

# Concepts and Applications of Engineering Economy

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● **MANY OF THE** professionals in the field of modern engineering economy are too young to be aware that the father of their subject is Arthur M. Wellington. Certain of Wellington's remarks made eighty-two years ago in his classic work, "The Economic Theory of Railway Location," seem to be appropriate to the theme of this conference. For example, he stressed the point that no two problems in railway location were quite alike with respect to traffic, topography, and other matters. In the usual case (in 1877) where railway managements failed to recognize the existence of any economic principles to govern location and design, this diversity of physical and economic circumstances had a number of bad results. One such result was that management was unable to distinguish between good and bad decisions on location and design.

"He who has done well," said Wellington, "is shut off from adequate recognition of the fact. The same is true of one who has done poorly. The level of average practice is restricted not to the sum of the united abilities of all engaged in it, but to the average level of capacity and knowledge. Corporations take it for granted that there is no measurable difference in qualifications for such work, and such work is entrusted to lowly paid subordinates who consider the work mainly from the constructive standpoint. It is assumed that whoever is competent to design the railway structures is competent to design the railway system as a whole. . . . And yet there is no field of professional labor in which a limited amount of modest incompetency of \$150 per month can set so many picks and shovels and locomotives at work to no purpose whatever."

The purpose in mentioning Wellington is not to stress the well-known similarity between certain types of decision making for highways and for railways. In fact, the attempt to think clearly about matters of highway economy has sometimes been handicapped by drawing too close an analogy between highways and railways. Wellington is mentioned chiefly because the present condition with respect to highway decision making is not unlike the condition that he observed during the great period of railway construction in the United States in the 1870's and 1880's.

At heart, Wellington was primarily an evangelist. He desired to convert railway engineers and railway administrators to his viewpoint that the location and design of a railway should be thought of primarily as a problem in economy. Today, there still remains the job of persuading most highway engineers and administrators that many of their problems are economic ones that are capable of quantitative analysis.

But Wellington was a very practical type of evangelist. He recognized that it was not enough to exhort railway engineers and administrators. He had also to show them how to make the needed economic analyses by developing specific principles and techniques to solve the various types of problems arising in railway location and design.

In this respect, any present-day evangelists who want to promote the use of economic analysis to improve the quality of highway decisions are in a better position than Wellington's eighty-two years ago. Wellington had to start from scratch in the development of principles and techniques. In contrast, today it is possible to draw on general principles and techniques applicable to all kinds of economy studies. Engineering economy is a subject that has been taught in some engineering colleges for nearly fifty years; today, courses on the subject are given in more than a hundred colleges and universities. Moreover, the techniques are widely and successfully applied in private industry. Research on specific techniques applicable to highway economy studies dates back to the early 1920's.

Nevertheless, certain aspects of economy studies for highways are inherently difficult and troublesome — in many respects more difficult than economy studies in private industry. Possibly these inherent difficulties constitute one of the reasons why most decisions today on highway programming, location and design are made without benefit of formal economy studies (even where formal studies are made, some of these studies are made very badly). Certainly there is ample justification for this workshop conference in these inherent difficulties of highway economy, together with the wide-spread failure to use the techniques of engineering economy to guide highway decisions.

This paper outlines a set of concepts out of the general body of concepts in the field of engineering economy; the concepts that seem to have particular application to the highway field have been selected. The concepts themselves should not be regarded as really controversial. However, the applicability of certain of the concepts to specific types of cases has in fact been quite controversial — in private industry as well as in public works.

It will be evident that most of the following nine concepts are not limited to decision making in the field of engineering economy; the concepts are applicable to the making of all kinds of decisions. However, the interest here is particularly in the making of decisions about proposals for the acquisition or construction of tangible physical assets.

1. All decisions are among alternatives; it is desirable that alternatives be clearly defined and that all reasonable alternatives be considered.

In all types of decision making, a first step in reaching a sound decision is a clear definition of the alternatives. In fact, it sometimes happens that as soon as the alternatives are clearly defined, the appropriate decision is evident.

It is characteristic of decision making about proposed investments in physical assets that each major alternative has a number of sub-alternatives. Moreover, many of the sub-alternatives will have their sub-sub-alternatives, and so on. For example, for each of two major alternatives in the location of a new highway, many decisions will need to be made between alternative designs of structures, alternative details of location, etc.

In the specialized language that has been developed for discussion of the economics of proposed public works, an analysis to determine whether or not to undertake a major proposal is called "project justification"; an analysis to choose among the numerous alternatives in design is called "project formulation." Many decisions are required in project formulation for every decision in project justification. In both private industry and public works, it is desirable that the criteria and methods of analysis used for project justification should be equally applicable to project formulation.

The need to look at all of the promising alternatives cannot be overemphasized. Often a proposal appears to be attractive only because some good alternate course of action has not been analyzed. This point may be illustrated by the following example which is adapted and simplified from an actual recent study of alternate highway locations.

Proposal A required a major improvement of an existing through highway. Proposal B called for an entirely new location that would relegate the existing road chiefly to the service of local traffic. A prospective favorable consequence of the new location was to make possible the development of new economic activity in a certain area not now served by an adequate highway. This consequence, included in the economic analysis as a "benefit" for B but not for A, was a major factor in the analyst's recommendation favorable to Proposal B. The analyst failed to recognize that the same benefit could be obtained by making a relatively small additional investment to add to Proposal A a low cost secondary road that would serve the new area.

2. Decision making should be based on the expected consequences of the various alternatives. In comparing investment alternatives, it is desirable to make the consequences commensurable with the investments in so far as practicable. Money units are the only units that make consequences commensurable with investments.

Proposals for new physical assets involve many diverse types of items associated with the investment. For example, a new highway may require land presently devoted to a variety of different uses, man hours of many different kinds of labor, various amounts of a great variety of materials, and different numbers of hours of usage of many different sorts of capital equipment. In a similar way, the consequences of investments may be of many diverse types. A new highway may be expected to cause changes in the amount and character of the usage of motor vehicles, changes in the usage of people's time, changes in the production and distribution of the products of farm and factory, changes in patterns of land use, changes in the type and frequency of traffic accidents, etc.

It is obvious that such diverse matters are not commensurable if they are expressed solely in different units such as acres of land, man hours of engineering labor, pounds of reinforcing steel, and gallons of gasoline. In making decisions, there are obvious advantages if the various consequences of alternate courses of action can be made commensurable with one another. The money unit is the only unit that comes close to making commensurable the diverse consequences of alternate investment decisions.

In private enterprise the case is clear for converting the prospective consequences of decisions into terms of money. A private enterprise cannot survive unless it is profitable in the money sense. An essential step in an engineering economy study for private enterprise is to express the expected consequences of a decision in terms of cash flow. Obviously it is necessary to apply the standards of the market place to investment decisions in private enterprise.

In deciding between alternate courses of action, any prospective consequences of the decision are relevant, whether or not it is possible to express the forecasts about these consequences in quantitative terms. In investment decisions in private enterprise, there frequently are expected consequences to which it does not seem practicable to assign specific money amounts. Some forty years ago, J. C. L. Fish coined the phrase "irreducible data of the problem of investment" to apply to such consequences. For the sake of brevity, this paper will refer to them simply as irreducibles. Other terms sometimes used by analysts are imponderables, intangibles, and judgment factors. However, they may be described, it is reasonable that these irreducibles be given weight in investment decisions; they are particularly important in those borderline cases where the comparisons in money terms are fairly close.

### 3. Only the differences between alternatives are relevant in their comparison.

This is one of the most important principles in all decision making, a principle that often is disregarded. As applied to engineering economy studies, the principle has several aspects.

One aspect is that everything that has happened up to the moment of decision between alternatives is common to the alternatives and therefore is irrelevant in the choice. In general, past investments should be viewed as irrelevant in present decisions except as they may affect the future differently with different alternatives for the future. This aspect is sometimes referred to as the principle of sunk costs. Some of the literature of highway economy has exhibited extremely fuzzy thinking about this matter of sunk costs.

Another aspect is that the use of allocated costs or average costs per unit of output should be viewed with great suspicion in any economy studies. For example, in estimating the saving in motor vehicle operating costs due to a proposed reduction in highway distance, it is the incremental cost per mile of operation that is relevant, not the average cost per mile.

Still another aspect is that each separable increment of investment ought to have its own justification. It sometimes happens that methods of analysis are adopted that make it difficult to judge whether separable increments of investment are economically justified. For example, considering several proposals involving different levels of improvement and different relocations of an existing highway, if the method of analysis used is to compute a benefit-cost ratio for each proposal as compared with the present condition and if these benefit-cost ratios are used as the sole criteria for decision making, there is no adequate basis for judging the relative merits of the different proposals. If the

benefit-cost technique is to be employed in economic analysis, increments of benefits should be compared with increments of cost in addition to comparing total benefits with total costs for each proposal.

4. It is necessary to have a criterion for decision making (or possibly several criteria). The criterion for investment decisions should recognize the time value of money and related problems of capital rationing.

In competitive industry today, a common state of affairs is that the funds available for plant investment are limited and there are many proposals for making such investments. The more sophisticated analysts who deal with problems of capital budgeting in competitive industry view their basic problem as one of finding the best use for a scarce resource, limited investment funds. This view leads to the conclusion that the primary criterion for investment decisions ought to be prospective rate of return on investment. Although there are many different ways of computing so-called rates of return, the only correct methods involve the use of the mathematics of compound interest. (In recent literature of capital budgeting, correct compound interest methods of computing rates of return have been referred to by various names, including the "discounted cash flow method," and the "Investors' Method." A rate of return so computed has been called the "Profitability Index.")

Minimum attractive rates of return used in capital budgeting in competitive industry in the United States vary from industry to industry and from company to company. Typical rates today seem to be from 8 percent to 20 percent after income taxes. Minimum attractive rates of return used in economy studies for regulated public utilities in the United States tend to be equal or slightly above the rates of "fair return" allowed by regulatory commissions in rate making; these rates of return tend to reflect the overall costs of capital to the utilities considering both borrowed capital and equity capital. There are economy studies for public utilities using interest rates from 6 percent to 10 percent after income taxes; it seems that 7 percent after taxes is a common figure.

Where economy studies to evaluate proposed investments employ the techniques of comparative equivalent annual costs or comparative present worths, or the comparison of "benefits" with "costs," the interest rate used in applying these techniques is the minimum attractive rate of return, whether or not it is so described. The common use in benefit-cost studies for public works of low interest rates from 0 to 3½ percent implies that such low rates of return are sufficient to justify the investment of public funds. Such rates are too low, all things considered.

5. In considering the predicted consequences of various alternatives and in establishing criteria for decision making, it is essential to decide whose viewpoint is to be adopted.

Economy studies for competitive business enterprise should normally be made from the viewpoint of the owners of the enterprise. Economy studies for those regulated public utilities that are successful in earning a "fair return" on their investments should normally be made from the viewpoint of the customers of the utilities; alternatives in such enterprises should normally be compared on the basis of "revenue requirements."

The matter is much more complicated in economy studies for public works because it obviously is incorrect to make such studies merely from the viewpoint of the effect of investment proposals on the cash flow of the particular governmental unit. In most cases, it is desirable to take the viewpoint of the entire public. The often-quoted phrase "benefits to whomsoever they may accrue" from the Flood Control Act of 1936 indicates the generally accepted viewpoint.

However, it would be much better if the viewpoint were now expressed as "consequences to whomsoever they may accrue." It is characteristic of many public works projects that they result in favorable consequences to some of the public and unfavorable consequences to others. The concentration of attention on "benefits" in the economic evaluation of proposed public works has often led analysts to consider the favorable consequences and disregard many of the unfavorable ones.

The inherent difficulties of economic evaluation of proposed expenditures for high-

ways and other public works are related in large measure to the problems caused by the need to estimate consequences to the entire public. In part, these are difficulties of fact finding about the effect on the public of various aspects of specific public works. But in part, also, they are conceptual difficulties related to making sure that certain consequences are not counted twice and that other consequences are not disregarded.

6. In so far as possible, separable decisions should be made separately.

In both competitive enterprise and public works, decisions on financing are largely independent of decisions on the specific assets to be financed. In both fields, attempts to base the economic analysis of proposed assets on some particular scheme of financing the assets has been responsible for much muddled thinking.

One example is the advocacy by some engineers and administrators of a 0 percent interest rate in economy studies for proposed highways on the grounds that because highways are financed by current taxation no money for highway construction has to be borrowed.

Another example is the practice of judging the economy of a proposed highway improvement on the basis of the fuel taxes to be collected on the particular stretch of highway. If this method of analysis were carried to its logical conclusion, no reduction in highway distance would ever be justified.

The third example is more subtle because it cannot be proved that the mental block that prevented the analyst from making a sensible economic analysis was related to a proposed method of financing. In previous discussion of the importance of examining all the reasonable alternatives, an example was given in which an analyst had failed to consider the alternative of adding a certain secondary road to a proposal for the improvement of an existing through highway. It seems likely that, because the secondary road would have to be financed locally whereas 90 percent of the cost of either through road would be financed from Federal funds, it simply did not occur to the analyst to consider anything that required 100 percent local financing.

7. In organizing a plan of analysis to guide decisions, it is desirable to give weight to the relative degrees of uncertainty associated with various forecasts about consequences. In this connection, it is helpful to judge the sensitivity of the decision to changes in the different forecasts.

In certain cases, such as the design of drainage structures against extreme floods, it is appropriate to use the mathematics of probability to deal with problems of uncertainty. But for many of the elements of an economic analysis of highway alternatives, there is no rational basis for the estimations of probabilities.

It is always worthwhile to remember that the end product of an economy study is a decision among alternatives (or possibly a recommendation for a decision). In his initial analysis to guide the decision, an analyst should make the best estimates he can about the various elements in his economy study. But where there is question about particular estimates, he can vary these estimates within reasonable limits and determine how the decision will be affected by each assumed variation. The more sensitive the decision to a particular type of estimate, the more care it is desirable to take with that particular estimate.

(The useful descriptive word "sensitivity" as applied to the foregoing type of analysis is a comparatively recent term that was introduced in the literature of operations research. However, the type of analysis itself has been used for many years.)

8. Decisions among investment alternatives should give weight to any expected differences in consequences that have not been reduced to money terms as well as to the consequences that have been expressed in terms of money.

In connection with this topic of the "irreducible data of the problem of investment," there are three points related particularly to economy studies for highways.

The first is that many of the consequences of highway decisions that are not consequences to highway users are likely to fall in this class of irreducibles; at least, this

is likely to be true until further research makes it possible to place monetary values on these consequences. The fact that these non-user consequences are treated as irreducibles is not a valid reason for disregarding them in economy studies for highways. (Neither is the fact that many highways are financed largely or entirely from user taxes a valid reason for disregarding non-user consequences.)

The second point is that in economy studies for public works there are certain types of consequences for which the market provides no valuation, even though the consequences may be forecast in other than money units. A proposed highway improvement may have a number of consequences of this type. For example, it may be estimated that the number of fatal accidents will be decreased by so many fatalities per year, that time and saving by pleasure vehicles will be so many vehicles minutes per year, and that there will be increased "comfort and convenience" for so many miles of vehicle operation per year. A critical issue arises in economy studies for public works on the question of whether it is better to treat such extramarket consequences as irreducibles or to assign them more or less arbitrary money valuations and thus include them in the formal economic analysis.

It seems that there is no justification whatsoever for a practice of failing to identify such extramarket consequences separately in computing and reporting benefit-cost ratios or other criteria for decision making. If, for example, a computed benefit-cost ratio is 0.8 with extramarket consequences omitted and 3.0 with them included, this fact should be disclosed by the analyst in summarizing his economic analysis.

A third point is the fact that decisions on public works are sometimes made by legislative bodies or the electorate largely or entirely on the basis of irreducibles does not constitute a valid objection to the making of any economic analysis. The public is entitled to have economic analysis used in design decisions (that is, in project formulation) even though some projects are undertaken that are selected primarily on the grounds of irreducibles. Moreover, legislative bodies and the public are entitled to a measure of their extravagance when they authorize projects that are not justified solely on economic grounds.

9. Decisions among investment alternatives must be made at many different levels in an organization. The implementation of rules aimed at rational decision making may appropriately be different at different levels.

Both in private industry and in public works, the major emphasis in recent literature has been on the analysis of major investment proposals for presentation to top management — analysis at the level of capital budgeting in private industry and at the level of project justification in public works.

Although it is essential to have rules and procedures for implementing economic analysis at the top management level, it seems that it is equally important to give attention to the problems of implementing such analysis at the level of design or project formulation. A great many design decisions are made between sub-alternatives for every decision that top management makes between major alternatives. Unless there are some ground rules for economic design that are clearly understood, some designers are bound to overdesign in the sense of making unproductive increments of investment and other designers are likely to underdesign in the sense of avoiding investments that could be extremely productive.

It is inherently more difficult to implement economic analysis at the design level. Even in fairly large organizations, a relatively small number of professional specialists may be involved in economic analysis at the capital budgeting level. In contrast, hundreds of engineers and other persons may be involved in design decisions — persons whose major interests and fields of competence are in areas quite different from economic analysis.

Neither industry nor government have yet found a satisfactory solution to the problem observed by Wellington 82 years ago, a problem arising out of the uniqueness of sets of engineering alternatives. Wellington said: "He who has done well is shut off from adequate recognition of the fact. The same is true of one who has done poorly." Perhaps the future will bring, in industry and government, some system of internal audit of decision making that will make it possible to identify the economic designers and the uneconomic ones.

This paper has intentionally avoided a discussion of the merits of the benefit-cost ratio as the major criterion for decision making on public works. It is the author's view that other criteria are superior to the benefit-cost ratio. One of the chief objections to the benefit-cost ratio technique is that analysts who compute the ratios and administrators and legislators who use them as a basis for decisions seem, generally speaking, to be unaware of certain special characteristics and limitations of this technique.

### *Discussion*

**Burch.** — As contrasted to the normal viewpoint of the economist and those who deal in the realm of corporate profit-based decisions for corporations, we in public service have certain basic peculiarities, and I think they are well recognized. Dr. Grant has referred to several of them and they certainly are basic.

In the first place, our function is not the creation of profit, but rather our function is in terms of service, a very intangible element.

Secondly, we are properly subject to political decisions in the higher sense — the decisions of the people for whom we work, and we work for all of the people. The people are at the same time our stockholders and also the customers of our service. They pay for it and they expect to get it. We are constantly under public pressure and the demand for immediate performance and urgency. All too often, there is a complete lack of interest in the cost of the service or the economic considerations or results.

We work in a field highly charged with local "pride and prejudice." The people with whom we are concerned are always a local group, concerned almost always with "our community." And they ask for immediate help through some highway or street improvement.

Furthermore, we are in an atmosphere of constantly changing personnel, whether it is legislative or highway department, or Bureau of Public Roads, in which our products outlast our personnel. That is not customary in most corporate operations.

We can not gage our services exactly to the need. As one man has expressed it in terms of secondary roads, you can't build a little road. If you have a little bit of traffic, you can't put a 2-ft wide road there to serve it or a 2-ft bridge, nor a 2-ft anything else. We have to move in certain more-or-less standardized gages. Our product is absolutely immovable. Once it is there, it can not be moved. Our operations must be tuned always to the flow of funds over which we really have no control.

Surely we have made progress through these years, and every year brings a certain amount of clarification, perhaps, with a certain amount of additional confusion. But more recently we have been able to get away from some of the difficulties through photogrammetry, through the use of digital computers, thus being able to compare more alternates with each other than had been possible in the past because of the urgency under which we worked. The adaptation of sufficiency ratings has become a tool which is very effective in showing to pressure groups some of the facts of life, which they are more inclined to accept with the sufficiency ratings than otherwise.

But the final questions come down to this, it seems to me, and this is a question that comes up every day with any one in state highway administrative work and in many other fields. Just who or what are we serving? Of course, we do serve. We do not create economic values. The building of a super highway through the Sahara Desert would create no economic values, I presume. There is nothing there to serve. So we do not create economic values but certainly we have a function in serving the creation of economic values. But who and what are we serving? Simply, it is the users of the highway or the street, simply the users; and if so, is it the users of today or the users of tomorrow? Are we also serving land? If so, to what extent? Which comes first, agriculture or industry? Existing or future development? Are we serving tourists? Certainly. Real estate? Certainly. The promotion of land development, the movement of goods — all of these are certainly in the picture, but which are we going to stress the most? These considerations become controlling in everyday operations.

Finally, as a public agency, we must serve every one equitably or attempt that noble purpose.

We must attempt to establish a uniform level of service, a uniform level of traffic service, if possible; even though to do so would mean the involvement of subsidy on the one hand and lost operation on the other, and I am sure that every highway system has a great many miles that must subsidize a great many other miles.

Lindman. — Professor Grant, your paper has done an excellent job of dividing this problem into several compartments, and I am directing my attention to this sentence, "I could give you many examples of errors in analysis caused by the introduction into our economic analysis of considerations related to a particular method of financing."

Can we have a method of economic analysis that is independent of the method of financing? I think that one of the concepts of economic analysis that has prevailed through the years, based upon an annual cost with depreciation, interest, and so forth, — this method I think, has resulted in the development of methods of highway financing that have proved to be unacceptable.

I have in mind methods dating back to the 30's when there was considerable discussion of the public utility method of highway financing. More recently, I would say there was the Clay Report which involved interest and long-term use of credit.

Actually, the method of financing which is most prevalent in the highway field currently, and has been for 25 or 30 years, is the pay-as-you-build method of financing. Those of us who work closely with the financing problem and try to develop economic analyses which are in tune with and based upon that method of analysis find that we use approaches that do not include depreciation accounts and return on investment, etc. We are more prone to start with the program costs, the costs that the legislators talk about, the costs that have to be budgeted, etc., and work back from there. I suspect that engineering economics (starting with Wellington) developed under the economics of the marketplace.

We are involved in major decisions which are not made in the marketplace. Our major decisions are not made in Wall Street with respect to highways. To the extent that we have toll roads and the like, the use of market economics is fine, but that is just a part of the over-all picture. It seems to me we are faced with the fact that our major controlling decisions are made at 1600 Pennsylvania Ave. and in the state legislatures. These decisions are basically political. Those of us who are trying to introduce economic concepts find that engineering economics do not seem to fit too well. It seems that you are suggesting that we should have two different methods of analysis, one for the financing part of the problem and another for the specific engineering decisions.

If that is the case, I think it is going to add confusion because the two will be constantly mixed up. We will have one type of decision resulting from the major decisions that are political in nature, which will require a metamorphosis to bring them down to the operating level. We will have the design decisions occurring at the operating level, which may be in conflict with the chain of decisions starting at the top.

Other aspects of this distinction between different methods of finance and methods of economic analysis will come out from time to time at this conference, but I want to set it forth in general language at this point.

Grant. — Let me clarify a bit: I was trying to say that decisions that are separable should be made separately and financing is usually separable from decisions among physical alternatives, for example, the choice among several possible locations.

Let's take a case entirely apart from the public works field where the financing decision is not separable from the decision of physical alternatives. Suppose you are considering the alternative of home ownership versus renting, and you have enough for a down payment on a home but you do not have enough to purchase your home outright.

Then, associated with the alternative of purchase of the home, you have a specific scheme or perhaps several alternative schemes of financing and this is part of the consideration of home ownership versus renting. Here is a case where financing is definitely tied up with the physical decision.

Let's take a decision in industry. Here is equipment that conceivably might be purchased from equity funds or it might be purchased partly from borrowed funds. It might be leased. There, we see, are three schemes of financing.

Now, you are going to judge the productivity of this equipment. This is perhaps



materials handling equipment, that is to save operating costs in the manufacturing operations. If you tie to this a particular scheme of financing with 20 percent equity funds and 80 percent borrowed money and you borrow at less than the return available from the materials handling equipment, there is in effect a leverage there so that the rate of return on your equity funds seems to be very high indeed. If you change the ratio of equity funds, you get different prospective rates of return on equity funds. These are basically irrelevant as far as the merits of the equipment is concerned. That is what I meant when I said I could give illustrations from industry.

When you get to the issue "Should investments in public works be productive," it seems to me that the advocates of the zero interest rate are in a very weak position when they say that all that is necessary from public works is that the public gets its money back without interest. If the highway agencies are not able to invest taxpayers' funds productively enough to earn a return commensurate with that earned by a taxpayer, this is an unwise collection of taxes.

Let me say how we look at the actions of the highway users in judging benefits, in judging what weights they put on such things as comfort and convenience. About 80 percent of the highway users, in financing their automobiles, borrow money. If you really analyze the cost of this borrowed money to finance an automobile, it is in the general neighborhood of 12 or 15 percent. If you say you can take from this highway user some of his funds that he can invest directly at 15 percent by not borrowing to buy his automobile, and invest it in highways at zero percent return, I think you are mistaken.

Lindman. — What I want to emphasize at this time is that the concept of borrowed money seems to result in going to the legislature with programs that they will not accept. Congress has many other things to consider besides the engineering merits of the project when it comes to a question of whether or not they are going to use credit financing for a public investment; and we surely have come to the conclusion that the public utility method of setting up highways is unacceptable on a large scale. From the financing viewpoint, I think economic analysis methods result in suggested programs which have proved unacceptable in the finance field.

Gardner. — I think we quite often overlook the very pertinent fact that a state highway department is run on income and it has to spend that income on improvements and maintaining the road. Very recently in making a quick analysis, I came to the startling finding that in Pennsylvania no 2-lane highway of 24 ft or less in width can be self-sustaining on our present tax revenue. The only highway that I could find self-sustaining was the median, or divided type, with its volume of traffic, and this analysis was on the basis that we are providing a level of service that is generally accepted.

So, in economic analysis, if we find that a highway is going to cost more than the state highway department is taking in, I raise the question, where does the financial aspect fit into the economic analysis. Are we spending ourselves into bankruptcy, and I am quite certain that in Pennsylvania we have been doing so. (See Appendix A.)

Berry. — I would like to direct a question toward Grant's second concept having to do with the fact that all decisions are among alternatives. Professor Grant mentioned two kinds of decisions, one on project justification and one on project formulation. Apparently the rest of it relates to project formulation rather than project justification. I want to ask, in this project justification area in highway work, do we not get into the priority aspect? Presumably benefit costs are felt not to apply for that, but I was wondering what Professor Grant's view is.

Grant. — It is clear that matters of priority are decided on political grounds in many instances. I suspect however, that the legislators would have a better basis for these politically based decisions, or perhaps highway commissions or highway administrators responsible to legislators would have a better basis for these decisions, if there were an opportunity to look at the prospective rates of return on the various alternatives.

Let's look at the prospective rates of return. We will then array these proposals in order of prospective rate of return. We wouldn't necessarily take the top ones because there may be irreducibles or considerations of company policy or in highway agencies considerations of "We can't get the votes from these cow counties unless we take this relatively unjustified proposal on economic grounds."

But it seems to me that in this there would be a more sensible basis for decision making than in just conversation.

Of course, you can have the conversation approach in industry and you do have. There was a good paper in the *Harvard Business Review*<sup>1</sup> by Joel Dean a few years ago taking the point that the rate of return approach is appropriate in industry. He classified the capital budgeting decision-making procedures. In many companies that he observed this was all done by conversation — the department head who was the best politician, or the one who pounded the table the hardest, was the one who got the money. This was not really in the interest of the company and competitive industry to make decisions that way. The objective analysis is bound to leave some things out but you have a better start for your decision making.

Jorgenson. — What is your approach to the problem of dealing with roads of relatively low volume on which the rate of return would be relatively low; that is, I gather from your discussion you are talking about projects and not integrated systems.

Grant. — I am not a highway agency man. I have not lived with this problem. My assignment was to take out of the general body of engineering economy principles some things that seemed to me to be applicable to highways. I think my answer is substantially what I answered Professor Berry, that you need to look at these things and finally someone has to make up his mind that for one reason or another certain decisions that are not purely economic will be made.

Again this is a matter of looking at consequences. If the consequences of not building certain roads are that there will not be enough votes to finance the needed highway funds, this is quite relevant.

Jorgenson. — I did not mean to imply that this was a political decision. I think it is an engineering decision that highway engineers have to make all the time in programming the improvements to be made. I was proposing this just as a question that you might be helpful on. There is a huge area of highway improvements in which this is the case. Whether it occurs in every state at 24 ft or less I do not know; but if so, there is the big bulk of the highway transportation facilities in this country. How can we go about arriving at a judgment of these economic values with respect to road improvements that are not going to pay their own way.

Grant. — Keep in mind that I do not accept their pay-their-own-way status in the sense of gas tax revenues as a relevant matter. If you are talking about so-called solvency, it seems to me this is an entirely different proposition. What you should look at is the savings of various sorts and the other favorable consequences to the public of the construction of the highways.

I spent a couple of weeks in New Mexico pounding over very interesting dirt roads—trails as it were — that were not in the state highway system, and it would be nice to have those improved to serve some of the people with cattle ranches, but this would not be an economic thing to do. I think that economic analysis is relevant even on the minor roads, not merely on the major roads.

Moskowitz. — What we are getting into here, is the question of deciding what are the limits of the projects to which economic analysis is to be applied. The broadest concept lies in the thought that if you do not have these roads that do not pay for themselves either by solvency or by the benefit approach, you might not have any traffic at all for any other kind of roads.

That is the broadest look at this problem that we can take in deciding what are the limits of what we are going to call a project. Of course that comes right on down to an individual project. What we, in California, do call a project is normally about 10 mi long. If you make it 6 mi long it might not do the job or it might have an entirely different rate of return than if you made it 10 or 20 mi long.

In other words, everything you said is without doubt entirely true; but the difficulty

<sup>1</sup>Joel Dean: "Measuring the Productivity of Capital," *Harvard Business Review* (January - February, 1954)

of doing what you are supposed to do makes it almost impossible.

Grant. — What Mr. Moskowitz says is something that is very important. Having to leave out some things, I left out the operations researchers who have brought in a lot of new lingo. One of their favorite phrases is "suboptimize." Another phrase is "systems viewpoint." In decisions in a limited area — design decisions — one has to look at them essentially in relation to the specific alternatives, for example, a drainage crossing. Here are several competing designs for this drainage crossing. Which will we take?

In addition to suboptimizing, one needs to take a broader viewpoint. Often the decision that is appropriate, looked at narrowly, is not the decision that is appropriate when looked at more broadly; and this is a matter of what your alternatives are. It is an inherently troublesome matter in industry as well as in government to be able, as one has to in design decisions, to take a narrow look; and then to take a broader look. I do not think there is any disagreement among us. This is important.

Moskowitz. — There are so many alternatives. In fact, there are an infinity.

Lockner. — I think Mr. Moskowitz has a point. We have to recognize how far we can go as engineers or as engineer economists or whatever we call ourselves. If the agency people come over with all of the sufficiency ratings and on the basis expect to have all the highway programs made up, or if the governor calls up and says he wants the road built here, and that is frequently done — we do have a very good use for these studies. I found them very helpful, and I think we ought to recognize that field and try and stick with it and not get off into this other one, which, possibly being cynical, according to our democracy, we are not going to fix. It is going to stay that way, so we ought to stick to our own knitting.

I am concerned because we set up criteria that I would certainly question. For example, we analyze a project in an urban area and decide to use parallel ramps; our traffic estimate shows that those ramps are going to be adequate for a 20-yr period of time. But in 21 years are they going to be adequate? Was our economic analysis worth anything at all?

Hoch. — In the eighth concept in his paper, Grant said, "However, it seems to me there is no justification whatever for the practice of failing to identify such extramarket consequences."

It seems to me there might be such a justification in that you might not be able to identify these things. These things might not be known in the first place. In the second place, you might have no way of evaluating them even if you could identify them, that is, at best you could only express your own personal preference about them. In sound economic analysis, this would not get you very far. This is a minor question about this particular sentence.

Grant. — What I meant was if you put a money value on these extramarket consequences, you ought to say that these are relatively arbitrary money valuations that do not have a money market value and separate them in the rate of return, or whatever the criterion is, from those consequences on which you have a market figure.

Hoch. — There seem to be a lot of non-user costs which cannot be evaluated except perhaps as some sort of personal preference.

Grant. — I entirely agree. All I said was that if you in your wisdom decide it is better on account of certain extramarket consequences to assign a money value and then you give to some one else the results of your study, you ought to identify that segment of the benefits, or whatever you call it, that you attributed to the extramarket consequences. You can still say there are a lot of other favorable or unfavorable market consequences, particularly non-user consequences, on which we cannot place a money valuation. I do not think there is any disagreement at all.