputs. The "losses" are indicative of the scale of effects which are accruing to the Santa Ana Freeway, but which result from price increases in diverse marketplaces largely outside the Los Angeles-Santa Ana corridor study area.

The second important issue raises the question of whether the Santa Ana Freeway maintenance and alterations investments only serve the current users. In other words, is there some "without the freeway" standard of maintenance and alterations investment expenditures to which one might compare actual costs? Alternatively, if freeways are constructed as an effective substitute for surface streets, might a portion of these higher maintenance and added investments be compensated for by lower costs on non-freeway, access streets within the corridor?

The "without the freeway" hypothetical world was discussed earlier: possibly a more compact settlement pattern and shorter average trips, perhaps lower rates of auto ownership and utilization relative to incomes, probably a greater burden on the pre-existing highway network. Again, we can only surmise what the trade-offs among these might be and what would be the final impact on the level of maintenance and additional expenditures for the pre-existing network.

However, freeway and surface street comparisons are critical for decision makers. Rather than being mutually exclusive networks, freeway and surface street systems are highly interdependent. Thus, the question arises whether higher freeway expenditures may represent cost savings for surface streets due to the diversion of traffic from the pre-existing system. This is a transfer of sorts, but one which is measurable. Essentially it requires a test of whether real cost savings are occurring or whether a deferral of maintenance and alterations investments are resulting from higher freeway expenditures.

The second test approach provides a workable framework in which to examine relative efficiencies of freeway and surface street expenditures, relative to their respective vehicle operating savings, within a given corridor. Data limitations militated against an effective test here, but hopefully resources will become available to undertake this type of inter-network analysis in the future.

All levels or generations of transportation systems are competing for the same scarce money, land, and other resources. Largely, it has not been so much a problem of whether complementary or substitutable systems could be compared, but rather whether sufficient information was available to be integrated into meaningful analyses of changes over time. The second test was attempted in this spirit and represents but an introductory effort to demonstrate one possible approach.

VI. Conclusion

Issues of optimality, efficiency, and economy are considered appropriate in the ex ante use of benefit-cost analysis. However, the ex post test results raise some critical questions about whether these issues continue to be relevant once the investment decision has been made, construction begun, and project effects generated. In 1947 only the projected level of investment provided any indication of the real scale of resources required by the highway project we studied--the Santa Ana Freeway. Users' savings and highway commodity savings-costs reflected the conservative optimism of the projected vehicle-capacity relationships.

There are other values, aside from those associated with traffic or investment cost, which are influenced by the freeway, and significantly so. Accident costs and savings, the net losses resulting from removing land from tax rolls or from displacing residences, and the imputed environmental benefits and costs should be valued on their own merits rather than in terms of how well users' time values or highway commodity benefits or costs "cover" them. The test results indicate there are weaknesses in estimates which are dependent primarily on how one projects vehicle-capacity relationships, regardless of the redistributive and external effects of the project.

One of the primary conclusions of the above tests is that benefit-cost analysis, when applied to actual experience, incrementally, provides a broader survey of effects than when applied only in a prospective context. Furthermore, over the life of a project, each "improvement"--as an attempt to ameliorate worsening congestion by increasing capacity--may be evaluated in terms of its own marginal effects.

Using the revised benefit-cost approach only prospectively in current project planning would produce results similar to the estimates developed for the 1947 planning. There is little advantage in its use unless the analysis examines the project recursively, by evaluating the effects throughout the impacted area. All users' outcomes otherwise will be assumed "sunk costs" of a prior period investment decision. Projected benefits will be calculated on the basis of time or speed savings which are expected to result directly from the capacity "improvements."

For some, this may imply a need to restate the users' valuation component in broader terms, by including some portion of the value of areawide development as imputed freeway benefits. However, the alternative argument is very convincing--that the areawide, external or redistributive effects should be analyzed in their own value terms. Changing land use configurations reflect economic development--which can be quantified by using market determined data. Changing configurations also may mean agglomerative economies or diseconomies, where

> " . . . assessments of the costs and benefits of alternative configurations raise several problems, not the least of which would be the determination of which costs and benefits should be measured, whether to include nonmonetary costs and benefits (and how to weight them), and whether adjustments should be made for the incidence of costs (which groups bear them), and the relative importance of costs and benefits on different interests and groups."[24]

Our test results for users' time savings/losses suggest a different conclusion: the significant "price" being paid implies the more relevant need to re-evaluate the interrelationship between development effects and traffic volumes. The users who "pay" and who are served by the facility are

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24. James A. Clapp, New Towns and Urban Policy (New York: Dunellen Publishing Co., Inc., 1971), p. 220.

upwards of 120,000 cars a day more than anticipated for the project period. The price and volumes are significant because the rate and scale of changes in land use patterns were significant. The error is not in the failure to incorporate land value changes into the users' valuation calculus, but rather the failure to associate increments in development with increments in the "price" required of users to drive on the facility.

Our test results for the highway commodity relationship suggest a possible need to re-evaluate the interrelationships between highway development effects and the rising costs associated with increased demand for the factors of freeway expansion. The highway commodity relationship indicated the need to investigate price and quantity effects of continued demand for highway development. The important question is how public works subsidies reappear later in a project's life (i.e., in the form of more expensive added physical investments) or impact concurrently on surface street efficiency.

In trying to explain the divergence between actual and expected user benefits, it was noted that a series of effects occurred simultaneously as the freeway under consideration was developed and put into operation. Certain of the effects which impacted on the demand for freeway trips can be treated as exogenous to the freeway development. In particular, we refer here to the general growth of both income and population in southern California and to the resulting increase in aggregate demand for trips. There probably would have been an increase in the utilization of existing capacity if no freeways had been built and assuming the alternative transport mode had not been strengthened. The critical dilemma emphasized here is that other effects occurred which are traceable directly to the freeways.

Freeway construction initially reduced the effective price of trips along selected routes. While our tests do not sort out the impact of the changed price for trips, they do indicate the scale of the impact on the level of demand. Separate measurement of the erosion of travel time savings for users of the freeway requires a system of pricing trips explicitly. The conclusion appears to be that trip prices are too low. Trips are "underpriced" in the sense that the contribution which marginal users make to congestion is not valued properly.

Congestion repeatedly has prompted decision makers to consider alternative approaches which, theoretically, would establish a traffic flow that is "better" than the existing congested situation, even though the optimal flow might not be attainable. Only implicit and "partial" prices are built into the alternatives. For example, the location of freeways along selected routes means that some producers and consumers will experience price advantages, while others--not within access of the route--do not. Similarly, decisions on the provision of entry and/or exit points along a freeway imply different effective trip prices for users. Most recently, decisions to control ingress and egress by ramp metering (signalization) create selective price adjustments in addition to the pre-existing effects of locational and access decisions. Potential users face physical constraints rather than real price competition among alternative routes or locations.

Trips currently are underpriced on freeways, and schemes of implicit pricing do not function well to induce improved traffic flows since consumers and producers can and do relocate to circumvent constraints imposed. The relocation or "spread" subsequently generates another level of alternatives with the same implicit, rather than explicit, prices. Therefore, alternatives must be sought to price trips so that the marginal social cost of trips comes closer to the marginal social price of increased congestion. Ramp metering and sensing systems which permit congestion-pricing, actual charges to users, deserve serious consideration as alternatives to be examined. The primary advantage of differential pricing on freeways and surface streets is the explicit valuation of all units supplied. Thus, when a user selects a route and time of travel in the marketplace, his choice clearly reflects what the trip is worth to him. With explicit prices, users will select alternative routes or times to travel with a clear understanding of the real trip costs involved. Users' options are expanded through competing price mechanisms. Society, in turn, can rank incremental investments in accord with how users explicitly value highway development investments.

Several of the authors referred to earlier[25] suggested or argued that explicit pricing was necessary before one could evaluate the relative merits of alternative investments in expanded capacity. Currently, with no effective pricing system operative, off-peak travelers' "savings" may compensate or cross-subsidize peak hour "losses." Explicit pricing, through actual charges to users of a freeway, would work primarily to redistribute the peak hour travelers over a larger band of time. Therefore, the trip costs of all users would be evened out. In the long run, explicit pricing only on freeways could reproduce the same effects described in the evaluation of ex post-ex ante divergences (i.e., growth, redistribution, income and price effects). This might occur in the short run, as travelers switched initially to the implicit (lower) price system available on surface streets. As more travelers were diverted, congestion would reappear on surface streets,

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25. E.g., Hirshleifer, McKean, Mohring, Coase, Walters, op. cit.

making off-peak travel on the freeway the more desirable (least expensive) alternative. In the long run, all systems need to be priced at their total marginal social costs for redistribution to be efficient.

In anticipation of the long-run trend, the second test emphasized the need to evaluate the complements to a freeway, the surface streets, starting at least with comparative analyses of maintenance and added investment efficiencies. If any link or alternative is priced at less than its long run total marginal social costs, one or all of the effects must be expected to occur. Without this basis, there is no simple predictive method of analysis. The stability of the overall transportation system will be jolted by these effects. The first reasonable alternative to simple acceptance of such instability is an incremental, recursive review of disaggregated actual and projected trends. The second reasonable alternative is an investigation of the scale of the full range of effects and the real level of traffic generated thereby. The long run and inevitable next step may be some form of system-wide explicit pricing.

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