Bernard R. Bell files – Economic Evaluation of Public U... October 1974

Mr. Bell

CONFIDENTIAL

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
INTERNATIONAL DEVELOPMENT ASSOCIATION

POLICY REVIEW COMMITTEE

PRC/C/74-10

October 3, 1974

ECONOMIC EVALUATION OF PUBLIC UTILITIES PROJECTS

Attached is a revised version of the paper 'Economic Evaluation of Public Utilities Projects' prepared by the Public Utilities Department. The paper was distributed for staff level comments on July 2, 1974, and has since been revised in the light of the comments received.

It is distributed for information only; no meeting of the PRC is planned.

Frank Vibert
Secretary
Policy Review Committee

Distribution:
PRC Members
Vice President - IFC
IBRD Department Directors
Regional Chief Economists
Regional Program Coordinators

ECONOMIC EVALUATION OF PUBLIC UTILITIES PROJECTS

Prepared by Public Utilities Department
September 30, 1974

C O N T E N T S

ECONOMIC EVALUATION OF PUBLIC UTILITIES PROJECTS

SUMMARY AND CONCLUSIONS

i. This paper attempts to place in proper perspective the significance of the internal economic return (IER) calculation as applied to investments in the public utility sectors, which are defined here to include water supply, power and telecommunications. The paper is explanatory in nature, and does not raise new conceptual issues.

ii. Economic evaluation of such projects involves consideration of three basic factors:

(a) The demand forecast;

(b) The least-cost method of meeting the predicted consumption; and

(c) The comparison of project costs and benefits.

This analysis should be carried out in the context of a development program for the whole of the relevant sector. This involves consideration of competing demands of various types of consumer, of overall institutional implications, and of technical systems effects on costs of supply.

iii. With respect to demand estimates, a useful distinction can be made in less developed countries between established markets, where consumers have adapted to the supply of public utility services, and potential new markets, where people currently do not obtain public water supply, electricity or telephone service. In the case of established markets, projections of past growth trends have generally been the principal basis for demand forecasts. This technique is often subject to considerable error, particularly where there has been a history of shortages, for example, supply of water for only a few hours a day, power outages, and waiting lists for telephone service. However, it is difficult to prescribe a general remedy.

iv. Where new markets are being considered, it is even more difficult to make predictions of demand. Surveys of the current reliance on alternatives, income, and ability to pay, may be helpful. In new low-income markets it is important to determine the "threshold" level of development where demand begins to develop. This involves consideration of agricultural and industrial activity in the region,

government plans for the area, local wage levels, householders' priorities and needs, and the income levels at which demand for the utility services becomes effective. The Bank is currently carrying out a number of research projects in this area.

v. However, accurate prediction of demand, at given prices, is not an end in itself. The basic question is whether the predicted rate of consumption is desirable in the sense that project benefits -- broadly defined to include economic and social goals-- exceed, by as much as possible, project costs.

vi. This requires that two considerations be satisfied. First, projects need to be built and operated to meet a given level of output and a given standard of service as cheaply as possible. Selection of least-cost facilities, including proper timing and sizing of projects, is based on comparison of the present worth of the construction, operating and maintenance costs of various feasible alternatives, using the opportunity cost of capital as the discount rate. Shadow pricing may be employed to determine the least-cost solution from the viewpoint of the economy.

vii. Second, the expected benefits should exceed by as much as possible the costs (of the least-cost program). A comparison of project costs and benefits (such as are carried out, for example, for agricultural and industrial projects) is usually frustrated in the case of public utilities by the difficulty of quantifying benefits. Some attempts have been made to quantify benefits by examining the contribution which project outputs make to other activities and so assessing their value.1/ Research of this nature has been undertaken in the telecommunications sector in Pakistan, and other studies are currently underway in El Salvador (village electrification) and Costa Rica (telecommunications). Similarly, attempts have been made to estimate the benefits from water supply and sewerage projects by determining the impact of such investments on property values, and a number of unsuccessful attempts have been made to measure the health benefits of improved water supplies. The general conclusion reached is that this approach to quantification of benefits of public utility projects is generally too difficult and time consuming to be applied routinely in the appraisal process. Possible exceptions to this may however include evaluation of the productive application of electricity in rural areas.

viii. Revenues are therefore normally used as a substitute measure of the economic benefits of public utility projects. However, revenues may be only a partial expression of economic benefits (measured in monetary terms). People may value service by more than the amount they

---

1/ Similar to the measurement of the benefits of irrigation projects which are evaluated not in terms of sales of irrigation water, but of induced increases in agricultural output.

have to pay for it, and to that extent economic rate-of-return calculations based on revenues provide only a "minimum" measure of economic benefits. In addition there may be external benefits, such as community health benefits from improved water and sewerage supplies. It follows that if prices (and thus revenues) reflect costs, economic benefits will be at least as large as costs. Finally, social reasons may suggest that services are worth more (or less) to people than they are willing to pay, and providing subsidized services for poor customers may have favorable income distribution benefits.

ix. In order to arrive at economically sound investment decisions, consumers should be asked to pay a price for service which reflects the cost of supplying additional output. This would require the traditional accounting approach to tariff setting to be replaced by one that not only provides a satisfactory financial performance but relates to the costs (the marginal or incremental costs) of providing additional capacity and output. Practical problems of implementing this latter approach, including analysis of tradeoffs between various objectives -- financial, economic and income distribution -- of pricing policy, are currently being studied within the Bank.

x. Project evaluation in the course of the Bank's appraisal process includes a calculation known as the internal financial return (IFR) adjusted to be the economic return (IER). The IFR is the discount rate which equalizes the present worth of incremental costs of construction and operation and incremental revenues due to the project over its life; it is an estimate of the financial profitability of the project. The IER is, in principle, the rate of discount which equates the present worth of economic benefits and economic costs. In practice, however, an estimate of the IER is derived from the IFR by adjusting costs in economic terms (e.g. through the substitution of shadow prices for market prices), while using revenues as a minimum measure of benefits. Hence it simply shows the relationship between the price and the cost of additional -- or incremental -- output. This means that the IER requires a special interpretation.

xi. To interpret the IER, it is useful to distinguish between existing and new markets. In existing markets, with a regular growth in demand from established consumers of the utility services, a major issue is usually not whether capacity should be expanded, but when. The relevant alternative to be considered in the IER calculation is then whether the project should be postponed. This can be evaluated by comparing the cost-savings of postponing the project with the revenues which are then lost (or by comparing the incremental costs of advancing the project with the incremental revenues this generates). If this IER is low, it may suggest that prices should be raised or restructured so as to slow down the rate of growth of

demand. (Often, this does not mean postponing the project in question since it takes time to change prices and to adjust demand; sometimes, however, postponement may be warranted if the value of the additional output made possible by additional capacity is very low.)

xii. In the case of new markets, postponing a project for long periods, or rejecting it altogether, is often feasible because people are adapted to the use of substitutes. If the IER, based on a comparison of the revenues and costs of serving new markets and connecting new customers, is low, this indicates that either the tariffs are too low or that the project is not justified, or both.

xiii. In rural areas, low IERs based on revenue-cost comparisons can sometimes be expected to be low. There may be economic reasons for keeping prices down in the early years (to promote use of the service) and social reasons (to help small businesses). It is then necessary to look beyond the revenues and estimate additional benefits people obtain (though this is, as discussed in para. vii., a difficult exercise).

xiv. In both new and established markets, the IER thus provides a test of pricing policy, as well as of project acceptability. When the IER is low, the required action is to revise prices; this has the effect of revising the level and growth of demand such that the benefits to consumers exceed the costs of supply.

I. INTRODUCTION

1.01 This paper attempts to place in proper perspective the significance of the internal economic return (IER) calculation as applied to investments in the public utility sectors, which are defined here to include water supply, power and telecommunications. The paper is explanatory in nature, and does not raise new conceptual issues.

1.02 The IER is generally used in the Bank as a test of a project's economic desirability; high IERs are interpreted to signify an acceptable project, low IERs one that, on economic grounds, should be rejected. However, with public utility projects there is a complication to this rule arising from the extensive control of the utility over the access to services and the prices charged for them.

1.03 Indeed, while the IER derived from the existing tariff structure may provide a rough initial guide as to the merits of a proposed investment, it usually reveals more about the adequacy of the level of the utility's tariffs. Since the IER is derived from revenues, and therefore reflects the level of tariffs, it can point to the way in which prices should be adjusted in order to provide a better signal for the justification of investment. Tariffs are thus important, not only from the viewpoint of the enterprise's financial viability, but also because they can influence consumer behavior and thus eventually the allocation of resources.

1.04 This paper, in reviewing the procedures for public utility project evaluation, discusses such interpretations of the IER.

1.05 The economic evaluation of public utility projects involves consideration of three basic factors:

(1) The demand forecast;

(2) Selection of the least-cost method of meeting the predicted rate of consumption; and

(3) Comparison of project costs and benefits.

1.06 These three aspects are dealt with in order in the rest of the paper. It is, however, important to emphasize at the outset that in the case of public utilities the "project," as defined by the Bank, may be a somewhat arbitrary concept. It is necessary for project evaluation to be dealt with in the context of a development program for the whole of the water, power or telecommunications sector. On the demand side, there are many markets to study, new areas to be served, and demands stemming from

many types of consumers; on the supply side the institutional implications of project selection and operation have to be considered and the technical impact of a project on the operation of the whole utility system estimated. Project evaluation can frequently be performed satisfactorily only when it stems from or is accompanied by a study of the sector.

II. THE DEMAND FORECAST

2.01 The first stage of appraisal consists of a forecast of demand. While any forecast requires an assessment of the quantity and quality of service demanded by various categories of consumer -- urban, rural, domestic or industrial -- a particularly useful distinction in the context of less developed countries is that between established markets, where there is historical and current evidence about demand by existing consumers, and new markets, where no such evidence exists.

2.02 In the case of an established market where supply has been reasonably adequate, the customers have had access to service for some time and have taken its availability into account in establishing their living patterns and consumption habits. In such cases it is common to find sustained trends in the growth of demand of various consumer groups. Although simple trend projections, supplemented by econometric or other analysis of the industrial and domestic markets and of government plans, are subject to considerable error, it is difficult to make general recommendations as to improvement in generally accepted techniques.

2.03 There are, however, many instances of established markets where supply has fallen short of demand so that past consumption levels and trends provide no firm basis for estimating future trends in growth of demand. Proposed investments frequently do little more than bring the quantity and quality of service to a level that matches the existing level of (unsatisfied) demand. Such improvement, necessary to catch up on overdue investment, is often an important economic justification of projects, which may be reinforced by pressing social needs, for example, to ensure minimum health or sanitary conditions.

2.04 These considerations are illustrated by the following examples:

(1) Bombay Water Supply and Sewerage Project:

> "...unless urgent measures are taken to improve water supplies and sanitary systems, living conditions will be intolerable. This program is to improve living conditions by (i) alleviating the existing water shortage and increasing the present 3-5 hours of

intermittent supplies to 7-8 hours supply daily; and (ii) mitigating the present dangerous and offensive sanitary conditions by providing an effective sewerage and sewage disposal system." 1/

"Currently 71% of the domestic demand is estimated to be satisfied, by irregular and inconvenient supply hours, but by 1981, supply hours would be doubled and about 80% of domestic demand satisfied."

(2) Istanbul Power Distribution Project:

"...between 1967 and 1971 system outages increased by 20% annually in number and 24% in duration... In 1971 at least 70% of the outages were due to inadequate facilities."

"...local industry lost working days...(with a) resulting loss in industrial output...conservatively estimated at US$20 million."

2.05 Where established markets have become dependent, at least in part, on the availability of a service, there may be a prima facie case for installation of new facilities to meet increasing demand or to maintain the quality of service at a reasonable standard. Without such additonal facilities the inevitable consequences are deterioration in the quality and continuity of supply and ultimately, rationing; subsequent water or power shortages can disrupt industrial production; commercial activity may be damaged by congested telephone networks; water shortages may endanger health. In these cases, short-term demand may be so great as to clearly warrant investment in additional facilities, although tariff increases to reflect rising costs of supply may dampen further growth of demand.

2.06 A different situation obtains in the case of new markets. Where service is not yet provided, the possibility of continued reliance on alternatives must be taken into account, and since there is no direct experience of consumers' willingness to pay for the service provided by the utility, surveys of income and ability to pay for service may be necessary. In new high-income markets, forecasts can be made by comparison with the consumption of similar existing customers in other

---

1/ This and other quotations in this paragraph are from the Appraisal Reports for these projects.

areas. For new, low-income markets, forecasting is more difficult. One problem is that of estimating the "threshold" level of development in a region, above which the project's output will be demanded. It becomes necessary to consider the extent of agricultural and industrial activity in the region; government plans for the area; local wage levels; householders' priorities and needs; and the minimum income levels necessary to generate a demand for the utility service.

2.07 In view of the increasing emphasis being placed on rural development, research in these areas is now underway. Bank-sponsored research activities in El Salvador (village electrification) and in Costa Rica (telecommunications) are studying projects in various environments to develop an understanding of the factors which affect consumer behavior. For the same reason the Bank is also paying particular attention to monitoring the results of projects of this type. This approach is being followed in Ecuador (village electrification), in Brazil (Minas Gerais water supply) and initiatives are being taken elsewhere in telecommunications, as well as power and water supply. In general, these studies seek information in five major areas:

(1) The use of substitutes, which generally declines following the project's operation;

(2) The quality of supply, particularly in the case of water, where decisions must be made between house connections and use of standpipes;

(3) The aims of the project, which may be e.g. the use of more water per capita or use of electricity for agro-industries;

(4) More comprehensive understanding of the consumer: literacy, income level, business profitability, etc.; and

(5) Better appreciation of the community: local infrastructure, credit availability, government support, etc.

Development of this information gives a clearer picture of a project's impact, desirability, and areas of possible improvement, which in turn will form a more reliable basis for predicting the demand for potential projects in similar areas.

2.08 Much can be done along the above lines to improve demand forecasts, but no matter how sophisticated the predictive method, uncertainties remain. Changes in tastes, in the composition of industrial output

and -- particularly in the case of water supply -- in the location of economic activity, all introduce an element of risk and indicate that continual updating of demand projections is necessary.

2.09 One such uncertainty is associated with the impact of price changes on demand. In practice, demand forecasts are rarely adjusted to reflect projected changes in tariffs. This is due to a variety of reasons, such as the knowledge that forecasts are, at best, only approximations; information on price elasticity is limited; price changes are usually slight in real terms, being made largely to keep pace with inflation rather than to reflect changes in marginal costs of supply; and there is often a pre-existing inadequacy of supply. While this failure to adjust demand forecasts is a shortcoming of the conventional approach, it may not be too serious in the short run as price changes have in practice to be implemented gradually. Rather more serious is that while predictive accuracy is an important objective of utility management, much less attention is paid to whether or not the predicted demand target should in fact be met. This is discussed further in Section IV.

III. THE LEAST COST SOLUTION

3.01 The second principal stage in the appraisal of a public utility project is a consideration of all realistic alternatives that would meet the projected demand in order to assure that the one selected will provide the service required at the least cost. Techniques for doing so are straightforward in principle (although their application may be complex) and generally well understood by public utility engineers. Systems effects are of course important. The addition or removal of a component of a water, power or telephone system may affect the behavior of other components. Therefore, what must be compared is not simply the costs of alternative components, but the costs of expanding and operating the whole system with alternative components.

3.02 In the basic cost comparisons outlined above, it is appropriate to incorporate the use of shadow pricing in the decision-making process. Hydro projects, for example, usually require more capital than thermal projects but much less foreign exchange, and exchange rates may not correctly value the latter. Similarly, the choice between coaxial cable and microwave systems for long-distance telecommunications extensions are materially affected by the use of a shadow price for labor when substantial unemployment exists, because the proportionate labor content for coaxial systems is much higher.

3.03 In such situations it is important to recognize the difference between the least cost solution to the utility and the least cost solution

to the country. The use of financial cost criteria produces the least cost solution to the utility, while the use of shadow prices in project design results in the least cost solution to the economy.

3.04 The problems of uncertainties in costs and effects of changes in growth of demand or delay in construction, and combinations of these factors, are treated by sensitivity analysis. This gives a range of the probable alternative solutions. However, sector studies of power, energy, water resources or communications may be a necessary prelude to this. Moreover, there is often a long lead time between the initial sector study and selection of the appropriate investment program. System planning techniques may have to be improved, research in low cost technology undertaken, and feasibility studies made to consider a wide range of technical options. Least cost solutions are sometimes not found because of failure to devote adequate time and effort to study and research.

3.05 The project selection process is carried out by the utilities or their consultants often with guidance from the Bank from the early stages of the project cycle. When the choice between alternatives is particularly doubtful and complex, or involves issues beyond the scope of utilities and consultants, the Bank often makes its own investigations. Particularly significant examples include the Indus Basin Development in Pakistan, the Elbistan lignite-fired plant in Turkey, and the water supply project in Nairobi.

IV. MEASUREMENT OF THE BENEFITS OF PUBLIC UTILITIES PROJECTS

4.01 Comparison of the costs and benefits of public utility projects is usually frustrated by the difficulties of benefit measurement. Some attempts have been made to quantify the benefits which result from public utility projects by examination of the use made of project outputs and assessing their value. Such calculations are being undertaken in the study of village electrification in El Salvador for a variety of farm, commercial, and agro-industrial activities. The process of quantifying such benefits is difficult and can generally only be done in special cases. In the study in El Salvador it was necessary to consider and quantify benefits arising from such items as lighting, ironing, refrigeration, water pumping, radio and television in homes, motive power for farms and for sugar, cotton and coffee processing, and electric welding. Projects supplying large urban markets are even more difficult to evaluate by this approach. Since project outputs are normally both final consumer goods and intermediate goods used for a wide array of commercial and industrial activities, the information required to permit an independent assessment of their value is normally overwhelming. Generally, it is only possible to undertake such

studies routinely when the applications are less diversified and more elementary (though nevertheless important) such as in the productive uses of electricity in rural areas.

4.02 Similar research work done in the Bank in water supply and telecommunications confirms the research experience in village electrification, namely the difficulty of estimating project benefits by means other than the demonstrated willingness of consumers to pay a price established by the public utility or regulatory authority. Attempts have been made by the Bank to estimate the benefits of water supply and sewerage projects by determining the impact of such investments on property values. Data on property transactions in Nairobi and Kuala Lumpur, two cities in which records are particularly good, were analyzed. It proved to be impossible to disentangle the impact of water sewerage investments from the many other variables influencing property values in the areas concerned. 1/ Similarly, a survey of attempts to quantify the impact of improved water supplies on public health showed that statistically significant results were exceptionally difficult to obtain (despite large sample surveys) and were of little use in quantifying benefits. Problems arise not only in quantifying the economic and social benefits of an improvement in health, but also in disentangling the influence of improved sanitation facilities on health from all the many other influences, such as nutrition, climate, and household income and assets.

4.03 Attempts have also been made to quantify the benefits that arise from investments in telecommunications projects, such as time savings, marketing advantages and so on, compared with alternative forms of communication. A particularly detailed analysis was carried out by the Bank in Pakistan. However, since the qualitative superiority of telecommunications over its alternatives is so great, it is not surprising that such studies are unsuccessful in fully measuring benefits. The general conclusion stemming from these research efforts, which are continuing in the Bank, and from our experience in public utilities is that benefit measurement along these lines is at present too difficult to be applied routinely in the appraisal process, though such studies have considerable heuristic value.

4.04 In many other sectors benefit measurement is somewhat easier. In the agricultural and industrial sectors, for example, it may often be possible to use import or export prices of products to measure the value of additional output, while certain transportation projects may be evaluated to some degree by the cost savings that accrue in the private sector. In irrigation projects measurement of benefits on the

---

1/ For example, in one case the installation of sewers was accompanied by a rezoning ordinance which simultaneously tended to increase property values.

basis of water revenues faces similar difficulties as in public utilities, but benefits can be assessed by considering the impact on agricultural output. This latter approach, as pointed out above, has proven to be not feasible in public utility projects. In most public utility projects, the only concrete information available on the benefit side relates to incremental revenues. This is generally a minimum measure of economic benefits because:

- people may value service by more than the amount they pay to obtain it;
- in the case of water and sewerage systems, there may be additional health benefits to the community;
- in the case of telecommunications, new consumers also increase the benefits of telecommunications for existing consumers (because the extent and value of communications increases for the latter);
- the government may attach more value to a service than the beneficiaries themselves, or consumers may not be fully aware of the benefits they obtain from improved service (this may apply particularly to water supply and sanitation); and
- subsidized services for poor consumers may have income distributional benefits (which may or may not be judged to outweigh the cost of the subsidy).

4.05 Moreover, there are problems with using revenues as a minimum measure of benefits for public utility projects because:

- the price structure often does not correspond to the cost structure; and
- sometimes, average prices may be below costs.

This results in misleading signals since, in this situation, customers are not paying for the incremental costs of additional output and therefore are not given the opportunity to reveal the value they place upon it. Further, even if tariff structures and levels do reflect incremental costs, reliance upon consumers' willingness to pay for project outputs ignores -- as in other sectors -- income distribution and other social factors. These matters are further discussed in the next section.

V. PRICING POLICY AND THE INVESTMENT DECISION

5.01 Public utility pricing policies are generally dominated by financial considerations, in particular by the need to maintain tariffs at levels that will help finance the large capital requirements of continually expanding systems; and also by a questionable accounting approach to the design of tariff structures. Other objectives, however, also need to be incorporated into pricing policy to respond, for example, to the following kinds of questions: How fast should expansion be? How should output be divided, say, between industry and homes and between rich and poor? How can capacity be more fully utilized? The answers to these questions require a broader approach to pricing policy than traditional practice.

5.02 The traditional accounting approach for example is concerned with the recovery of sunk costs, whereas for efficient resource allocation it is the amount of resources currently used or saved by consumer decisions which is important. Prices are the amounts paid for increments of consumption and, social objectives aside, they should therefore be related to the increments of cost thereby incurred. If new consumers are connected to the system, or if existing ones increase the amount of power, water or telephone service they use, it is important that prices should signal to consumers the costs of such changes in their consumption. Hence prices need to be related to the value of resources used (or saved), and the valuation of these resources (the estimation of their costs) requires a forward-looking estimate. The backward-looking estimate of the accounting approach creates the illusion that resources which can be used or saved are as cheap or as expensive as in the past; that is, that resources are as abundant or as restricted as in the past. On the one hand, this may cause over-investment and waste; and on the other, under-investment and unnecessary scarcity.

5.03 The traditional accounting approach to pricing is preoccupied mainly with average costs, so that large discrepancies often appear between the structure of prices and costs. This (1) generates large cross subsidies and (2) often results in prices too low when demand is high, and too high when demand is low. To promote better utilization of capacity, and to avoid unnecessary investments to meet peak demands (which tend to grow very rapidly), it is often useful to structure prices so that they vary according to the costs of serving demands:

- of different consumer categories;
- in different seasons;
- at different hours of the day; and
- in different geographical areas.

5.04 Another shortcoming of the traditional approach is that it considers "fairness" from the rather narrow point of view that consumers should pay for the share of accounting costs allocated to them. As just explained, these costs may very well differ from the costs which consumers are currently causing the economy, and such cost allocation involves (often arbitrary) judgements. However, the cost allocation per se is neither fair nor unfair; whether tariffs are fair depends on who is required to pay them. While questions of fairness and the need to raise sufficient revenue to permit system growth are relevant for tariff making, separate analysis of these aspects is necessary. Many of the fairness aims of the traditional approach were, in any case, conceived for urban projects in North American or European conditions, and obviously do not relate to the problems of developing countries.

5.05 The foregoing suggests that if price is to be used to signal the economic justification of investment (social matters are discussed later), the traditional approach to tariff setting has to be replaced by one that allows price to reflect the cost of the resources used up in making additional consumption possible. This would permit consumers to reveal, expost facto, whether the value that they place upon additional output at least equals the additional (or incremental) cost of a water, power or telephone system, thus signalling the justification of investment in additional capacity. This policy requires, inter alia, that differences in incremental costs attributable to different consumers or types of consumption should be reflected in the prices charged. This may include variations in costs of supply according to the geographic location of consumers, or to the time pattern of consumption. A number of case studies dealing with the problems of obtaining efficient pricing policies in public utilities have now been completed in the Bank. 1/

5.06 If it is impossible, in practice, to establish price in the foregoing manner, economic justification of a project is made very difficult, for reasons explained in Section IV. If price is less than the incremental cost of expanding a power, water or telephone system, there is no evidence as to whether or not consumers would pay for it if they were given the choice. On the other hand, if price is greater than incremental system cost, demand may be unnecessarily restricted, and the project smaller than optimal; how much smaller is however unknown. Moreover, even if on average prices equal incremental system costs, project justification will not be automatically signalled by consumer behavior if differences in the cost of various types of consumption are not recognized in the tariff structure.

1/ For example, Electricity Pricing Case Study - Tunisia, Public Utilities Department, June 1973 (draft), and Lahore Water Supply Tariff Study, Public Utilities Department, August 1974.

5.07 However, in addition to the problem of externalities, referred to earlier, there are a number of practical difficulties that confront us in attempting to rely upon pricing policy as a better means of signalling the justification of investment. These include:

(1) Cost of Implementation - Pricing itself may be costly. For example, the cost of special metering of domestic consumers to distinguish peak from off-peak electricity consumption may be greater than the benefits. Furthermore, price changes themselves may be difficult -- and costly -- to implement.

(2) Fiscal and Financial Constraints - Public utilities may be an efficient means of raising revenues for general governmental purposes. The gains from taxing them should therefore be weighed against or reconciled with the objective of using price to determine the justification of system expansion. Similarly, the financial viability of the public utility could conceivably be at odds with the approach to pricing described here, and reconciliation may be necessary.

(3) Social Objectives - As the pricing concept is related to an effective willingness to pay, it depends in part upon the pattern of income distribution in a particular society. Thus, the very poor may lack an effective willingness to pay for water from a public supply, but they should not therefore be denied access to service. In other words, social objectives often are in conflict with the policy of allocating resources in accordance with willingness to pay, and appropriate adjustments to prices are necessary in these circumstances (in the absence, of course, of any measures to deal with the social objectives in more effective ways). Providing the service to the poor will then involve cross subsidization either by other consumers or by general taxpayers in the municipality itself or the country at large. Subsidies and taxes should be made explicit and justified in the overall assessment of the pricing policy for the service.

(4) Forecasting Problems - Investment decisions will certainly be assisted by pricing according to marginal cost, differentiated by classes of consumer, etc. However, evidence as to consumers' willingness to pay a price for a service at a given point in time does not entirely remove the difficulties of predicting demand, which will in subsequent years be influenced by a number of variables, including changes in income, population movements and tastes.

5.08 Reconciliation of the various objectives of pricing policy efficiency in the allocation of resources, financial, fiscal, income distributional and other social goals -- may be a complex task, as is being increasingly recognized in Bank appraisal reports. While tradeoffs between the various objectives may often be necessary (being reflected, for example, in tariff structures which allow poor consumers to obtain a basic supply of water for health purposes at a subsidized rate, while wealthier consumers pay more than cost), it remains true that pricing according to incremental or marginal cost remains the most direct, simple and practical method by which reasonable resource allocation can be achieved. In a well functioning private sector, prices are determined by market mechanisms. In the public sector, prices are determined by regulation. However, by attempting to reflect the level and structure of costs in tariffs, utilities also can secure an efficient use of resources; where necessary, they can adapt those tariffs to achieve social goals and mobilize resources for expansion.

VI. THE INTERNAL ECONOMIC RETURN

6.01 Project justification rests, as a rule, upon a calculation of the internal economic return (IER) which is the discount rate that equates the present value of economic benefits and costs associated with a project. Since economic benefits of public utility projects cannot as explained previously, usually be estimated directly, economic appraisal normally starts with a calculation known as the internal financial return (IFR) on the project investment (or program of which the project is a part). This return is the discount rate that equalizes the present worth of incremental costs (construction and operating) and incremental revenues resulting from the project over its life. This rate presents an estimate of the financial impact of the project on the utility.

6.02 A further calculation, adjusting the data for costs and benefits, produces a rough estimate of the IER. In this calculation, costs are adjusted so that they reflect costs to the economy as a whole rather than just to the utility, e.g. taxes on project inputs are not treated as economic costs, but subsidies are. Further adjustments may be made in cases where the market for productive factors does not provide an adequate measure of their real cost to society and shadow prices may be substituted for market prices. In both calculations, IFR and IER, revenues are used as a minimum measure of benefits. In the IER revenues are adjusted to include such items as consumption taxes, and then compared with the social opportunity cost of capital i.e. the return on capital in its most productive alternative use, in order that a judgement may be made as to the economic justification of the project.

6.03 To interpret the IER, it is useful to distinguish between two markets:

- existing markets, where the local economy is highly adapted to service; and
- new markets, where the local economy is adapted to using substitutes or doing without.

Existing Markets

6.04 The rate of growth of demand for the outputs of public utilities depends upon economic growth, the pace of industrialization and other such factors. It is also influenced by tariffs. Thus, while a utility cannot choose the rate of growth directly (except for the number of new consumers connected), it can influence the rate of growth by pricing policy. In the case of projects to supply existing consumers IER analysis can be used to indicate whether the rate of growth should be faster or slower, with corresponding implications for project timing. For this purpose, an IER should be calculated which equates the present value of the change in system costs from bringing forward or postponing the project -- say by one year -- with the present value of the change in revenues that would be gained or lost by the change in timing.

6.05 In carrying out IER calculations, it is important to note that the addition to system operating costs in any one year will not be the same as the cost of operating the new capacity, i.e. there is usually a "systems effect." This is because the efficient operation of the system as a whole may involve fairly full utilization of the new, efficient plant and lower utilization of older existing capacity. Similarly, the relevant returns are neither the selling value of the production from the new capacity nor the whole of the year's increase in revenue. They consist only of the revenue from that part of this increase which could not have been achieved if the installation had been postponed. In most cases this will consist of revenue from extra peak sales, since existing capacity can normally accommodate some increase in off-peak sales.

6.06 If the rate of return so calculated on investment this year instead of next year is high, the message is that to expand capacity sooner rather than later will be profitable. If this rate of return is low, the message is that rapid expansion will subtract from the utility's performance. Extra capacity to meet an increase of peak hour or peak season sales is particularly expensive; the economic message of a low return is that the resource costs to the country of providing the extra capacity are not covered by the extra revenues from sales

during the peak periods. The reason may be that consumers are getting the extra capacity too cheaply and tariffs should be raised, with the structure probably altered as between peak and off-peak consumption, thus slowing down the general growth of demand for capacity and output. Or if tariffs do reflect the (short run) cost of additional supplies, it may signal that investment in additional capacity is premature.

6.07 There are of course problems in raising tariffs suddenly: both equity and politics argue against it. In any case, demand may be fairly inelastic in the short run, since it takes time for consumers to adjust their usage of equipment that is competitive with or complementary to the services of the utility in question. In cases where capacity is fully utilized at a less than optimal price, some capacity expansion is likely to be justified to avoid the problems associated with water and power shortages, telephone service congestion, and so on, during the period required to revise tariffs upwards, and the growth of demand for services to adjust itself downward.

New Markets

6.08 In the case of a project serving new markets and connecting new consumers, as with rural water supplies or rural electrification, the rate of return has a somewhat different significance. Here costs include connections and the construction of the new distribution system as well as the addition to system costs of supplying water or power to the new network. The returns include the whole of the revenue from the new consumers. A high rate of return would then indicate that the geographical extension of the system is justified since, with the proposed tariffs, consumers value the new service at more than its cost. A low rate of return indicates either that the project is not economically justifiable, or that the proposed tariff is too low, or both. The point is again that the tariff and the project have to be considered together rather than separately. The question is whether there is any tariff which will lead to a consumption level and hence a revenue which will yield an acceptable rate of return. (As noted earlier, the analysis should of course also take account of any relevant social, or income distributional considerations.) The rate of return may need to be calculated for several alternative tariff levels in order to see whether the initially calculated low return argues against the project or for a modification of the proposed tariff. If it argues against the project, the project should be postponed until development in the area has become more favorable for investment.

6.09 There is one special problem to note regarding projects serving rural areas. The IER based on revenues may often be below the opportunity cost of capital even if pricing policy is satisfactory:

- initial fixed costs, and thus the average costs in early years, are high; to promote use of the service, without holding back consumption unnecessarily on account of large "sunk" costs, prices may need to be below average costs in early years; and

- it may be desirable to keep prices down to help consumers from small businesses and low-income families.

Often it may be necessary to look beyond the revenues and try to estimate some of the additional benefits consumers obtain; this can be done for productive uses of electricity in rural areas. But the extent to which it is necessary is partly a function of the acceptability of subsidizing the project -- if a long-run view is taken, recovery of sunk costs may be desirable. These matters are discussed in the Issues Paper on rural electrification.

Conclusion

6.10 In both established and new markets, the analysis of tariffs and their relation to the IER should consider both the structure and the levels of tariffs. Alternative tariff structures affect the IER directly through their impact on revenue and, to a varying degree, on the pattern of demand. Conversely, the tariff structure should reflect variations in costs of supply according to the type of service, the geographic location of consumers, or the time pattern of consumption.

6.11 The foregoing discussion of the role of pricing and the IER does not lead to any firm rules, but provides "guidelines" which need to be adapted to the circumstances of any particular project. The IER analysis is a starting point for the examination of both pricing policy and the justification of the proposed investment. It focuses on the relationship between price and marginal cost and tests investment decisions against the willingness of consumers to pay for additional consumption, rather than a more intuitive judgement that the project is economically justified.

SecM75-95

FROM: The Secretary

February 13, 1975

SUBSTITUTION OF LABOR AND EQUIPMENT IN CIVIL CONSTRUCTION

Attached for information is a copy of a paper entitled "Study of the Substitution of Labor and Equipment in Civil Construction: Phase III" referred to by the Chairman at the Executive Directors' meeting held on February 11, 1975. This has been prepared for submission to a meeting of the Steering Committee to be held in April.

Distribution:

Executive Directors and Alternates
President
Senior Vice President, Operations
Executive Vice President and Vice President, IFC
President's Council
Directors and Department Heads, Bank and IFC

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
INTERNATIONAL DEVELOPMENT ASSOCIATION

STUDY OF THE SUBSTITUTION OF LABOR AND EQUIPMENT IN CIVIL CONSTRUCTION: PHASE III

STATUS REPORT

January 20, 1975

Report to be presented to the Steering Committee meeting in Washington, D. C.

April 2-3, 1975

I. INTRODUCTION

1. The World Bank Study of the Substitution of Labor and Equipment in Civil Construction is attempting to establish the technical feasibility of alternative civil construction technologies utilizing different combinations of labor and equipment. These technically feasible solutions are in turn related to relative factor scarcities so that the economically optimum technology can be determined in any given case. Two phases of the study have been completed and work is currently underway on the third phase of the study. This paper is intended to review the work to-date of the Phase III of the study.

2. In the report of the Phase II studies[1/] it was concluded, inter alia, that traditional labor-intensive construction techniques currently in use in many developing countries are not economically competitive with modern capital-intensive techniques under most conceivable factor prices and environmental conditions. This is mainly because these technologies are technically inefficient and generally do not make use of even elemental mechanics, and because they are usually employed in an atmosphere where the primary emphasis is on employment generation rather than the efficient use of labor. However, even though the Phase II studies clearly showed that the traditional labor-intensive techniques are not economically viable, it was not concluded that modern equipment-intensive methods, which are generally developed for capital-abundant, labor-scarce economies are appropriate for developing countries where the factor endowments are radically different. Generally the results of the studies indicated that if the productivity of labor could be increased three to four-fold, then the resulting modified labor-intensive techniques would become economically competitive in such countries as India and Indonesia where the current market wage for unskilled labor is about 50 U.S. cents per day. The objectives of the Phase III of the study are to develop and demonstrate such labor-intensive technologies in a number of different countries encompassing different environmental conditions.

3. Improvements in labor productivity is to be achieved by:

i) introduction of improved tools and equipment specifically designed or adapted for use by labor;

ii) improvements in organization and management at the project and sub-project level; and

iii) improvements in health and nutrition status of the labor.

1/ "Study of the Substitution of Labor and Equipment in Civil Construction: Phase II Final Report", IBRD Staff Working Paper No. 172 (January 1974).

II. WORK PROGRAM

4. The Phase III study is planned to be carried out in three different countries representing different environmental conditions. India and Indonesia were selected as the first two countries and the third country is to be selected in Africa or Central and Latin America.

5. The study in each country consists of two parts: an initial period of 6 to 9 months for experimental studies during which experiments are conducted with new tools, equipment and work organization, followed by a period of 2 years during which up to three projects are undertaken for demonstration purposes. The projects selected for demonstration will include new roads, road widening and surfacing and canal excavation works.

6. The study commenced in India in October 1973 and in Indonesia in September 1974. The following parts of the study had been completed or were in progress as of the end of 1974:

India

a) Experimental Studies (October 1973-April 1974): Four different project sites were included in the study; two of these sites were located in northern India and the other two in the State of U.P. After an initial six-week period of training of the local team, experiments were conducted in: (i) stone crushing by manual and mechanical methods, including reorganizing of labor for feeding of crushers; (ii) testing and use of different designs of wheelbarrows; (iii) use of railway wagons for haulage of boulders; (iv) use of a pulley arrangement for hauling sand for a lift of 18 meters; (v) reorganization of excavation along hillside to improve labor productivity; and (vi) experiments with hauling earth with tractor trailers, wheelbarrows, bullock carts and donkeys. Increases in productivity ranging from 10 to 200 percent were achieved in different tasks.

b) First Demonstration Project - Excavation on Hillside and Road Surfacing (May 1974 - December 1974): A road paving project in northern India was selected as the first demonstration project. Experimental and demonstration studies on this project included labor-intensive methods of stone production, alternative methods of road surfacing and continued experiments with manual excavation along hillside rather than the existing method of using a bulldozer.

c) Second Demonstration Project- New Road (October 1974-): Two parts of a new road were selected as the second demonstration project. Works include pavement construction and construction of earthworks for a bridge approach. Intervention will be undertaken in stone production and haulage, murram haulage, compaction and work reorganization. Experimental studies will be undertaken for short-haul earthworks. The project will be completed in May 1975.

d) Health/Nutrition Study (February 1974 - May 1974): A small study was undertaken in northern India to determine the health/nutrition status of a particular population of road construction workers and if possible to relate it to their work output. The study indicated several deficiencies including iron, protein and vitamin A. Earlier studies in Indonesia indicated severe iron deficiency in rubber plantation workers. Iron interventioned raised worker output by 25 percent.2/

Indonesia

a) Experimental Studies (September 1974 -): Experiments with improved tools and hardware for canal excavation are now underway after an initial delay of two months. Experiments are planned with: (i) an animal drawn scraper; (ii) a swing arm arrangement for removal of excavated material from canal bed to spoil; (iii) a bottom dump animal drawn cart; (iv) use of ripping before excavation; (v) animal drawn rollers; and (vi) use of different design hammers for stone breaking. The experimental studies will be completed in May 1975.

2/ See "Iron deficiency Anemia and the Productivity of Adult Males in Indonesia", World Bank Staff Working Paper No. 175 (April 1974).

III. DETAILS OF WORK (September 1973 - December 1974)

7. Details of work for the experimental studies in India have been given in a separate report.3/ Results of the work on the first road demonstration project are presently being analyzed and will be reported in the near future. A summary of the results of the experimental studies and the tentative results of the first demonstration project are given below.

A. Experimental Studies (India)

8. Stone Crushing by Manual and Machine Methods (pp 39-43):4/ An experiment was conducted to compare the cost of stone crushing by hand and by small mobile crushers (5-10 ton per hour) commonly used in India. It was found that for stones of size 4.5 cm and above (stone used in macadam), at unskilled labor wage rate of US$0.50 per day, hand breaking is generally competitive with equipment. However, for stones smaller than 2 cm, the crushers are more economical than manual crushing. The productivity of different laborers varied considerably. The most productive workers were found to use a hammer of 1 kg weight with a pointed face, the preferred handle being of 45 cm length and 2 cm diameter.

9. Reorganizing of Labor for Manual Loading and Unloading of Mobile Crushers (pp 44-48): In India where small mobile stone crushers are used, labor is generally employed to feed rock or boulders to the crusher and to load the crushed stone into trucks. The slow rate of feeding stone reduces the throughput of the crusher. The manual loading of trucks causes the trucks to be idle while being loaded. Both these factors increase the capital cost per unit of stone crushing and hauling. An experimental study was undertaken in which the following changes were introduced:

(i) construction of a loading platform and changing of the loading procedure such that boulders were collected in a pan which was then unloaded into the crusher rather than using a human chain;

(ii) construction of a retaining wall on the output side to raise the stock pile of crushed stone above the level of trucks being loaded; and

(iii) selection of smaller boulders to reduce crusher reduction factor and therefore increase output.

3/ "Study of the Substitution of Labor and Equipment in Civil Construction: Phase III Technical Report No. 1," prepared by Scott Wilson Kirkpatrick and Partners on behalf of the World Bank (August 1974).

4/ Number in parenthesis refer to the page reference in Technical Report No. 1 where elaboration of the study may be found.

10. Three days of production trials were carried out by using the above mentioned changes. Increase in crusher output of 10 to 40% was observed. This represents a direct capital cost saving of the same magnitude. On the output side, since manual labor was employed to load the trucks with a negative loading height (downwards), there was a 50% reduction in the truck loading time (20 minutes compared with 40 minutes before) and therefore the cost of idle time of truck was reduced to one-half.

11. Comparison of Alternative Design Wheelbarrows:[5/] An important aspect of labor-intensive methods is the proper design of tools and equipment. A small study was undertaken to compare the productivity and economics of different design wheelbarrows. Two-wheel and one-wheel barrows, solid tired vs. pneumatic rubber tired barrows, and ball bearing vs. bushed bearing wheels for barrows were investigated. On the basis of 6 weeks of trials it was concluded that a light weight, single-wheel barrow with a scooter-tire and ball-bearing wheels, is the most economical type of wheelbarrow for earth haulage.

12. Use of Light-Railway Wagons for Haulage of Boulders (pp 61-70:) A study was undertaken to investigate the possible use of manually-hauled tipping wagons on a light railway. An experiment was conducted with hauling of boulders over leads of 100-200 meters. The existing method employed labor for haulage. A single line railway was used with two tipping wagons, each of 1.4 tonne capacity. A siding was provided at the loading end so that the filling of wagons could be made a continuous process, thus avoiding unnecessary idle time for loaders. There was a slight downhill gradient (1.4%) in the loaded direction.

13. The wagons were put into operation for a period of one week and observations were taken on productivity. The output of manual haulage was about 5.8 man-hours per tonne for 100 meter haul and 8.30 man-hour per tonne for a 200 meter haul. The corresponding figures for wagon haulage were observed to be about 1.75 man-hours and 2 man-hours per tonne respectively, which represents a four-fold increase in manual productivity. Assuming a rental rate of equipment of $1 per hour and the unskilled labor wage rate of $0.50 per day, the cost of haulage by the manual and by railway wagons calculates to be $0.8 per tonne and $0.28 per tonne respectively.

14. Haulage with Lift of Materials (pp 48-60): In labor-intensive haulage activities, labor productivity is reduced substantially if the materials have to be lifted over more than a certain height. The reason for this being that a man has to overcome his own weight in addition to the weight being lifted to perform such haulage. Spoil of excavated material from large canals is a typical example of such an operation. In the course of the experimental studies, an opportunity arose where sand was to be hauled for about 100 meters with a rise of some 18 meters. The traditional method of haulage was by manual labor carrying sacks full of sand up to the embankment. The productivity by this method was about 0.06 cubic meters per man-hour.

5/ "Comparison of Alternative Design Wheelbarrows for Haulage in Civil Construction Tasks," World Bank Study of the Substitution of Labor and Equipment in Civil Construction, Technical Memorandum No. 1 (January 1975).

15. A ropeway arrangement was designed whereby sand was loaded into sacks which in turn were loaded on a tackle at the bottom of the slope. Haulage was done by two men pulling the rope over the pulley. The productivity of labor by this method was about 0.22 cubic meter per man-hour, or an increase of almost 300% over the traditional method. Considering the cost of the pulley arrangement, the cost of sand haulage was calculated to be $0.61 per cubic meter compared with $1.00 with the existing methods.

16. Reorganization of Manual Excavation Along Hillside:[6/] Proper work organization can have an important bearing on the productivity of manual labor. Work must be organized so that there is a minimum of interference among the various gangs of labor and the different activities are scheduled to allow for smooth progress of work. To demonstrate the importance of proper work organization, a study was conducted on a road project in northern India where road widening was being carried out at specific place to provide for passing places. The work involved excavation into the hillside and haulage of the cut material across the road where it was spoiled down the slope. Manual labor was being employed in all activities and the overall productivity of the entire task (excavation and hauling) was observed to be 0.11 cubic meters per man-hour in soil and 0.06 cubic meter per man-hour in soft rock.

17. The following changes in the work organization and procedures were introduced:

(i) the excavators and haulers were separated in two groups working on two separate sections of the passing place, which avoided their interference with each other;

(ii) excavation was planned to take place in a series of benches working generally from the upper level downwards to allow the spoil to fall to road level with a minimum of haulage and to allow excavation along a vertical face;

(iii) with the excavation being carried out in benches, the excavators could face outwards which permitted them to excavate in front of and below their working position;

(iv) improved, quality tools were introduced and regular maintenance (sharpening, replacing damaged tools) was performed; and

(v) a task work system of payment was introduced.

18. The combined effect of these changes resulted in an increase in labor productivity of 150% in soil and 250% in soft rock. If it is assumed that the effect of incentive payment in this type of work is to increase output by 50-75%,[7/] it is apparent that at least a 100% increase in output has been obtained by simple reorganization and scheduling of work.

6/ See "Increasing Output of Manual Excavation by Work Reorganization: An Example of Passing Place Construction on a Mountain Road", World Bank Study of the Substitution of Labor and Equipment in Civil Construction, Technical Memorandum No. 2 (January 1975).

7/ This was one of the conclusions derived in Phase II of the study.

19. Earth Haulage by Various Modes: [8/] Traditionally in India headbaskets are used for short-haul, animals and animal drawn carts for medium-haul and flat-bed trucks for long-haul in earthworks. An experimental study was undertaken to study the use of the improved type of wheelbarrows (see para 11) in short to medium hauls, and tractor and tipping trailers for medium to long-hauls. The productivity in haulage by wheelbarrows was about twice the productivity by headbaskets. For haul lengths of 200-1,000 meters, tractors and tipping trailers with manual loading of trailers were found to be more economical than donkeys and mulecarts. However, comparing the improved methods with totally capital-intensive methods, a bulldozer is found to be the most economical for short-hauls and a dozer-scraper combination for longer-hauls.

20. Comparison of Paver Laid and Hand Laid Surfacing (pp 140-147): Laying of hot pre-mix by manual methods is quite common in India. It is generally believed that the quality of riding surface for hand laid pavement is considerably inferior than that of a paver laid surface. A small experiment was conducted on a road surfacing project in nothern India to compare the quality of surface (as measured by the surface roughness) for hand-laid and machine-laid surface. Road surfacing in the project studied was being carried out with a standard 12 ft Barber Greene paver. After some days of operation the paver broke down and the spreading operation was continued by hand. The crew that normally worked with the paver reverted to using manual methods using whatever tools that were available.

21. The rideability of the machine-laid surface was found to be markedly superior to the hand-laid surface. Irregularity factors [9/] for the two types of surfaces were measured as 210 and 508 mm per 100 m respectively, indicating a ratio of rideability of approximately 2.5. However, it should be pointed out that manual operation was initiated at short notice and the men lacked proper training and tools to do the job. In future studies an effort will be made to investigate the quality of hand-laid surface under improved operating conditions and compare it with machine-laid surface.

B. First Road Demonstration Project (India)

22. A hillside road excavation and surfacing project in the mountainous region of Kashmir in northwest India was selected as the first road demonstration project. The project consists of pavement construction of 15 km of road length during the 1974 construction year (May-December). The earthworks in this section were completed in the previous year. The road pavement is 12 feet wide constructed on a 20 feet wide formation. The pavement structure consists of a 15 cm layer of stone soling (increased in places to 9 inches); an 8 cm layer of water bound macadam with maximum stone size restricted to 5 cm; and a 2.5 cm of premix carpet.

8/ See "Comparison of Different Modes of Haulage in Earthworks", World Bank Study of the Substitution of Labor and Equipment in Civil Construction, Technical Memorandum No. 3 (January 1975).

9/ According to Dodd and Sherbourne.

23. The traditional methods of construction employed heavy equipment for certain activities and manual labor for the others. The formation cutting was done using a Komatsu D-80 dozer. Small mobile crushers were used for the production of fine aggregates and 3 to 5 tonne tipping trucks for haulage. All compaction was done by self-propelled rollers. Labor was employed in the collection of stones, loading of trucks, feeding of crushers, breaking of larger size (5 cm or larger) stone and in all pavement laying activities. Overall the project could be generally termed as equipment-intensive.

24. In planning improvements in the construction methods, the following principles were followed:

(i) where the interface between labor and equipment inhibits equipment productivity-- as in the case of hand loading of trucks, manual feeding of crushers--emphasis was to be placed on work organization and tools which would increase equipment output;

(ii) where labor is the major independent factor of production--as in the case of stone breaking, pavement laying, etc.--emphasis would be placed on increasing labor output; and

(iii) where equipment is the main factor of production--as in the case of formation cutting by a dozer and stone breaking --an attempt would be made to replace the equipment with more labor-intensive methods.

25. Using these principles and on the basis of the experimental studies already completed, a number of interventions were undertaken. 10/ These are described in the following:

(i) Project Organization: A detailed plan of work was prepared before the construction started. As the project proceeded it was found that while the necessary labor could be mobilized, there would be delays in equipment mobilization. The project plan was used in rescheduling labor to alternative activities which could proceed without having the equipment on site. This flexibility in the use of labor permitted the project to be carried out with lesser delay than would have been encountered otherwise.

(ii) Organization of Surfacing Gangs: Boulders were collected in measured piles along the road at regular intervals such that stones used in pitching and W.B.M. could be laid with a minimum of haul. This increased the productivity of the base laying gangs. The materials used for surfacing (bitumen, chips, sand and firewood) were placed along the road in such a way that uphaul in loaded wheelbarrows was minimized. This combined with a proper gang balance and the use of an improved heating and mixing tray (see para (vi) below) increased labor output from 5.5 square meters to 8.5 square meters of premix surface laid per man-hour.

(iii) Stone Breaking by Hand: Experiments with hammers of different weight and type were tested. Output rate, for example, of a 2 lb hammer was found to be about 50% more than that of a 4 lb hammer. The best design of hammers was adopted for stone breaking in the project.

10/ At the time of preparation of this paper, the reports and final results from this project were not available. In this paper only tentative results are given. It is expected that a final report on this project will be available by March 30, 1975.

(iv) Stone Crusher Layout: The layout of the crushers developed during the experimental studies was adopted for the two mobile crushers used in the project. On the input side, a loading platform was constructed which permitted labor to feed the crushers at a higher rate. Studies were also carried out by pre-breaking the larger boulders before feeding them into the crusher. It is expected that the crusher output could have increased by up to 40 percent because of these changes. On the output side, where the terrain permitted, the crusher was set up on the hillside so that there was a natural downard flow of the crushed aggregates into trucks. Where this was not possible, loading ramps were constructed (as was done during the experimental studies) so that trucks could be loaded from above. A significant reduction in wait-while-loading time of trucks is expected.

(v) Formation Cutting: On certain stretches of the road, formation cutting was to be undertaken in the 1974 construction season. Traditionally, a bull-dozer was employed for this operation. The labor-intensive work organization developed for the construction of passing places in the experimental studies were implemented on this activity. A significant increase in labor productivity over the traditional method of manual excavation was obtained. However, the results of the comparison with the dozer output are not yet completed.

(vi) Mobile Heating and Mixing Tray: A special mobile heating and mixing tray was adopted for surfacing works. The tray had an enclosed box for fuel used for heating aggregates. The tray is mounted on wheels and can be moved along the road length. A tipping mechanism was incorporated to unload the heated aggregates directly on the road. This type of tray resulted in substantial savings in fuel because of more efficient heating (compared with the traditional method heating on open fire) and increased labor productivity because of reduced double handling of materials. The tipping mechanism, however, did not prove to be very successful because the restricted space on the mountain road did not permit easy movement of the device. It was therefore necessary to use wheelbarrows to transfer hot-aggregates from the heating tray to the road.

(vii) Wheelbarrows and Tractor-Trailers: For haulage of aggregates over short distances, scooter tired wheelbarrows were introduced. For haulage of crushed stone over three to four kilometer hauls, a tractor-trailer combination was introduced. The productivity rates of these methods were observed to be similar to those obtained during the experimental studies and demonstrated significant improvements over the existing methods.

26. Effects of the Demonstration Project: The purpose of undertaking the demonstration projects is to disseminate the results of the study to the local construction authorities. It is expected that actual demonstration of intermediate technologies would encourage adoption of these methods by contractors and engineers in their own projects. The first road demonstration project was partly successful in accomplishing this objective. It is expected that the Border Roads Task Force which participated in the execution of the demonstration project would adopt most of the suggested changes in their future work. As a result of the project, particular emphasis is now being given to the types of tools, wheelbarrows, etc. Of particular importance are the results of the planning exercise carried out in the study which enabled the project to be completed despite the late arrival of some of the equipment. It is expected that the study team will continue to work with the organization in disseminating the results to other projects being carried out in other parts of the country by Border Roads.

27. The main limitation of the demonstration project was its relatively short duration (6 months). It was not possible in this period to get the various interventions underway and to arrange formal dissemination of their results. It would have been preferable to continue on this project for at least another construction season so that much more emphasis could be given to the dissemination aspect as the interventions would have been well underway. It is hoped that, wherever possible, an attempt would be made to select future demonstration projects for a longer term.

C. Health/Nutrition Study (India)[11/]

28. In collaboration with the All India Institute of Medical Science (New Delhi) and the Border Roads Organization, a small pilot study was conducted to assess the health and nutrition status of a population of road construction workers in northern India and, if possible, to relate these to the worker productivity. A total of 198 workers from two distinct population groups were selected for the study. One group of workers was selected from the local population engaged in road construction and the second group was selected from among the sizeable number of workers imported from the state of Bihar for road construction. These workers were subjected to clinical dietary and biochemical analysis to assess their health and nutrition status. At the same time their output in one particular activity (sand haulage over a slope) was carefully recorded over a period of six weeks.

29. The workers from the two populations had rather different levels of health and nutrition and therefore it was decided to analyze them separately. The differences in the anthropometric measurements between the two groups were insignificant except for weight which averaged less for the local labor. Clinical signs of vitamin B complex deficiency were observed in a few of the local labor and a significant portion of the imported labor. Vitamin A deficiency features presenting as night blindness and/or Bitots were present in about one-third of all workers. No workers had moderate or severe anemia although mean hematocrit values were lower for imported labor as compared to the local group. Both groups suffered from intestinal infections. Hookworm infection was the most common and the next in order of prevalence was the amoebic infection.

30. Comparing the average dietary intake of the workers against the recommended allowance, both groups were found to be deficient in their intake of calories, fats, vitamin A, C and B_{12}. The imported laborers again were more deficient in the intake of these than the local laborers.[12/]

31. Laboratory studies were carried out on a sub-sample of the workers. On the basis of their hemoglobin levels, none of the local but 51% of the imported laborers were found to be anemic to a mild degree. Serum folic acid and red cell folate was 'deficient' or 'probably deficient' in all of the imported laborers and in about 50 percent of the local laborers. Dietary history, however, indicated a good intake of dietary folate. It is likely that cooking destroyed the folate content of the diet. Laboratory analysis also confirmed the Vitamin A and B_{12} deficiencies in a segment of the population.

11/ See "Effect of Health and Nutrition Status of Road Construction Workers in Northern India on Work Output", World Bank Study of the Substitution of Labor and Equipment in Civil Construction, Technical Memorandum No. 4 (January 1975).

12/ It should be noted that the imported laborers weighed more than local laborers which would indicate a higher caloric intake for imported laborers. Thus there is an apparent discrepancy in the dietary survey.

32. An attempt was made to correlate output with the various health and nutrition parameters. Output of the local labor positively correlated with hematocrit levels. For the imported labor, no such association could be discerned. For both groups, output was strongly correlated with height, weight and arm circumference. No significant correlations could be derived between work output and any of the other parameters. It is believed that this is probably because of the errors involved in measurement and because the work content was such that each worker could "pace" himself according to his colleagues. Diet intervention studies are probably necessary to analyze the effect of one or more deficiency on output. The analysis does confirm, however, that there is some dependency of output on protein status and serum vitamin A levels.

IV. DISCUSSION OF RESULTS

33. Although the results available to-date are based on a limited number of experiments in the field and many of these have not been implemented on full scale construction projects, it is clear that substantial improvements in labor productivity can be achieved. Improvements in productivity have been obtained by one or more of the following factors:

(i) use of improved tools and hardware;

(ii) proper selection and maintenance of tools;

(iii) improved work procedures at the activity and task levels; and

(iv) adequate project planning.

34. All of the "innovations" mentioned above should fall under the general purview of project management. It should be the site engineers' responsibility that the workers are supplied with appropriate tools, and that their work is planned and scheduled in such a way that there is a minimum of effort wasted. The use of "unfamiliar" tools or hardware which would improve labor performance is perhaps more difficult and can only be done by people external to the project execution. It may therefore be necessary to provide additional management assistance to labor-intensive construction projects, particularly in environments where they are not traditionally used. It is recommended that a few projects or portions of projects should be selected for execution by labor-intensive methods on this basis. Of course, the whole area of inducing the laborers and small contractors to using improved methods needs further study but the experience of this study indicates that some incentives will have to be provided. For example, it may be necessary to adopt a payment method which allows the benefits of increased productivity to accrue to the laborers in the form of higher incomes.

35. The health and nutrition studies in Indonesia have indicated areas where nutrition intervention on manual workers may be economically justified. While the pilot study in India failed to show relationships between work output and the workers health and nutrition status, many deficiencies have been identified. It is believed that follow-up work would indicate the areas of intervention which may be economical.

36. The study has encountered major difficulties in the selection of suitable demonstration projects. The study plan had envisaged selection and planning of demonstration projects well before the start of construction. In practice, however, it has proven to be difficult because the construction programs for the year are generally not finalized until late in the year. In addition, budgetary and other constraints have sometimes forced the authorities to cancel or postpone some of the projects just before they are scheduled for construction. In some instance (for example the second road demonstration project in India), the project selected for study was one of the projects affected which disrupted the work program. It is felt that in future, we would have to select projects for which financing is already available. The projects would be for two or three year duration so that delays of two or three months do not affect the demonstration plan drastically. We propose that preferably the projects be externally financed by one of the participants in the study which would enable us to exercise some control in its execution.

V. FUTURE WORK (1975)

37. The program of work for the calendar year 1975 will be:

a) India

(i) The second road demonstration project in Madhya Pradesh was scheduled for start of construction in November and was to be completed in April/May. There has, however, been a delay encountered because of a cut back in government funds for road construction. If the project is carried out as scheduled, results of the various experimental and demonstration studies will be disseminated to the various Public Works Department.

(ii) An irrigation canal in U.P. has been selected as the third demonstration project. Experimental work will commence in February and construction of the project will commence in September. Some preliminary results will be available from this project by the end of the year.

(iii) A survey of the labor market for civil construction workers will be carried out to determine the factors which effect the supply price of labor. This study will also attempt to determine the elasticity of supply of labor in one or two selected regions of the country.

b) Indonesia

(i) The experimental studies presently underway will be completed by June. Technical notes will be prepared describing the different intervention experiments.

(ii) One irrigation demonstration project and one road demonstration project will be undertaken commencing July, subject to suitable projects being available. (At the time of writing this paper, an irrigation project had been selected but the study team were still attempting to select a road project.) These would be used for dissemination of any intermediate technologies developed in the experimental studies and for further development.

(iii) A follow-up health and nutrition intervention study will be undertaken using rubber plantation workers. Effects of iron, protein and calorie supplementation on work output will be investigated. Public health measures and their effect on morbidity and work output will also be investigated. Alternative delivery mechanisms will be identified.

c) Country 3: Extension work is proposed to be carried out in a third country in Central America or Africa. In this country, a greater emphasis will be given to application of the results derived from India and Indonesia and on dissemination. We expect to identify a country by the end of the year.

VI. FINANCES

38. Up to December 31, 1974, a total of $465,000 had been spent on the study. Of these $248,000 were spent in fiscal year 1974 and $217,000 in fiscal year 1975. A total of $440,000 in contributions were received from Japan, Sweden, Denmark, Finland and the Bank. A breakdown of the expenditures and the contributions is given in Annex I.

39. Projected expenditures for the different years are:

Fiscal year	Expenditures
1974	247,856 (actual)
1975	
July-December	215,482 (actual)
January-June	520,000
1976	875,000
1977	615,000

40. As of December 31, 1974, commitments had been received from the various donors to cover the budgeted cost of the study. However, several costs have escalated in the past eighteen months at a rate faster than anticipated. Full impact of these cost escalations would be better known by the end of 1975. We would propose a review of the costs and the study scope next year to decide the necessary adjustments in the budget and/or the scope of the study.

ANNEX I

SUMMARY OF EXPENDITURES

(In U.S. Dollars)

	FY 1974	FY 1975 (Up to Dec. 31,1974)	Total
Consultants Fees	144,133	187,804	331,937
Travel & Subsistence	75,652	15,178	90,830
Equipment, Instruments	29,101	12,500	41,601
Total	247,856	215,482	464,368

CONTRIBUTIONS RECEIVED (Up to December 31, 1974)

	FY 1974	FY 1975	Total
IBRD	130,000	150,000	280,000
Japan	50,000		50,000
Sweden		26,880	26,880
Denmark		74,138	74,138
Finland		13,080	13,080
Total	180,000	264,098	440,098