Highway Costs as a Factor in Engineering Needs Estimates

J. P. BUCKLEY, Chief Engineer, Highways Division, Automotive Safety Foundation, Washington, D.C.

● HIGHWAY NEEDS studies include an analysis of the physical requirements for construction and maintenance of highway systems over a period of future years. Their common denominator is cost in dollars. Thus, "highway costs" are the major factor in engineering needs estimates. There is hardly a conceivable kind of cost relating to highway transportation that is not a factor in these studies. All costs of all kinds are involved one way or another.

Needs studies are used for a variety of purposes and the cost factors are more important in some uses than in others. In broad terms, needs studies have four major uses, as follows:

1. They provide the basis for determining the revenue requirements for the highway network, methods of financing including taxing and equity determinations, and methods for allocating funds between the various governmental units and the various road and street systems.
2. They set forth, for specific planning purposes, the physical requirements (the standards) of the road and street plant, both in terms of construction and of maintenance needed to provide the desired level of traffic service over a period of years.
3. They provide a factual basis for the scheduling of work so that projects can be undertaken to meet first needs first and to permit orderly long range development of the highway system.
4. They provide an almost inexhaustible source of data for research and analysis in areas such as investment requirements, finance policy, cost-benefit studies and systematic programming.

To a considerable degree the use to be made of the study will dictate the type of cost analysis required as part of the study. In the conduct of needs studies it has continually been attempted to refine the engineering base and to improve the cost estimates so that they will be applicable for all of the purposes cited.

DIRECT COST ELEMENTS

There are six classes of costs that enter directly into highway engineering needs estimates. They can be listed as follows:

1. Costs for constructing the necessary improvements, including right-of-way, at identifiable locations and to specified standards, considering the status of the existing system.
2. Future replacement requirements must be estimated in order to derive the long-term total needs. Most of these replacements cannot be determined precisely as to exact location or nature of the work to be done. The road life studies, reflecting the experience of all highway agencies, prove that the job of building and re-building highways is never ending; therefore, the replacement requirements (over and above those which can be identified in the particular period under study) must be determined by statistical means.
3. So-called "stop-gap" needs also should be incorporated into the total costs. The stop-gap needs are temporary capital expenditures designed merely to hold the existing facility in service until the proper type of necessary improvement can be constructed. The amount of such stop-gaps depends greatly on the speed with which the program is

prosecuted. If available funds are limited in relation to the total needs then, unfortunately, it will be necessary to spend greater amounts in stop-gapping. It is possible to detail such work, project by project, for varying rates of financing—but that job is very complex. Study of various samples and historical analysis of past expenditures lends considerable validity to a statistical approach for such work which ordinarily is only a small percentage of the total needs.

4. The total financial requirements would not be complete without as detailed knowledge as possible of maintenance needs. This area of operations is the most difficult to pin down with as much accuracy as might be desirable. Various methods are used, depending on the available information and the circumstances.

5. Engineering costs are a substantial element that must not be neglected. Here, too, it is not possible to estimate in detail the precise engineering costs for separate projects, many of which may not be built for 10 to 20 years. Past relationships to the total programs, coupled with consideration of future efficiencies in engineering methods, seem to be the best guides.

6. Finally, administrative costs must be added to complete the total needs picture. Again, like engineering costs, these must be evaluated in terms of the extent and amount of the total program requirements.

ECONOMIC RELATIONS

When it comes to determining the type of facility to be constructed and the level of traffic service to be provided, the engineer has to take into account many things which have an important bearing on costs. Basically, he estimates the probable benefits, including intangibles, of a certain type of improvement, measures those benefits against the prospective cost, and accordingly determines whether the proposed improvement is economically justified.

For example, even if money were no object, there are many types of improvements that are economically unsound. Despite the many known advantages of freeway design, building freeways to serve localized light traffic in sparsely populated rural areas, would not be considered or would building high type facilities simply to provide access to private residences. But there are many situations where a decision cannot be easily made.

It is well known that adequate shoulders add to the safety of a highway. Before specifying shoulder standards for any given highway mileage the engineer needs to analyze all costs related to shoulders of varying widths, study the benefits to be derived from each type, and then decide accordingly.

For complete safety and convenience all highway-rail crossings should be separated. But is the heavy expense of a grade separation structure justified in the case of a crossing that is passed by just one freight train a week, and only a few dozen vehicles a day? If not, what are the justifiable limits?

Vehicle operating costs admittedly are higher on gravel roads than on paved ones. Yet, gravel roads are less expensive to construct. At what point do the savings to highway users, computed over a period of years, make the paving of a particular highway a sound investment of public funds?

There are many situations, especially in urban areas, in which deferring needed improvements will tend to increase motor vehicle operating and accident costs, may result in higher right-of-way costs in the future, and may hamper economic development of the area. On the other hand, speeding up the improvement program may require extra costs for interest, divert scarce resources which might be used more effectively otherwise, require excessive amounts of engineering and other services to take care of big loads, and result in earlier obsolescence of facilities.

The balancing of these considerations requires the maximum of adequate, accurate cost data not only for the direct highway system costs, but for the indirect user and public costs just mentioned.

METHODS OF ESTIMATING

Where actual observation of work requirements is possible, the "identifiable" costs can be determined. When detailed plans and quantity estimates are available, the proper application of current unit prices should produce cost estimates reasonably close to the ultimate contract price. This is the ideal way of estimating costs and should be utilized whenever possible.

In most needs studies, however, the entire mileage of a highway system is included and has to be reviewed and estimated. This precludes the detailed kind of job which would take years to complete. So, other methods have to be employed, except for those relatively few locations for which detailed plans are ready.

Through proper analysis of past costs (classified by the various types of work, the standards utilized, the terrain, and the several regions of the state) it has been possible to produce average quantities and costs per mile, which when adjusted for price differentials, can be applied to comparable proposed work in each region.

Engineers also must consider other adjustments, some of which may partially compensate for upward movements in prices. For example, despite the general post-war price increases, earth excavation is being done today for unit prices not much different from those of pre-war times and considerably lower than those of the early 1920's. This has come about solely through the development of bigger and better machines.

Using the methods just mentioned, field engineers of some experience have been able to do a remarkably accurate job of estimating costs at current price levels, as reflected in actual contract awards.

Estimating Replacement Costs

Replacement costs which can be identified as stage construction can be handled by methods similar to those just described. The majority of replacement costs, however, must be dealt with on a statistical basis. The key to this problem is adequate road life data.

Usually, needs studies have dealt with the physical side of estimating future replacements by analysis of the life history of existing roads classified by surface types. It is recognized that a road is reconstructed or replaced for structural deterioration or functional obsolescence or both. Data are not available to segregate the importance of these two factors.

Road life data provide averages, indicating the mileage of the total construction in any year which is likely to be replaced. Thus, for 100 mi of highway built in a given year, the first few years show only a very few miles that would require any work. On the other hand, in 30 or 40 years there may still be a few other miles of the original 100 on which no work (other than maintenance) had been necessary. Meanwhile, all of the remainder will have been rebuilt or resurfaced. Road life studies provide the basis for such estimates but they have to be used with understanding, modification and judgment of the nature of the replacement work. Moreover, even the matter of definition must be carefully considered as to whether the work would be classed as maintenance or construction.

The next problem is to establish the unit costs of the probable required work. With modern design it is anticipated that the majority of future replacement would involve simply heavy re-surfacing but with some reconstruction and, occasionally, some new construction to take care of obsolescence which must be anticipated.

The unit costs are ordinarily derived from the detailed studies of the identifiable projects. These are then applied to the estimated mileage of each type of replacement need.

Local Road and Street Estimates

For most purposes, it is important to obtain good estimates of the total needs for the great mileages of local rural roads and local city streets. In many cases, however, it is impractical, because of insufficient manpower and money, to attempt a section-by-section analysis of the detailed costs involved. Sampling procedures and other statistical devices can provide satisfactory estimates for most purposes. This is

especially true since the majority of such roads would be developed to similar low cost standards—the greatest differential involving consideration of the current state of development of such systems in each of the many local jurisdictions involved.

Estimating Maintenance Costs

Maintenance cost records are notoriously poor for needs study purposes, especially in local governmental jurisdictions. There have been many problems of proper definition and accounting practice. Moreover, there appears to be a lot of freedom granted within the budgeting process to switch from construction to maintenance accounts or vice versa. Nevertheless, the historical record represents the first step in proper analysis of maintenance costs. Wherever possible, these are classified by surface types over a number of years, so that the changing nature of the highway system may be properly accounted for.

One of the most difficult areas of proper estimation involves the establishment of proper standards of maintenance performance. Past practice has been to limit artificially the total amount of the maintenance budget, and the maintenance engineer does the best he can, up to any given amount. As a result, maintenance may be quite inadequate in some areas and occasionally overdone in others. Accordingly, it is important that a good objective analysis of the proper work load should be made, either in total or by sampling methods.

The work required then should be priced in terms of labor, equipment and materials, and the results applied to the type of highway system which will be developed by the anticipated program growing out of the construction needs studies.

Engineering and Administrative Cost Estimating

These costs are related to the size and scope of construction and maintenance. Therefore, a review of the historical record provides the chief data on which to base future costs. They are usually taken as a percentage of the total program requirements with consideration given to possible efficiencies in future operations, as well as the scope of the administrative responsibilities.

The latter frequently involve administering grants or subsidies and dealing with local governments in carrying out their own programs. Most needs studies have provided 10 percent for engineering and about 6 percent for administrative costs of state highways. More detailed analyses of these requirements would be desirable.

CONCLUSIONS

In all highway cost elements, both direct and indirect, general economic conditions play an important part. The price levels of the future will have an effect—especially on long-range financing plans—which must be taken into account. For engineering studies, however, current levels are generally used, permitting direct adjustment of direct costs as the future unfolds.

A safeguard in the estimating process is a system of checks against various indices relating costs to travel, population, etc., and a comparison of the averaged costs with the classified historical data. Dependent on the purposes for which the costs are to be used, in the final analysis the grand totals should average out within reasonable limits of accuracy. One job may be over-estimated and the next under-estimated, but if this averaging is carried too far, the usefulness of the data is impaired for economic analysis of alternative locations, for priority and programming purposes and for the detailed study of standards. To the extent that emphasis can be placed on these important matters, engineering needs estimates should be improved through a greater amount of advance planning which will provide more exact basic plans on which to make more accurate quantity estimates.

Continued research is vital to the many problems of refinement of estimates, to means of testing their validity, to study of the economic relations and cost-benefit analyses which are essential to establishment of standards of maintenance, location and design and, finally, to the equity of finance policy necessary to develop future highway programs.

Discussion

Baker. —Mr. Buckley, in a previous reference to maintenance costs, it was mentioned that the amount spent was how much you have. How do you recommend getting at the "proper" level of maintenance in any study?

Buckley. —We have tried a number of methods and we are not satisfied with any of them, but we have tried to approach it on a basis of square yards of pavement to be maintained, miles of shoulders, miles of ditches and so on, plus, to the extent possible, per-mile costs where there are valid estimates of these unit costs. It depends so much on the type of data available that I could not give any formula for it.

Baker. —I think principally you hit on states where the level of maintenance is quite low. Do you ever encounter conditions like this, or is it normal to merely extrapolate the maintenance?

Buckley. —No, we have found those conditons and it is quite true that the normal maintenance budget is an arbitrary figure, arrived at by a compromise. We find that the level is low by observation. The engineers involved, in one manner or another, try to determine what a proper level is. You don't add two and two and get four, believe me.

Jorgensen. —In line with the thought about trying to get something in the way of economic measure against the total system improvement, would it be practical and effective to compute rate of return on a sampling of these projects to go into a needs estimate, whether it be a 10 percent sample or a 2 percent sample. And then to express this in the form of economic justification, for example, by the rate of return. It could be done by the primary system, secondary system, etc. For this purpose I think the average of this sample, or maybe the range of this sample, would be getting close to what you express as the minimum rate of return. As far as the sample is concerned we would have more than we have now. Would it be practical of accomplishment?

Buckley. —I can't answer the question, but I do agree with Mr. Fritts that is has been one of the greatest deficiencies of these needs studies, the total benefit to the economy of the state. We say if you spend X billion dollars you will take care of some vehicle-miles of travel much faster, but what does it do to the over-all economy? I think we can reasonably demonstrate the benefits of convenience, and safety and all the other user items, but it is the broader aspect that we have never been able to grasp.

Hennes. —It seems to me these last two papers bring up some of the same questions. The costs that are used for the needs study could require the interest to be included if you were going to do it on a justification basis. This is one of the two purposes of a needs and costs study—to determine whether this total investment is justified. But the other use is to determine the amount of revenue that has to be raised and I think this conflict or the danger of its being misused is a real one. I noticed that Professor Grant did not put out the warning that his remarks on interest were confined to comparison and justification studies.

In cost allocation studies interest cannot be included as something to be recovered from the investors because the taxpayers are actually the investors who forego the interest. The foregone interest is the interest I forego when I pay the gas tax. If I were charged twice, once for the interest I myself had foregone.

The second point is that the investor in these justification projects is the taxpayer. He is on a pay-as-you-go plan and on the basis of earmarked funds. If this is part of the general picture, then the foregone interest is the interest that this taxpayer could get with his $50 a year, because approximately 65 percent of the funds come from private automobiles and 35 percent from commercial vehicles. We have to consider whether the interest that he foregoes is comparable to these larger sums that might be available to the larger investors.

The use of Grant's example in that case of the man who purchases the automobile on time is not quite a fair one, because he in general does not have this as a choice—of paying this $50 a year in user taxes and buying his automobile for cash or paying for it

on time, because the sums are too disparate. There is no real economic choice between the two, so the alternate investments he has are the rates that are available to the average citizen (4 or 5 percent) except for this matter of risk. And the risk that is involved here, of course, is on the forecast. The basis for determining the evaluation of that is quite difficult. About the only way we can judge the figure is to go in the past and look at the record as to whether the forecasts of traffic over the past years have been pessimistic or optimistic.

In viewing the consequences of the error of neglecting interest in these justification and comparison studies, I think that it would be interesting to know what is in general the lowest ordinary benefit-cost ratio for which projects are actually approved and investments made. If the cutoff point is quite high, then although the error might be quite real, its consequences are not so real.

Rothrock. —The problem generally is the choice between two or more alternates as presented to me. We compare them with the present situation as it is. Quite frequently on some of these particular projects we find that the benefit-cost ration is less than one or approximately one.

Now, at the interest rate you use, if that is a satisfactory term and the calculation is right, a benefit-cost ratio of one is satisfactory. We recently had a case where there were three alternates that were compared by the benefit-cost ratio, and one gave 0.96, another one gave 1.1 and the third gave a trifle more than 1.1. We recommended any of them, because to carry that thing out to the second decimal point was rather foolish.

Berry. —Were these projects with very low benefit ratios on the Interstate System where you are really designing to high standards?

Rothrock. —That is what happened in this case. We were using extremely high standards. We used the consultant 's estimate of costs and traffic because we were told that we did not have time to go into our own estimates. We were told later, however, after we came up with these ratios, that they thought the estimates of traffic were too low. Probably in that particular case traffic would be about three and a half times the volume used. On the basis of that we told the administrator that any of the three projects were comparable. We could find no appreciable difference. The high standards and the 4 percent interest rate we use, do cause benefit-cost ratios of somewhat less than 2.0 on the Interstate projects.

Zettel. —I am sure Professor Grant will rebut some of the things that Professor Hennes said. I do not think that the interest rate for the highway user he is talking about is relevant to the problem at all, but if it were, I suggest that there are a lot of highway users that are paying 1½ to 3 percent a month interest rate to finance companies. If you want to use the average interest rate of the highway user you will find it very high, rather than low.

But that is not what we are talking about. We are talking about the return on alternative investments, not from the point of view of the individual, but from the point of view of the economy which is what we are interested in after all.

There is this distinction between financing of a growing program and what Professor Grant is talking about. Professor Grant is saying that the needs estimates that ASF would turn up with is possibly something other than what they are. And I think Professor Grant would say, "I don't know whether these are the needs until I have evaluated them in these terms." You are saying that we are going to finance what ASF says are the needs, and Professor Grant is questioning whether they are the exact needs until he knows the interest rate and how it has been used.

Grant. —On the interest paid by the highway user who finances his automobile, I am not really advocating 12 percent or 15 percent as the rate that should be used in economy studies for highways. I am simply pointing out that in many studies we draw inferences about the values that highway users put on such things as time and comfort and convenience by their actions. The highway user who is willing to buy a new car and pay 12 or 15 percent is in effect deciding that the services of that new automobile are such

that he is willing to pay a 15 percent interest rate. If he did not have so much taxes to pay he could do either of two things. He could spend it for consumption or he could use it to increase his down payment on the car so he would not have to pay so much interest. Therefore, he would in effect invest it at 15 percent, or if he spends it for a vacation he is saying in effect, this vacation is worth more to me—the consumption expenditure is worth more to me—than the 15 percent.

But don't think that I am advocating this rate in our analyses. I am pointing out an inconsistency in that the economic analysts for highways look at the actions of highway users. They analyze them carefully when it is to their interest to justify more highways. But let me say cynically, they do not analyze them when it is not to their interest.

I am just not close enough to the highway needs studies to have any respectable opinion about them. I would think it would be clearly impracticable, within the time and staff and other restrictions, for an outside group such as ASF to look at prospective rates of return for all of the program of the state.

But Mr. Jorgensen's suggestion that this might be done on a sampling basis, if you started with a stratified sample, and then randomized within that stratified sample, certainly sounds to me as if it would be interesting.

After all, the effects of the highway needs studies are generally good. But one effect, as was the case in 1946 in California, was to increase the gas tax and this is always lurking in the background.

Well, is this really a justifiable expenditure? You do not have much objective evidence if you just say, well, we are short of good highways and we have lots of traffic. Maybe this could be improved, on a sampling basis.

Buckley. —That might be applicable to the higher volume roads, but in the lower volume roads we cannot prove economic benefits even excluding interest.

On roads of 25 or 50 vehicles a day, you compute the cost of even a very low type surfacing and it runs up to vehicle-mile costs that you cannot justify in time savings or vehicle operating savings, or anything else.

However, we are certain that there are intangible benefits which in the limits of our knowledge today we cannot measure in dollars and cents. Therefore, adding interest, or not adding it, in the 75 percent of the mileage, I don't think would make a bit of difference.

Rothrock. —The sampling could be done to include a weighted part of the lesser highways. That would have to be the sort that would be the average, representative of all the highways. But the benefit, or the computation of the benefit, would be based on an expenditure of the entire amount, half a billion, or a billion dollars immediately.

Buckley. —It probably could, because the profit-making roads are now subsidizing these other roads that I am talking about.

Rothrock. —You could take the subsidization and still get a net benefit. But would that be a fair analysis, to say that if we spend a billion dollars now we will get a certain benefit ratio out of it, and then come up with a 15-yr program of expenditure rather than an immediate program?

Fritts. —You won't do it if you are just going to measure the vehicle saving. You are going to have to put in the general economic justifications, what are called consequences today. The consequences are going to have to be measured, and those consequences—not just the user benefits—are going to justify a total system.

Rothrock.—I say the net consequences which result in benefits. I don't mean user benefits strictly, any benefits to whomever they occur.

Buckley. —We have always been accused of coming up with fantastic costs and now you people are trying to make them bigger.

Zettel. —We may reduce them. Concerning this land-use aspect, I think it is a matter on which we can't have a way of measuring the user benefits.

Buckley. —I think they are there but you can't measure them in dollars and cents.

Zettel. —In any methods of measuring user benefits that we know about you would say the driveway to my garage is not justified. I insist that the driveway to my garage is just as much a user benefit as it is a property benefit, except that I put it in as a property owner. I bought it as a property owner, but it is as important to me as a user as it is as a property owner. We just don't know how to evaluate that kind of benefit to me as a driver of an automobile.

Berry. —Mr. Blensly previously said that research has not been used in priority determination. Professor Grant has really thrown out a challenge, and we ought to start doing more research, possibly even to the extent of having a subcommittee of this group prepare a prospectus and get it under way. Also on benefit-cost versus rate of return. We have done a little on that at Northwestern, but I think a lot more needs to be done.

Winfrey. —Gentlemen, as we come to the end of this session, Mr. Rothrock has an announcement.

Rothrock. —Professor Grant spoke of the use of tables or charts for determining rate of return. In Ohio we have prepared a set of tables and charts for determining rate of return, present worth, etc. (Appendix B.)