APPROPRIATE TECHNOLOGY FOR LOW VOLUME ROADS

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In recent years there has been a growing interest in the development and application of more labour-intensive methods of construction. This interest originated from the feeling that the technology presently used in road construction in developing countries was inappropriate both to the economic and social environment. Some 5-6 years ago both the World Bank and the ILO initiated major programmes in this area. The objectives of the programmes have been to ascertain whether it is feasible to use more labour-intensive methods in construction. Whilst some work has been done on irrigation the major effort has been concentrated on road construction. The studies and programmes carried out have shown that labour-based methods are indeed viable particularly for the construction of rural roads. This paper describes the work that has been carried out in Iran, Thailand, the Philippines, Nepal, Kenya, Guatemala and India. It shows how the initial concern with increased productivity and economic evaluation gave way to an emphasis on institutional, administrative and managerial problems. The paper highlights the major problems of the implementation of an effective labour-based programme. It is argued that the use of labour-based methods requires a re-appraisal on the part of engineers of their traditional attitudes not only to the details of design, management and organisation of low volume road programmes but also to the integration of these programmes into the general development of rural areas in the developing countries. Finally, it is suggested that to provide an environment in which labour-based techniques are considered as an alternative technology will require changes in fiscal and institutional measures to ensure that there is no inherent bias against these methods.

In most developing countries, investment in construction is of the order of 60% of the total public investment in the economy as a whole. Investment in road construction is usually higher than in any other form of infrastructure, being as much as 50-60% of the investment in construction. Because the vast majority of road construction is financed and supervised by the government, there is the means to ensure that resources are used in the most effective manner. In fact, there is clearly some responsibility placed upon the government to make the most optimum use of the available resources. It is on the question of the way in which the resources should be used that we shall be concerned in this paper.

The Case of Road Construction

In recent years various investigations have been made on the technologies presently in use in developing countries in an attempt to show which were the most appropriate. Not surprisingly one of the first activities that came in for scrutiny was road construction. As we have seen, it consumes a large proportion of government investment. If it were possible therefore to make the techniques used in road construction more labour-intensive, whilst being still efficient, then this large government expenditure would be used to promote employment and reduce the level of dependence on foreign imports.

Apart from these obvious benefits, there are however other good reasons to consider road construction. There is, after all, a historical precedent for the use of labour-based methods. (In this paper the general term 'labour-based' has been used so as to avoid confusion between the terms labour-intensive and labour-extensive.) In 19th century Europe and America, before the advent of the internal combustion engine, roads were built by men using simple hand tools and animal-drawn equipment. Furthermore, in countries like India, roads built using large equipment are the exception rather than the rule. Then, again, the tasks involved in road construction are relatively simple and can be carried out by relatively unskilled labour who require little training. Much of the labour to be used will be from the rural areas and the tasks, tools and techniques utilised in the major activities such as earthworks are not dissimilar from those used in agricultural activities. In addition the amount of

employment created per unit of investment is potentially large. Moreover, employment creating activities which take place in the rural areas, as much of the road construction programmes do, could help to limit rural/urban migration.

Construction equipment is a major import in many developing countries. Furthermore, import of such equipment implies the future importation of spare parts. The cost of using the equipment is extremely high, requires skilled personnel and relies on fuel which is permanently subject to international economic factors. Any reduction in the level of equipment imports would reduce the pressure on limited foreign exchange resources.

There is also scope for the increased use of labour-based methods in the extremely important activities of road maintenance, particularly for routine activities such as ditch clearance, culvert maintenance and minor road surface repairs.

The case for an evaluation, at least, of the feasibility of using labour-based methods is therefore very strong. It would be wrong however, to assume that there are no fundamental objections to their use. Indeed some of the arguments against their use are quite potent and it is useful at this stage to present them.

First, and perhaps most important, is the feeling that the use of labour-based methods will automatically produce a reduction in standards of construction. There is certainly some justification for this objection, particularly in relation to the compaction of earthworks and the final surfacing where it is true that it is extremely difficult to provide the same standard using labour-based methods. It would be wrong to suggest that labour-based methods should be used when they produce inferior quality. Indeed, the approach should be that the methods used should be the most appropriate and if this means the use of equipment, then that should be the solution. There is, however, another aspect to this issue. The standard of construction is specified by the design. Often the design is orientated towards the use of equipment and it is therefore not surprising that labour-based methods cannot meet the requirements. In addition, as suggested later in this paper, the standards of construction may be artificially high.

Second, it is suggested that the productivity of labour-based methods is low. This naturally has repercussions in terms of the duration and cost of projects. It is pointed out that low productivity means either an extension of the project time or that the number of labourers on the site has to be very high causing managerial and logistic problems. Unimproved, traditional labour-based methods do have a very low level of productivity. On the other hand, there is a large variation in the productivity of manual methods. In the activity of excavation for instance, the World Bank (1) noted a six-fold difference in productivities for different parts of the world. Clearly, there is a potential for improvement of productivity given the right environment. There is therefore some validity to this criticism and consequently the improvement of productivity has been a major factor in the work on the development of viable labour-based methods. In one respect, however, low productivity may not be detrimental. There are certain construction activities which are non-critical, that is, the extension of their duration will not adversely affect the overall construction time. On these activities, it would be feasible to use labour-based methods even if they are not as productive as equipment.

Third, it is generally assumed that the cost of using labour-based methods is prohibitive. There is, as is discussed later, an automatic bias in most project appraisal criteria against these methods. Nevertheless, certain comparative studies have given support to this objection. It is worth noting, however, that in general these studies attempted to evaluate what would happen if labour-based methods had been used on a project which had used equipment. The comparison is therefore carried out in a framework orientated towards the use of equipment. One of the main themes of this paper is that to equitably assess the most appropriate methods the whole construction process must be "opened up" to allow the consideration of alternatives. In the final analysis, however, cost is supremely important. The Public Works Ministry or Highways Department has a limited budget for which it is accountable. It has to be sure that the best use is being made of that money. The use of labour-based methods must be shown to be not only socially but also economically appropriate.

Fourth, there is a strong feeling that these methods require a high level of supervision which gives rise to high overhead costs not only on site but also in terms of additional training programmes. It is certainly true that labour-based methods require a different kind of supervision. After all, one is considering the management of large bodies of men, not fleets of equipment. Whether the supervision is more costly is open to question and in any case should not be considered in isolation.

Finally, there are institutional forces within the construction industry which militate against the use of more labour-intensive methods. The design methods, specifications, conditions of contract and methods of tendering all tend to reflect the dominating influence of expatriate consultants and contractors and their equipment-oriented framework. Even the method of selecting contractors is often based on the amount of equipment they have, and not on any ability to manage men. There is a natural inertia within the industry which could make the introduction of labour-based methods difficult.

In summary, there seem to be two categories of problems. First, the purely technical problems of low productivity, limitations of quality and high cost. There are then other problems which seem to have more to do with existing systems in the construction industry. Any successful programme will have to show that the technical problems can be solved and then demonstrate how the design, management, planning and administration of road construction projects could be made to include the effective use of labour-based methods.

Translating Theory into Practice

It was with the above concepts in mind that, under the World Employment Programme, the ILO launched a major investigation of the most appropriate techniques to be used in road construction.

As noted above, the main technical problems seemed to be productivity, cost and quality. The initial work was therefore concerned principally with these issues. A series of studies was initiated which attempted to provide some form of comparison between equipment-intensive and labour-based methods. The comparison was made with the use of cost benefit analysis. The analysis, however, used "shadow" prices which allowed for the distortion of market

prices and reflected social values placed upon the various resources. The studies in Iran (2) and Thailand (3) were therefore particularly concerned with the economic viability of the use of labour-based methods in road construction. Both studies indicated that these methods could be competitive; however, they also showed that their viability was particularly dependent upon the level of productivity. For instance, the study of the substitutability of labour for equipment on gravel road construction in Thailand (3) showed that the range of productivity increases required to make labour-based methods viable for all activities was 15-40%. Work carried out by the World Bank had already indicated that increases of this order were perfectly feasible given the right type of management and supervision (16). Recognising the importance of improved productivity, the study in the Philippines (4) was more concerned with the development of effective techniques than with the finer points of social cost-benefit analysis. The work done so improved productivity that, even using a cost comparison based on market prices, the labour-based techniques were cheaper.

In the first instance, therefore, the studies, carried out by the ILO and the World Bank, lead to the conclusion that the use of labour-based methods was technically and economically viable for a wide range of road construction activities.

The more recent work has indicated that even though labour-based techniques can be competitive, it is quite another problem to initiate their use on a large-scale. This is partly because of the inherent bias against their use by engineers themselves. There are, however, other basic difficulties in connection with management, administration, planning and organisation. The studies in Nepal (5), Pakistan (6), Kenya (7) and Guatemala (8) were particularly concerned with these issues.

The study in Nepal showed that the mobilisation and motivation of large labour forces required a type of planning and organisation structure significantly different from equipment-intensive projects. It also showed that the sequential method of working may not be appropriate for labour-based methods and that a more segmented approach may be better.

In Pakistan, the ILO was requested to advise on the possibility of using labour-based methods in the construction of the proposed 1220 km Indus Super Highway. Preliminary findings showed that it would be more feasible to think in terms of the most effective mix of labour-based and capital-intensive methods and a first step was made in preparing guidelines on how the planning for this might be done.

In Pakistan, it was more a question of how to improve the existing techniques and indicate how they might be used in conjunction with equipment. In Kenya, on the other hand, a study that originated as a feasibility study on rural roads has been transformed into assistance with the operational management of the Rural Access Roads Programme (RARP). This programme aims to construct some 12,000 km of rural road throughout Kenya. The methods used will be as labour-intensive as is commensurate with technical and economic efficiency. It is hoped that the lessons learned in the development of this programme can be applied elsewhere in similar situations. To a certain extent, this is already being done in Guatemala where assistance is being provided to the government in the implementation of a labour-based rural roads programme. Moreover similar programes are now being initiated in Ethiopia and Botswana.

Programes in the field can demonstrate the feasibility of using labour-based techniques. Nevertheless, to reach a wider audience, it is necessary to disseminate the information that has been gathered. The reports on Iran, Thailand, Philippines, Pakistan and Kenya provided the detailed information. The Manual on the Planning of Labour-intensive Road Construction (9) attempted to provide policy-makers and planners with a basic knowledge of labour-based methods. It is hoped that this will provide a detailed argument for the use of these methods and the foundation from which a choice regarding the most appropriate technology can be made.

In the following sections, the major aspects of appropriate road construction technology are discussed in detail; tools and techniques; appropriate design standards and the problems of project appraisal; a more detailed analysis of the planning, management and administration of labour-based programmes. Finally, some basic policy measures that could help the large-scale implementation of labour-based techniques are presented.

Tools, Equipment and Techniques

Most text books on construction management will almost certainly have a section on the choice and utilisation of construction equipment. A typical phrase from a well-known book (10) reads "correctly chosen and well operated plants will enable a construction project to be completed quickly and economically". Given that on a road construction project in the developed countries, equipment may account for upwards of 50% of the total cost, it is not surprising that so much attention is paid to this item. If the resource utilisation is changed, however, and it is labour which is the predominant cost item, then it is clear that much more attention has to be paid to their organisation and their level of productivity. On labour-based projects the choice of the right sort of tools is as important as the choice of the right type of machinery in a capital-intensive project (9). The cost of tools is not normally a major item even on labour-based projects, where they will account for 5-10% of the total. It is their effect on the productivity of labour, however, which is of particular importance. To the best of our knowledge, few detailed studies have yet been done on the difference in productivity for workers with "good" and "bad" tools. Nevertheless, all the experience reinforces the intuitive feeling that a well-designed, well-manufactured tool that is appropriate for the task increases the level of productivity.

Appropriate Tools

Much of the work carried out so far has shown that, as far as simple hand tools are concerned, the problems are principally to do with providing a reliable tool rather than providing an alternative. Attempts to introduce alternatives have generally met with failure partly because of unfamiliarity and partly because of a lack of understanding of social attitudes. The expertise and tradition of using traditional tools is not lacking. What is required is a range of shapes and configurations of blade to suit the soil conditions. It is known, for instance, that a fork-type blade is better suited to non-cohesive soils. Furthermore, we know that different shapes

of blade are more effective with hard and soft cohesive soils.

If money is to be invested in the use of labour-based methods it will be necessary to spend much more time in considering the most appropriate tools for the particular job in hand. A labourer is perfectly well aware of the most effective method of using traditional tools; what is needed is the most effective shape or type of blade and its manufacture to a reasonable standard.

In the consideration of appropriate tools, the first lesson to learn is that we must beware of imposing preconceived notions of what is the best tool for a particular job. Many of the basic activities of road construction and maintenance such as excavation, loading and spreading, have counterparts in agricultural work. The labourers employed for road construction will generally be quite familiar with the most appropriate tools. Simple expedients such as reinforcing the blade of the tool at critical points to make it more durable for heavy excavation work seem to be the type of improvements that would be most useful.

Appropriate Equipment

It is when the activities of workers become interdependent, such as in excavating and loading, or where the operations are markedly different from agricultural activities such as compaction, bitumen spreading or hauling with light equipment that there is scope for the implanting of new techniques or the modification of existing ones. Consider for instance the question of haulage vehicles. Wheelbarrows, small trucks on rails, headbaskets, animal-drawn carts are all in general use in agricultural work. However, in agriculture, they are used individually and they can often be improved in relation to the haulage of soil or aggregates (11). The wheelbarrow, for example, apart from being generally poorly manufactured is often also badly designed. Often, the weight distribution is wrong and the size and type of wheel is ill-suited to construction sites. Furthermore, the efficient use of wheelbarrows often requires a careful consideration of the balance between the loaders and the haulers.

Animal-drawn carts are often used in rural areas for the transportation of produce. The unloading is carried out by hand so as not to spoil the saleable goods. As far as the movement of soil in construction works is concerned, one of the main objectives is to unload the cart as fast as possible. Some system of tipping or bottom discharging would therefore have obvious benefits.

For long haul distances it may be appropriate to use trucks or tractors and trailers. The important point to mention here is that the integration of labour-based and equipment-intensive methods requires special care. It is of little value asking labourers to excavate and load in a similar fashion to machines. If they are asked to load into trucks or trailers, therefore, the height of loading must be appropriate and furthermore the size of the truck must not be so big that it requires such a large number of workers to load it that they are in each other's way.

The work carried out so far indicates that even for those road construction and maintenance operations which are not directly comparable to agricultural activities, it is possible to adapt and modify agricultural equipment to do these operations effectively.

Some Examples of Improved Tools and Equipment

The ILO studies in India (12), the Philippines (4) and Kenya (7) were particularly concerned with the improvement and adaptation of tools and equipment. To illustrate what can be achieved it is worth, briefly, looking at the results of these three studies.

In India, the work was particularly concerned with the wheelbarrow and small trucks on rails. Both of these are effective over short haul distances. What the ILO team did, however, was to show, by detailed testing and evaluation, the most appropriate design of both wheelbarrow and trucks which would maximise productivity. In the case of the wheelbarrow, it seems surprising that there was, and still is, such diversity of design. Particularly when the relative positions of the load in the barrow, the effort of the barrower and the wheel itself are vitally important. The trucks on rails had been used for carrying coal and so needed adapting for hauling soil and for manual loading by providing easier methods of pushing the trucks and reducing the height of the sides respectively.

The Philippines study was a particularly good example of intelligent adaptation. To allow easy unloading, the traditional bullock-drawn carts were modified to allow bottom discharge. The traditional 'Chinese scraper' was taken as a model for a factory-made steel version which was relatively cheap to produce but much more effective. To eliminate the need for a motor-driven water bowser a bullock-drawn version with the traditional cart now used to carry oil drums with a sprinkler device was developed. The study, therefore, illustrated the three aspects of equipment improvement. First, the modification of existing agricultural equipment to make it more effective for construction work. Second, the development and mass production on the basis of a traditional technique and third, the innovative adaptation of local materials to provide a piece of equipment which normally would have had to be imported.

In Kenya, the work again concentrated on wheelbarrows and it was possible to develop an efficient prototype. One aspect of the work was of particular interest. Many labourers preferred metal-handled wheelbarrows even though the wooden ones were more durable. It appeared that their preference was based on familiarity breeding contempt for the wooden option which was a material they knew well.

Procurement Systems

The provision of small hand tools and light equipment for a project using conventional equipment is of relatively minor importance. In a labour-based programme it is absolutely vital that the requisite number of small tools are provided in the right place at the right time, otherwise the work will stop. It will often be necessary to develop special procurement systems for labour-based programmes. Furthermore, the increased attention that has to be paid to well designed and well maintained tools will place a much greater emphasis on having well qualified personnel to direct the provision and procurement of tools.

Design

It is often said that labour-based methods are incapable of complying with accepted

standards of design. The general implication being that these methods are therefore inferior. The standard of design referred to, however, is one that is appropriate in developed countries. It would be better if we questioned the automatic acceptance of the appropriateness of these design standards to a developing country.

The Choice of Design

One can approach the question of design and the choice of construction techniques in two distinct ways.

First, and most commonly, it can be assumed that the design is fixed and it is merely necessary to choose the most effective construction methods.

Second, the design, either in terms of the pavement or the geometric alignment, is variable to allow the consideration of alternative construction methods. This may or may not also imply that the maintenance and operating costs are fixed.

Consider the first case: The road is designed on the basis of certain economic and engineering criteria. In the simplest terms, it goes from A to B and the route it takes will generally be governed by the economic objectives it hopes to achieve. The actual engineering standards of design will govern the type of pavement, the vertical and horizontal alignment and the structures required to carry the predicted traffic load. What does this mean in terms of the choice of technique? The pavement design will generally be based on practice originating in the developed countries. Consequently, a bias towards equipment-intensive methods can happen in one of two ways. First, it is, of course, possible to produce the required strength and durability by using different materials. The laying of certain materials, however, does not lend itself to the use of labour-based methods. It is, for instance, difficult to lay bituminous material this way; however, an effective alternative such as, for example, stabilised soil can be laid effectively using labour. The first point, therefore, is that care must be taken not to specify materials which limit the scope of labour-based methods unless there is no alternative. Secondly, there is a natural tendency, reinforced by developed country practice, for the pavement thickness to be as small as possible. Put another way, the compaction of the sub-grade should be as high as possible. Whilst compaction achieves a variety of objectives, it is possible to consider that there is some sort of trade-off between sub-grade improvement and pavement thickness. Effective compaction being one of the operations that is difficult to execute using manual methods, a reduction in compaction (i.e. equipment) cost may be justified if it is not more than offset by the increased material cost of extra pavement thickness. In the Manual (9) already referred to, an attempt has been made to quantify this trade-off. It should be recognised that, in the case of a fixed design, there is no question of affecting the recurring maintenance and operating costs. The suggestion is merely that the design, being fixed in relation to certain standards, should allow the use of materials which may be more suited to the use of labour-based methods.

The question of the level of design standards leads directly to the second case when the design is considered as variable depending upon the techniques involved. What is being suggested here is that alternatives should be evaluated not in terms of construction cost alone but in terms of total costs. That is, one may be prepared to accept a lowering of design standards, reflected in a reduction in construction costs, if the increased cost of recurrent maintenance and vehicle operation did not exceed the reduction. Naturally, one is thinking of modifying the design standards so as to make labour-based methods more attractive. For instance, it is often suggested that gradients should not exceed a certain value, say 6%. This may require heavy earthworks when traversing hilly terrain. A relaxation of the gradient limitation may allow the road to take a more direct route, reducing the earthworks which will reduce costs and allow labour-based techniques to be considered. Naturally, it would be necessary to assess whether the attendant increase in operating costs offsets the reduction in construction costs. Taking another example, the standards for minimum horizontal curvature are dictated by the design speed. A reduction in design speed would allow the road alignment to more easily follow the terrain contours, again reducing the level of earthworks and not only reducing cost but also favouring the consideration of labour-based techniques. In regard to design speed, it is in fact possible to quantify the relationship between design speed and construction costs for various types of terrain. Taken to its logical conclusion, the argument for choosing designs which minimise the total cost of construction, maintenance and operating costs could mean the actual change of route. If the direct route necessitated heavy earthworks, large structures and major rock excavation, it could be possible to use an alternative, more circuitous route, which minimises earthworks and structure, favouring the use of more labour-intensive construction methods. This could of course produce a change in economic benefits which would have to be considered in the analysis.

The evaluation of total costs would compare the present value of the maintenance and operating costs over the life of the road with the construction costs for each design alternative. The evaluation should also consider the question of whether the maintenance methods to be employed will be capital-intensive or labour-intensive as there would clearly be additional secondary benefits with the use of the latter.

In a limited way, the study in Kenya (7) attempted to assess whether the total cost of providing a gravel road in the initial stage was less than that of providing an earth road with guaranteed periodic maintenance.

Road Maintenance

A greater investment in road maintenance would have major benefits not only in deferring the reconstruction of the roads but also by conserving foreign exchange. Even in the developed countries, maintenance is a relatively labour-intensive operation. The operations are simple and can be efficiently carried out by manual methods. Even regrading can be done by animal-drawn scrapers or graders. On the other hand, many rural roads are built to a width greater than justified by the projected traffic flow to allow a mechanical grader to maintain it. This ignores the fact that there are labour-based methods available and also assumes that there will be a mechanical grader available to maintain the road.

For simple routine maintenance, the scheme of having a "maintenance man" or group has been used in many parts of the world. Supervised effectively, and provided the worker (or group) is given the right incentives, this can be very effective. It has the advantage that the responsibility for maintenance is easily defined. This means not only that there can be effective supervision, but that the local people also know who is to blame if the road is improperly maintained. Often the worker or group can be given a certain minimum kit of tools (wheelbarrow, pick and shovel) to execute the work.

One reason for the lack of emphasis on maintenance is its limited cost in relation to construction and vehicle operating costs. It is also true, however, that whereas a great deal of work has been done on quantifying vehicle operating costs, little attention has been paid to maintenance costs. There are probably as many maintenance costs formulae as there are countries in the world. Moreover, most of them are based on relatively poor data. Whilst it is our intuitive feeling that labour-based methods could and should be used in maintenance operations, it is clear that a more rational data base is required, so that the options can be quantified.

Project Appraisal

At some stage in choosing the most appropriate technology for a road construction project, it is necessary to make a cost comparison, for in the final analysis it is on the basis of cost, in its broadest sense, that the choice will be made. It is extremely important, therefore, that the cost estimates accurately reflect the use of resources.

Of the data required for a reasonable evaluation, two problems are of particular importance in developing countries : (i) unreliable statistical data, and (ii) use of inappropriate costing formulae, especially in relation to equipment.

The first factor is fairly common and the obvious remedial measure is the development of a reliable data base. In the case of construction costs, reliable data is particularly needed for the estimation of hourly costs for various types of equipment. One should beware of using the manufacturer's suggested unit costs, however, since conditions under which equipment is operated in developing countries are very much different from those in industrialised countries. The manufacturer's suggested unit costs are, in general, lower than those prevalent in most developing countries. One main reason for this is that equipment yearly utilisation rates are usually much higher in industrialised countries than in developing countries (9).

The use of inappropriate formulae also seriously affects the reliability of estimated costs. In particular, many contractors and public works departments make use of inadequate formulae for the estimation of equipment depreciation costs. Often, these formulae lower these costs, and therefore favour the adoption of capital-intensive technologies.

The Use of Accounting Prices

The studies in Iran, Thailand and the Philippines (2, 3, 4) involved the use of social or accounting prices. For those not familiar with this system, a brief explanation is necessary. For some time, economists have suggested that in developing countries the true scarcity or surplus of resources is not reflected accurately by their market price. In short, the cost does not reflect supply and demand. To counteract this distortion, a system of shadow or opportunity costs has been developed which more accurately reflects the costs of these resources to society. Many books and articles have been written on this subject and the calculation of these shadow prices is now well understood. In general, the shadow price of labour is lower than the market wage and the opportunity cost of capital is higher than the market rates of interest and foreign exchange. When projects are costed using these shadow prices the bias towards capital-intensive methods is removed and a true indication is given of the social feasibility of various alternative methods of construction. Put another way, it may be that labour-based methods are more costly when evaluated at market prices. However, if one then takes into account such factors as income distribution, employment and the relative values of consumption now against consumption at some later date, it is possible that these methods are socially more desirable. Naturally, even though project evaluation is carried out using shadow prices, the government still has to pay the market cost of the project. If a labour-based alternative costs more than the capital-intensive at market prices, it is then the government's choice whether the increase in employment and redistribution of income towards the lower paid justifies the payment of this subsidy. Social cost-benefit analysis merely quantifies the choice so that it can be used in more accurately evaluating the use of resources.

Project Management

The process of management consists of seven recognised processes which can be grouped under two main headings viz.: planning and executive functions. In very broad terms, the planning functions (forecasting, planning and organising) deal with material things whilst the executive functions (motivation, controlling and co-ordinating) deal with the human aspects of operations. The seventh process, communication, ties all the other functions together. One of the principal functions of management is to motivate the members of the organisation. In the industrialised countries, this generally refers to projects utilising large fleets of equipment. If one replaces the major pieces of equipment by large bodies of men then it is clear that a certain amount of re-thinking has to take place in relation to the various management functions defined above. The following sections discuss what reorientation may be necessary in the light of the seven basic management functions.

Forecasting

By clearly defining the objectives of the project in terms of progress, duration and quality it is possibly to specify in some detail the level of resources required at any particular time or location. This, of course, is a routine activity on any project. However, on a project involving the use of labour-based methods the forecasting function is given an additional role to play. It is first necessary to predict what

will be the demand for labour. As in the demand for equipment, this will be based on the level of productivity expected. In recent years, a sufficiently sound body of knowledge has been developed for estimates to be made for most labour-based construction activities. There are, in addition, various methods of making an assessment of productivity rates (9). Apart from the reliability of data, the problems of forecasting labour demand are not severe. Labour supply is more complex. At the project level, it is necessary to assess the availability of labour for each activity in relation to the seasonal fluctuations of labour supply and the demand of other projects in the area. The project manager must have a clear idea of the relative levels of labour supply and demand so that the detailed plans can allow for any shortfall in supply and either defer activities until there is sufficient labour or used equipment for these activities. In its broader sense, forecasting in the case of labour-based construction also means an assessment of the needs of the large labour force. The recreational, social, health and welfare facilities that must be provided need to be assessed at the initial planning stage. Moreover, the number of supervisory personnel required will have repercussions in relation to any existing training programmes.

Planning

One of the major problems of using labour-based methods in road construction is that the flow of work has to be relatively even and not subject to large or frequent changes. A relatively stable labour force is more effective because morale is not reduced by constant hiring and firing and because management problems are reduced. Further, delays in projects that are equipment-intensive can often be easily dealt with by bringing extra machines on to the site. This is, often, simply not possible with labour-based methods owing to the number of workers that are required to do the same work as a machine. It is imperative therefore that (i) the project is planned in such a way that the labour demand does not vary enormously and (ii) that there is an even flow of resources to the project. As far as an even level of output is concerned, there are of course various techniques such as critical path network, PERT, bar or Gantt charts or the more recent Time and Location Chart, which can be used to arrange the activities in the optimum way. Once the basic requirement of a relatively steady labour demand is specified, these techniques are then used in the normal way. These techniques can also be used to ensure the effective integration of labour-based and equipment-intensive techniques.

The even flow of resources to a project is perhaps more difficult to achieve because the project manager is dependent upon external factors. Nevertheless, it will be possible to assess what resources are required at any time during the duration of the project. Of specific importance is the supply of hand tools and any planning process should provide some indication, based on the life of each type of tool, of when deliveries will be required.

A planning system relies for its effectiveness on the reliability of the data used and the efficiency of the reporting systems which allow the system to be up-dated. A good planning system can provide the basis for effective control of the project. In the case of labour based projects, which are particularly dependent upon an even flow of output, a system which will ensure a steady flow of resources is vital.

Organisation

Having predicted the requirements and planned their use the next step, prior to implementation, is to provide an organisation structure capable of executing the project. It can be argued that if labour-based methods are to be used the whole organisation structure used for equipment-intensive projects must be changed. Whilst there is some evidence from China that this can work, it is certainly not yet proven in general. Our experience has been that what is required is an adjustment of the structure to take account of the fact that the main resource being employed is labour not equipment. This means that gang size and distribution is extremely important. So also is the question of whether the gangs are arranged along functional lines or whether each gang or group of gangs is given a certain section of the road to deal with. Equally as important as the balance and distribution of gangs however is the type and level of supervision. How many workers can one gang leader effectively control? How many gang leaders can one foreman direct? The organisation structure can be extremely important when motivation and co-ordination are considered. In the former case, the workers must feel that they are in touch with the project management and the objectives of the project. In the latter case, good co-ordination is a function of communication which, in turn, is dependent upon an effective organisation.

Motivation

If a large labour force is to be used it is of paramount important that they are motivated to achieve their potential in terms of output. It is fair to say that in most countries financial reward is the main motiviation for good performance. The ILO studies have clearly indicated that workers paid on a piece-rate system produce much higher output than under a daily paid system. The system of pay, however, if it is to be a good motivator must not only be fair but must appear to be fair. In the case of task or piece rate, the targets set must be scrupulously defined to ensure that there is no exploitation of the worker.

Money, however, is not the only motivator. A sense of belonging, good relations with fellow workers and adequate social and welfare facilities are others. A good project manager will ensure that all the aspects are well taken car of. Furthermore, the initial system of recruitment must be seen to be just so that there is no friction caused between the worker who receives a job and the less fortunate person who does not.

Controlling

In the discussion on planning, we noted that a good system will ease the problems of control. The physical and financial control of projects can be relatively simple as long as the original plan is constantly up-dated by means of data derived through an effective communication system. The supervisory staff must, therefore, be trained to provide clear and concise information

regarding attendance, output and future requirements. An effective communication system must exist which allows this information to be channelled to the project management for evaluation, decision and action. Not only will this ensure that the project is provided with the resources required at the right time, but also it will pin-point inefficient working or work that is behind schedule. This can be immediately investigated. In this way, a good control system can instill in the workers a feeling of participation.

Co-ordination

Labour-based methods require a greater number of supervisory staff. The methods may also be integrated with the use of equipment. To ensure that integration is possible and that the large labour force is working as a coherent mass, not as a set of independent units, it will be necessary to bring the supervisory staff together at regular intervals to discuss the work programme. This would also be the time when labour relations problems could be discussed.

Finally, no better summary of the problems involved can be provided than the words of a famous writer on construction management (10). "Not only is it necessary for a manager to be able to organise technologies but he must also be capable of organising individuals. He must be able to view the management activity as a whole and not from the bias of his own particular education and training. In the organisation of human beings, it is necessary for the manager to realise that improvements in the workers' physical and social conditions together with the sharing of a sense of participation in the enterprise are the two effective prime movers of effective performance."

Policies for larger scale implementation

In the previous pages, the problems of using labour-based methods in road construction have been discussed in detail. In the long term, one is concerned with the most appropriate use of resources in the construction of roads in the developing countries. The use of appropriate technology is not an emergency measure to counteract unemployment. The use of the most appropriate technology will automatically reduce unemployment because it will be using the available resources including labour, in the most appropriate manner. It is, therefore, not merely a question of providing a proper framework of design, planning and management. The long-term, large-scale implementation of appropriate technology in road construction, as in other sectors, will require that various policy measures are adopted in keeping with the shift away from the technologies which are patently inappropriate but for various reasons are presently preferred (13).

Fiscal Policies

In section 5, the use of social cost benefit analysis was discussed. This is a tool which can be used to take account of the distortion of market prices in developing countries. This distortion tends to favour capital-intensive methods. The use of accounting or shadow prices does not make any change to the actual prices, it merely takes account of the distortion to give a more rational allocation of resources. In the public sector, the assessment of the most socially profitable techniques can be made on the basis of the shadow price coefficients provided by a central planning agency. The manager in the public sector then executes projects up to the maximum number his market budget will allow based on the accounting prices. In the private sector, however, the use of social accounting would be extremely difficult to implement. It would definitely require some form of government intervention to ensure that the contractor perceives that there is no loss in profit if he uses the alternative technologies. In the long term, however, the use of these technologies should prove to be profitable and a great deal depends upon educating the private sector in the use of labour-based methods. The government can, however, take various financial and fiscal measures which would assist in the acceptance and implementation of appropriate technology in road construction. These range from the very simple to the very complex.

Surcharge - one very simple method for allowing for the distrotion of prices is to accept that it exists, to recognise that it favours equipment-intensive methods and to take the labour-based alternative where it is technically competitive as long as the market price is not more than a certain percentage more expensive than the capital-intensive methods. In the Philippines this has been done and labour-based methods are accepted if the increase in cost is not more than 10%. In a way, this is an implicit social accounting procedure as it implies that the distortion in market prices is of the order of 10%. This may seem crude and would, of course, require substantiation. However, given the complexity of the calculations to provide social prices it may administratively be the most acceptable.

Tariffs on imported equipment - in an effort to promote import substitution and to protect domestic consumer goods industries, many developing countries have adopted systems which provide high tariffs for consumer goods and low tariff rates for capital goods and raw materials. This has the effect of allowing the importation of construction equipment at low tariff rates and thus effectively distorting the real cost to the economy of using the equipment. There are various ways in which this problem can be solved. One is to provide discriminatory tariffs on equipment to be used on activities that can be carried out labour-intensively. This may be extremely difficult to implement in practice as a machine may carry out various functions some of which could not be done labour-intensively. An alternative is to make the importation of equipment dependent upon the provision of a licence which would be provided by the Government only after it was convinced that the equipment was needed.

Adjustment of the market rate of interest - many governments impose low ceilings on interest rates in order to prevent private banks from exploiting their monopoly power. However, if the capital market does not function properly low ceilings may have negative effects. Small investors are often unable to borrow money since the banking institution prefer to deal with the modern organised sector, where

risks of default seem to be lower. Under these conditions, large contractors can easily borrow money to import construction equipment, and find it profitable to do so since the low ceilings on interest rates result in a decrease in the equipment rental rate. In some cases, moreover, given high inflation rates, low ceilings on interest rates imply a negative real interest rate on loans, and imports of equipment and the adoption of capital-intensive technologies become even more attractive. The proper government policy if there are low ceilings on interest rates is to remove the ceilings completely or to set them at much higher levels. High ceilings on interest rates will lead contractors to think twice before asking for loans in order to import construction equipment, and may thus induce them to reconsider their position with respect to efficient labour-based technologies.

Taxation of owned capital equipment - a number of factors, including low ceilings on interest rates, difficulty of importing spare parts for construction equipment, and lack of proper equipment for repair and maintenance facilities, tend to make contractors import more pieces of equipment than may be stricly necessary in order to be sure that construction work will not be slowed as a result of lack of equipment. The government may put an end to this situation by imposing a tax on owned capital equipment. The cost of keeping construction equipment idle will therefore increase, and contractors will refrain from importing more equipment than is really needed. Furthermore, the imposition of such a tax will increase equipment rental rates. A tax on capital equipment is, however, difficult to administer. The government must annually assess the value of pieces of equipment at various degrees of depreciation. Needless to say, such an assessment is difficult to make and may lead to a large amount of litigation between contractors and the government. This type of government intervention is, therefore, not very practical and should not be attempted unless other types of action are politically or economically infeasible.

Wage policies - The question of the most appropriate measures in relation to wages is perhaps the most difficult of all. This is partly because the difference between the market and shadow wage is often so marked. Other issues such as minimum wage legislation and trade union activity also have an effect.

Action in relation to wages is often seen as an effective way of favouring labour-based methods. All too often, however, the action is counter-productive because it directly interferes with market supply and demand. For example, the use of wage subsidies has been advocated. In its simplest terms this is the payment, by the government, to the contractor of a subsidy for each man-day of unskilled labour used on a project. Unfortunately, the result of this is that the contractor can continue to use capital-intensive methods, the increased labour force stands and watches, and the contractor pockets the subsidy (14). It is not sufficient to make it financially feasible for contractors to use methods which require more labour. They must also be convinced of the technical and managerial efficiency of these methods.

Finally, in regard to fiscal policies, a comment from the Iran study (2) is particularly apt. "The argument concerning the relative merits of specific tariffs, quantity restrictions and wage subsidies does not turn on any simple notion of economies in government finance. The issue is basically one of ease of administration and relative efficiency of the set of measures adopted. Tariffs or quantity restrictions would appear to have a certain appeal as they are more easily administered than a direct wage subsidy. By themselves, however, they will not guarantee the adoption of appropriate technology. In the final analysis it will be the practitioners who choose the technology and any fiscal measures must go hand in hand with the appreciation of the technical feasibility of using appropriate technological methods."

Policies on standards and specifications

The ILO's employment strategy mission to Sri Lanka noted that "the problems in the construction industry were aggravated by the stolid enforcement of regulations, professional codes of practice or contractual procedures, the inadequacies of which have long been recognised in the very industrialised countries from which they were copied; copied moreover in the face of unquestionable evidence of their ineffectiveness in local conditions". The situation in Sri Lanka is probably no different from that in many other developing countries. The unsuitability of European standards and specifications is most blatantly illustrated by such examples as the application of snow-loading criteria for roof construction in tropical Africa. Less obvious, but more common, however, is the specification of materials, methods of working and testing procedures which would be perfectly appropriate in Europe and North America but not in the developing countries.

There is no suggestion here that the systems and procedures used in the construction industries of developed countries are inefficient. Within their own environment, they are generally effective. To expect them to work as efficiently in an environment where the basic economic situation is totally different, where the administrative systems are limited and where the information flow to the local construction sector is poor, is somewhat optimistic. The basic dichotomy in construction caused by the division of responsibilities for design and construction becomes an even greater problem in countries where contractors lack even the basic financial and managerial expertise.

In regard to specifications and codes of practice, therefore, governments need do no more than make an investigation of whether they are orientated towards the environment in which they are supposed to operate.

As regards methods of tendering it is clear that certain aspects of the tendering procedures are biased towards the use of equipment. One can think of the selected tender where only those with, among other things, a minimum plant holding will be eligible to tender. As far as government is concerned, what is recommended is a more flexible approach to tendering procedures. These procedures were developed in the industrialised countries where there is an inherent tradition of contract responsibility and where the design, construction methods and procurement of materials are already institutionalised. They may apply also to vast development projects: however, it would be surprising if they are wholly appropriate to construction industries whose members have extremly limited financial and managerial resources.

The influence of foreign consultants and contractors

If one accepts that infrastructure development is vital to economic development, it almost goes without saying that this implies some form of foreign involvement in the construction industry. This may merely be in the form of feasibility studies or managerial assistance. More commonly, it will involve the use of foreign consultants and contractors. Properly arranged, their involvement can be mutually profitable. Unfortunately, certain conflicts often present themselves. As the ILO's study in Iran showed (2), foreign firms will draw their technology from an international market in whcch innovation has consistently moved in the direction of equipment-intensive methods. As the consulting engineer is often involved at the feasibility, design and supervision stages, the technology used is dictated by his expertise and background and all too rarely by a detailed consideration of the most appropriate resource allocation. In addition, one has a contractual system based on the industrial country practice, and a contractor who, if not foreign or foreign-owned, will have been schooled in the efficient use of equipment; it is not surprising therefore that the technology chosen is capital-intensive.

The use of foreign expertise in the development of a country's infrastructure is a fact of life and has many beneficial effects. Properly handled foreign firms can be a great asset in assisting in the growth of the local construction sector. It would be wrong, however, to view the activities of foreign firms in any philosophical way. Principally, their object is to make a profit. Whilst governments should support this objective it should also ensure that profit is generated in a beneficial way for the country. This means that when the government, as a client, hires a consultant to carry out a feasibility study for a road project, it makes it quite clear that the study should assess the construction technology to be used. It means that in its dealing with foreign contractors it should insist that labour is used to the fullest extent compatible with technical and economic efficiency whilst the importation of equipment is kept to a minimum. Governments can also take measures to support the growth of local contractors. This can be done not only by preferred treatment but also by putting money into training courses on financial management, administration and the most appropriate construction techniques. In the long term, each developed country must have a viable domestic construction industry, whether public or private,for its own economic stability.

Training and Education

The use of labour-based technologies would require managerial and supervisory skills significantly different from those required for equipment-intensive techniques. In addition, the education of engineers would have to place much greater emphasis on the use of appropriate technology. These two separate but interdependent issues are of vital importance. For, if one cannot convince the practitioners, and if one does not have the requisite level of supervisory staff, the use of construction methods which rely heavily on labour will be merely an interesting idea.

As far as training is concerned, it is still not clear whether it is better to have separate training courses for labour-based programmes or to attempt to integrate this training into the normal curriculum for foremen and supervisors. What is clear is that labour-based methods do require a higher degree of supervision than machine-intensive projects and thus governments will need to invest heavily in training.

As far as education is concerned, it has been recognised for some time that the civil engineering courses of many universities in developing countries appear unrelated to the environment in which the engineer will work. They tend to be carbon copies of courses in developed countries and the suggestion that they should be re-orientated to the needs of the developing countries is often interpreted as being requests to turn back the clock. However the developed countries use capital-intensive technologies because they are rich; they are not rich because they use capital-intensive technology. There is, of course, a need for engineers to understand sophisticated techniques and analysis. Indeed, these are vital to the effective management of labour-based schemes. There is also an onus upon civil engineering faculties to provide courses which will give students the capability to make the most appropriate use of the resources at their disposal.

At the end of a fairly detailed coverage of the problems of the most appropriate technologies in road construction the overall problem of what are the required policy measures for large-scale implementation appears particularly broad. In general, however, what is required is a flexibility of approach, firm direction and support from the highest level and motivation for all concerned in the road construction process so that the most appropriate methods in terms of resource allocation are also the most efficient in the execution of projects.

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References

1. IBRD. Study of the Substitution of Labor and Equipment in Civil Construction. Phase 1. IBRD, 1972.
2. G. Irvin et al. Roads and Redistribution. ILO, Geneva, 1975.
3. W. McCleary et al. Equipment versus Employment. ILO, Geneva, 1976.
4. Deepak Lal et al. Men or Machines. ILO, Geneva, 1978.
5. H.C. Rieger and B. Bhadra. Comparative Evaluation of Road Construction Techniques in Nepal. CEDA, Kathmandu, 1978.
6. ILO. Study of the Use of Labour-Intensive Methods for the Indus Super Highway (mimeograph) ILO, Geneva, 1976.
7. ILO. The Implementation of Appropriate Road Construction Technology In Kenya (mimeograph), ILO, Geneva, 1976.

8. R. Salas Rico. Proyecto de Evaluacion de la Factibilidad de Utilizar la Mano de Obra Campesina en la Construccion de Caminos Rurales en Guatemala. Guatemala, 1978.
9. M. Allal and G.A. Edmonds. Manual on the Planning of Labour-Intensive Road Construction. ILO, Geneva, 1977.
10. R. Pilcher. Principles of Construction Management. McGraw Hill, London, 1976.
11. I. Barwell and J.D.G.F. Howe. Equipment for Labour-Based Road Construction. W.P. 40. Technology and Employment Programme (mimeograph). ILO, November 1978.
12. ILO. Men who Move Mountains. ILO, New Delhi, 1963.
13. F. Stewart. Technology and Underdevelopment. Macmillan, London, 1977.
14. ILO. Employment, Incomes and Equality in Kenya. Geneva, ILO, 1972
15. ILO. Matching Employment Opportunities and Expectations. ILO, Geneva, 1971.
16. IBRD. Study of the Substitution of Labour and Equipment in Civil Construction. Phase II. IBRD, 1975.