Labour-Intensive Methods in Low-Cost Road Construction: a Case Study

How an initially highly mechanised project had to resort to more and more labour-intensive methods

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THE WORLD EMPLOYMENT PROGRAMME recently launched by the ILO has brought into sharper focus an issue that has preoccupied the Organisation for many years: labour-intensive methods in public works and construction in developing countries. This has been the subject of research and discussion, and technical meetings [2] convened by the ILO have made a number of far-reaching recommendations, yet many developing countries have been reluctant to adopt labour-intensive methods as a declared policy. This is very understandable since in the course of development such technology is bound to be superseded by the use of capital-intensive methods, and it may not seem very progressive to ask men to carry out burdensome physical work if it can be avoided.

Nevertheless, opportunities for productive employment for millions of people are lagging behind demand owing to shortages of capital for productive investments and to the rapid growth of the labour force in these countries. Precisely because capital is so short and unskilled labour so abundant it seems advisable to use such labour to the extent feasible in capital construction projects. As part of the World Employment Programme the ILO is therefore launching a major programme for the development of efficient labour-intensive techniques in public works and

[1] International Labour Office.

[2] Technical Meeting on Productivity and Employment in Public Works in African Countries (Lagos, December 1963): see " Economic development, employment and public works in African countries ", in *International Labour Review*, Vol. 91, No. 1, Jan. 1965, pp. 14-46; and Technical Meeting on Productive Employment in Construction in Asia (Bangkok, October-November 1968): for the report, papers and conclusions see ILO: Management Development Series, No. 8 (Geneva, 1969).

construction, especially directed to countries with vast programmes of infrastructure development.

The present case study is a modest contribution towards that aim. It is a record of a road construction project which ran into almost every obstacle that typically besets most bigger public works in developing countries. The exact location of the project is of no importance. Suffice it to say that it was carried out in a remote region of subtropical Africa. I was resident engineer in charge of the project.

The project

Objectives

An existing dirt road of 480 kilometres in length, which was closed repeatedly during the rainy season and difficult to pass for ordinary vehicles even in the dry season, was to be made into an all-weather gravel road.

The requirements were to provide—

(a) a compact gravel surface, averaging 12 centimetres in thickness and 6 metres in width;

(b) drainage works consisting of culverts and ditches;

(c) bridge constructions at some twenty sites;

(d) realignments to eliminate dangerous bends.

The project was planned by the Public Works Department headquarters. To start with, it was recommended that a foreign contractor should do the work, but for political and financial reasons PWD was told to carry out the project itself, i.e. acting as its own contractor.

Staff

The only person available to take charge of the project was a young, inexperienced civil engineer attached to PWD under a bilateral agreement (the writer). To assist him the following staff were planned:

- — a technical assistant (who never arrived);
- — a laboratory assistant (who never arrived);
- — an inspector of roads (who never arrived; instead an assistant inspector of roads arrived four months after the start of the project);
- — five sub-inspectors of roads;
- — a mechanical inspector (who never arrived);
- — four mechanical foremen (of whom only one arrived).

Equipment

The project was planned as a highly mechanised one, copying the methods of a foreign contractor operating in the country on similar projects. The following vehicles and plant were planned, most of which were not available in the country for this project and had to be purchased. Four construction units were envisaged, each composed of:

— ten 5-7-ton tipping trucks;
— one D4 or D7 bulldozer;
— one excavator, rubber-tyred, with hydraulically operated shovel;
— one motorgrader with hydraulic steering;
— two wobbly-wheel rubber-tyred rollers, towed by
— two tractors (agricultural type);
— two waterbowsers on long-wheel-base trucks;
— one water pump;
— one small car for supervisors;
— one small workshop-van, equipped with tools;
— one long-wheel-base truck.

Transport of equipment to the site

Nine months after the start of the project the last equipment arrived at the site. This was due to delay in importation and to the fact that the site was 1,000 kilometres distant from the import harbour. For the last 200 kilometres the heavy equipment had to " walk " its way down a dangerous escarpment. In the attempt to bring a bulldozer down on a low-loader, the latter turned over and the bulldozer rolled down a ravine. Two trucks turned over as well, one of which is probably still lying there.

Operators and drivers

As it turned out these delays were not as serious as they might have been since very few trained operators and drivers were sent to the project. Most of them had to be trained on the site. To operate the heavy plant the best truck drivers were selected, and for the trucks almost everyone who could produce a driving licence had to be employed. The biggest difficulties were experienced with the hydraulic excavators, as these were completely new to the country. Finally, after several requests, an instructor arrived from Europe and stayed for five days.

In the course of the project the machinery frequently broke down, some of it beyond repair, and this too " eased " the situation regarding operators and drivers, as the few good operators could be shifted from machine to machine.

Maintenance and repair

As a single mechanical foreman had to act as mechanical inspector, only now and then helped by a visit from the PWD regional mechanical inspector, the management of this most important aspect of the project was really poor. Responsibility had to be delegated to ordinary mechanics, who for the first time were called upon to assume responsibility for more than their own work. This was the main reason for the low utilisation of equipment discussed later. Here again the hydraulic excavators were the biggest problem, as no one had experience with this new and highly sensitive piece of equipment. The supply of spare parts was an almost insuperable problem because of the cumbersome procedure for ordering new items, coupled with long delays in delivery. The situation was saved by the fact that several parts could be cannibalised from broken-down machines.

Supply of fuel and lubricants

At first diesel oil and petrol were brought to the site in drums, but later fuel-tanks were installed at various places. Especially in the rainy season very long delays in delivery were experienced and most of the machines were often standing idle for days. This could be traced back to poor management of stores, but frequently also tankers got helplessly stuck on the way to the site. The machinery required a wide variety of lubricants. The need of the different hydraulic systems, in particular, for special oils was only much later really understood and satisfied.

Planned execution of the project

Having described the project in general terms, I shall now show how it would have been carried out if it had gone according to plan. To simplify matters, the main objective of the project—to provide the road with a compact gravel surface—will be examined, to the exclusion of the other three objectives (drainage, bridges and realignments), each of which could form the subject of a separate study.[1] It should be borne in mind, however, that these operations had to be carried out parallel with the main operation, with the same staff and equipment.

The gravelling operation (capital-intensive)

It will be necessary to break down the gravelling into separate operations, showing how these would normally be executed if no considerable snags were encountered. They form a logical sequence of works, which should be simple to understand for non-engineers.

(a) *Opening a quarry.* When a gravel deposit is found with the right content of coarse and binding material a quarry is opened by using a bulldozer to clear the bush and to scrape the first useless layer of earth

[1] Such studies would result in considerations and recommendations very similar to those put forward here.

away. Six workers assist this work, and the operation normally lasts 2 days.

(b) *Clearing the road.* At the same time a motorgrader is clearing the road of old sand or dust, and shaping up the sub-base, at a rate of 10 kilometres a day. This operation also requires 12 workers for 2 days to shovel the sand completely off the road.

(c) *Excavating and loading.* Upon completion of *(a)* an excavator starts excavating and loading gravel on to the trucks. Whenever the gravel is very hard, excavation is aided by a bulldozer heaping up the gravel. Six workers assist this job; 225 loads are needed for 1 kilometre of road and this takes the excavator 16 hours. During the same period the bulldozer assists for 8 hours.

(d) *Hauling and dumping.* The trucks then haul and dump the gravel on the cleared road, leaving stacks of approximately 4 cubic metres at short intervals along one side of the road. Six workers have always to be at the dumping site for various reasons.

(e) *Spreading and shaping.* With approximately 5 kilometres of stacks in place, the motorgrader can move in and start spreading the gravel until it has the desired thickness and shape. One day is required for 5 kilometres.

(f) *Watering.* At the same time waterbowsers are sprinkling the gravel to give it the right moisture for the next operation.

(g) *Compacting.* This is done by rollers towed by tractors. Assisting operations *(e)*, *(f)* and *(g)* are 12 workers.

Direct operational cost (capital-intensive)

Assuming that—

(1) everything is working according to the above plan;

(2) normal working hours are 7 per day [1];

(3) hire charges on equipment include operators' wages, fuel, normal maintenance and depreciation;

(4) the distance between quarries is 10 kilometres; and

(5) water is available every 10 kilometres;

the direct operational cost of 1 kilometre of road under ideal circumstances can be calculated as shown in table I.

Utilisation of equipment

With the highest possible utilisation of equipment as described above, 1 kilometre of road can be gravelled in 2.3 days. However, allowance

[1] In fact overtime and shifts were often worked.

TABLE I. DIRECT OPERATIONAL COST OF 1 KILOMETRE OF ROAD: CAPITAL-INTENSIVE METHOD

Operation	Machines and men needed	Unit cost in US dollars	Units needed	Cost of work in US dollars	Work accomplished	Total cost in US dollars	Cost per km in US dollars
(a) Opening a quarry	1 bulldozer 6 workers	8.4/hour 0.66/day	14 hours 2 days	118 8	Quarry for 10 km	126	12.6
(b) Clearing the road	1 motorgrader 12 workers	6.8/hour 0.66/day	7 hours 2 days	48 16	Clearing of 10 km	64	6.4
(c) Excavating and loading	1 excavator 1 bulldozer 6 workers	8.4/hour 8.4/hour 0.66/day	16 hours 8 hours 2.3 days	134 67 9	225 loads for 1 km	210	210.0
(d) Hauling and dumping	6-10 trucks 6 workers	0.2/km 0.66/day	1 200 km 2.3 days	240 9	225 loads hauled	249	249.0
(e) Spreading and shaping	1 motorgrader	6.8/hour	7 hours	48	Shaping of 5 km	48	9.6
(f) Watering	2 waterbowsers	0.2/km	200 km	40	Watering 5 km	40	8.0
(g) Compacting	2 tractors with rollers 12 workers	0.15/km 0.66/day	100 km 1 day	15 8	Compacting 5 km	23	4.6
Total cost per km . . .	—	—	—	—	—	—	500.2

must usually be made for unavoidable delays of all kinds, and a reasonable rate of utilisation would be approximately 80 per cent, reducing the operational speed to 1 kilometre in 3 days. The actual percentage of utilisation of the equipment was never calculated exactly, but varied between 30 to 70 for the reasons already described.

The bottleneck in the sequence of operations was the excavation and loading operation, the excavator not being able to produce more than 15 loads per hour even when fully utilised. The actual percentage of utilisation of the excavator was about 40, with the result that the utilisation of some of the other machines was further lowered, though they were serviceable, in some cases to less than 40 per cent.

Actual execution: workers start supplementing the machines

Whenever a gang of workers had to be employed on any section of the project, usually up to one hundred people would stand and wait to be selected. There were always many onlookers. We therefore started employing some of these people to load the trucks whenever the excavator broke down, and sometimes kept most of them when the machine started loading again, as this gave a considerable increase in speed of operation.[1]

Encouraged by this result, we devised methods of substituting labour for other equipment when necessary; we found that all the operations, except hauling (with trucks) and watering (with waterbowsers) could be accomplished entirely by labour-intensive methods. Though the quality of the finished road would be lower as a result, it could be made satisfactory provided that the motorgrader and roller were " run over " the road, say one month after completion.

The gravelling operation (labour-intensive)

Although the highest possible extent of labour-intensiveness was never applied in all the operations at the same time, every separate operation was from time to time carried out as described below.

It was possible to employ enough people on the different operations to ensure the same theoretical speed as with capital-intensive methods, i.e. 1 kilometre in 2.3 days.

(a) *Opening a quarry.* Twelve workers could make an ordinary quarry ready for exploitation in 12 days, with the help of an agricultural tractor for 2 days. There was no very great time pressure on this operation.

(b) *Clearing the road.* In 2 days 12 workers could clear approximately 3 kilometres of road. They were not able to do this as thor-

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[1] The number of available trucks then became the limiting factor, constituting a bottleneck that could not be " widened " since there was no way of using labour-intensive methods to haul gravel over a distance of several kilometres.

oughly as the motorgrader, but the gravel to be applied afterwards could be adjusted to suit the content of sand and granular material left on the old road.

(c) *Excavating and loading*. As mentioned above, workers were employed on loading the trucks. The target given to the loading gangs was 1 load per man-day. If the quarry was big enough 100 men could be employed at the same time and thus give the same output as the excavator. If the bulldozer was not available we added 50 workers and could keep the output the same. The daily average productivity of 1 worker excavating and loading was then 2.7 cubic metres a day.

(d) *Hauling and dumping*. As already mentioned, there was no way of replacing the trucks by labour for hauling and dumping.

(e) *Spreading and shaping*. With careful supervision 18 workers could spread the gravel as soon as it was dumped on the road, the material being dumped from the tipping truck not in stacks but while it was slowly moving to facilitate the spreading. It can be seen that 18 workers could replace 1 motorgrader in this operation since, although the grader covered 5 kilometres a day and the workers only 0.45 kilometre a day, the grader was operating at too fast a pace in relation to the excavating and loading operations.

(f) *Watering*. The waterbowsers could not be replaced by labour. In exceptional cases, when light rain fell, this gave adequate moisture to the dumped gravel and the waterbowsers were not needed anyway.

(g) *Compacting*. Preliminary compaction could very well be obtained by using the traffic on the road, including the trucks on the job. Of course careful direction of the vehicles was necessary, as it was not always easy to persuade a driver to drive on the " soft " part of the road; but the work was quite successfully done. For the following 2 days 6 workers had to stand by on the newly completed road to fill in the ruts made by the heavy trucks and to direct the traffic.

(h) *Finishing*. An additional operation had nevertheless to be carried out in order to ensure a satisfactory finish following operations *(e)*, *(f)* and *(g)*. A motorgrader followed by 3 waterbowsers and 2 rollers was sent out to give the road surface the right shape and final compaction; 15 kilometres could be completed in 1 day.

Direct operational cost (labour-intensive)

Given the highest possible labour-intensiveness, and on the same assumptions regarding working hours, hire charges and availability of gravel and water as in the case of the capital-intensive method, the direct operational cost of 1 kilometre of completed road can be calculated as shown in table II.

TABLE II. DIRECT OPERATIONAL COST OF 1 KILOMETRE OF ROAD: LABOUR-INTENSIVE METHOD

Operation	Men and machines needed	Unit cost in US dollars	Units needed	Cost of work in US dollars	Work accomplished	Total cost in US dollars	Cost per km in US dollars
(a) Opening a quarry	12 workers 1 tractor	0.66/day 10/day	12 days 2 days	95 20	Quarry for 10 km	115	11.5
(b) Clearing the road	12 workers	0.66/day	2 days	16	Clearing of 3 km	16	5.3
(c) Excavating and loading	150 workers	0.66/day	1 day	99	100 loads for 0.44 km	99	223.0
(d) Hauling and dumping	6-10 trucks	0.2/km	1 200 km	240	225 loads for 1 km	240	240.0
(e) Spreading and shaping	18 workers	0.66/day	1 day	12	Spreading 0.44 km	12	27.0
(f) Watering	2 waterbowsers	0.2/km	40 km	8	Watering 0.44 km	8	18.0
(g) Compacting	6 workers	0.66/day	2 days	8	Stand by 0.44 km	8	18.0
(h) Finishing	1 motorgrader 3 waterbowsers 2 tractors with rollers	6.8/hour 0.2/km 0.15/km	7 hours 150 km 120 km	48 30 18	15 km completed	96	6.4
Total cost per km .	—	—	—	—	—	—	549.2

Comparison of methods

The direct operational cost of the original planned capital-intensive method can now be compared with that of the hypothetical most labour-intensive method. To facilitate this, the detailed calculations shown in tables I and II can be summarised in the form of a breakdown of input factor costs. The total man-days of work created by the two methods are also shown in table III.

TABLE III. BREAKDOWN OF INPUT FACTOR COSTS AND NUMBER OF MAN-DAYS OF EMPLOYMENT CREATED UNDER THE TWO METHODS

Factor	Capital-intensive method		Labour-intensive method	
	US dollars	Percentage	US dollars	Percentage
Capital (maintenance and depreciation)	383.2	76.5	210.4	38.2
Material (fuel and lubricants)	57.0	11.5	32.0	5.8
Labour (including operators and drivers)	60.0	12.0	306.8	56.0
Total direct cost per km of road . . .	500.2	100.0	549.2	100.0
Total man-days of work created per km (unskilled labour)	34		428	
Capital required to create one man-day of work per km (US dollars)	11.25		0.49	

Note: It is presumed that 8 per cent of the hire charges on the machines goes to operators, and 12 per cent to fuel and lubricants.

The figures in table III show total direct costs of approximately US$500 per kilometre against US$550, making the labour-intensive method 10 per cent dearer than the capital-intensive. It should be repeated here that the operational speed assumed for the calculation of these costs is the same in the two examples. In actual fact the operational speed of the capital-intensive method was only 40 per cent of the theoretical speed owing to low utilisation of the excavator. That of the labour-intensive method, on the other hand, was kept up to 80 per cent of the theoretical speed and was thus twice that of the capital-intensive method.

Allowance is made for low utilisation in the hourly hire charges of equipment. But for a fair comparison the effect of the difference in speed on *indirect* operational costs (administration, management, etc.) must also be calculated. The economic cost of delays in opening the road should likewise be taken into account. Unfortunately these effects were never calculated and cannot be reconstructed since, it must be remembered, the project involved other operations as well. Suffice it to say that the indirect costs and the cost of delays, both of which are reduced by rapid execution of the project, have the effect of narrowing the cost difference between the two construction methods considerably.

So far we have been discussing only the money cost of the project. If the analysis went further and used opportunity costs or shadow prices [1] and took the social benefits of employment creation into account, the comparison would clearly come out in favour of the most labour-intensive method.

The optimum balance

In order to simplify the analysis we have been comparing the " most " capital-intensive with the " most " labour-intensive method. But more detailed study of the methods reveals that there are strong arguments in favour of a blend of these two methods.

It will be seen that the operational cost of the last operations (spreading, watering and compacting) shows a big difference: US$22.2 per kilometre capital-intensive against US$69.4 labour-intensive. The fact that the grader, bowsers and rollers are needed in both cases also indicates that this part of the work should be done by capital-intensive methods. If, therefore, operations *(d)* to *(g)* were done capital-intensively and operations *(a)* to *(c)* labour-intensively, we would have a third " method " which might be named the " optimum balance " method (this method would not use either the excavator or the bulldozer). The total direct operational cost per kilometre using this method would be US$511. Unfortunately this is not the whole truth because, if the grader were not used elsewhere, it would be standing idle for something like 90 per cent of the time.[2] Allowance for such a low utilisation is not included in the quoted cost per kilometre under the capital-intensive method.

The reader will realise that such reasoning could soon lead us into extremely complicated considerations. Let us just say that an optimum balance method would in most cases maximise both economic outputs and productive employment creation. Careful use of network planning [3] can shed much light on the possible combinations of input and output.

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[1] That is, hypothetical prices for the factors of production that would bring supply and demand of each factor into equilibrium under conditions of perfectly competitive factor markets. In developing countries the market price of unskilled labour is higher, and that of capital lower, than such shadow prices reflecting their real scarcity would indicate.

[2] Here is a typical example of the most labour-intensive method (shaping the road by shovels) not being able to give a satisfactory technical finish to the work, and the most capital-intensive method (shaping of the road by motorgrader) being so to speak " too effective ". An intermediate technique should thus be sought. In fact such a technique exists in the form of a very simple mechanical grader, towed behind an agricultural-type tractor. Moreover, such a " tow-grader " can quite easily be produced locally.

[3] See appendix.

Management of the bigger labour force

It must be admitted that managing the bigger labour force gave us many problems.

Housing and camp organisation fortunately raised only minor difficulties as most of the unskilled workers lived in their own villages and were picked up every morning. Only the drivers, operators, mechanics and certain others, numbering about thirty in all, were housed in camps. From time to time even this gave rise to problems enough to suggest what great difficulties we would have had if 200 more persons had had to be provided with living accommodation.

Supply of foodstuffs was solved by having a truck sent to the nearest town every week. The prices rose slightly as a result of the bigger demand, but the regional authorities stepped in with price controls. We noticed that, when the first month's wages had been paid and the workers had had an opportunity of getting supplies from the town, they were able or at least more willing to raise their daily output to a reasonable level.

Camp dispensaries were set up, but lack of medical supplies very quickly became serious. Adequate supplies would have been a great help, firstly of course in respect of physical welfare, but secondly because of their psychological effects. Some malaria pills were obtained from a mission and given to one unit working in a difficult area; though this medicine was not sufficient to cure the sickness, it gave the labourers the impression of being cared for and thus improved their willingness to work.

This brings me to the biggest question when dealing with labour-intensive methods: willingness to work. The wages sufficed to ensure an adequate supply of job applicants, but were not enough to motivate the workers to produce as much as could reasonably be expected.

Lack of experience of how much daily output could be expected of one man got us off to a bad start, as task standards were first set too low. With simple work study techniques these standards were raised to the point where the workers did not feel that they were being asked to produce more than to start with. Even higher output was experienced from time to time, but it was almost impossible to introduce task standards corresponding to such higher output. This could have been done if ways and means of improving willingness to work through a system of incentives had been at hand. First and foremost, bonuses for higher output could have been a considerable incentive, but the government regulations had to be followed, and one day's wage (US$0.66) had to be paid for one day's work almost regardless of how much was produced.

Better over-all management and sufficient trained supervisors would have given every worker the impression of good order and organisation, and a feeling of being respected and cared for. As it was, considerable results were achieved by delegating authority and responsibility to gang leaders and headmen; without this, indeed, the whole operation would have been impossible.

A foreign contractor steps in

As explained, progress for many reasons was slow. After ten months only 50 per cent of the job was completed (240 kilometres). Since only twelve months had been envisaged for the whole operation, the foreign contractor already mentioned in co-operation with a foreign consultant engineering company was asked to move in and assist completion of the road. This gave us the opportunity to study his methods closely. More and bigger machinery was used. All machine operators, except for the truck drivers, were Europeans, as were mechanics and supervisors down to the level of road foreman. The contractor had his own spare part supply organisation, and spares were sometimes flown in direct from abroad. He also had his own fuel supply. Operational speed was about three times ours. Cost per kilometre was unfortunately never revealed to us, but certain facts can be noted. On the one hand the road was made relatively quickly, and the quality of work was slightly better. On the other—

(a) very little employment was created (the contractor even brought in most of his food supply);

(b) there was practically no on-the-job training for the local people;

(c) all machinery was withdrawn after completion of the work;

(d) the local people were left with the feeling that the road did not belong to them, which presumably gave them little motivation to maintain it in good repair;

(e) although the cost of construction and the contractor's profit are not known, it is evident that the contractor and consultant must have been paid almost entirely in scarce foreign exchange, and that most of this left the country.

Conclusion

The project as planned may be said to have been too capital-intensive for various practical reasons, including inadequate management and supervision, and shortage of qualified operators and maintenance staff. As a result, we were obliged to improvise, making the best of what came to hand. In view of the difficulty of using much of the more sophisticated equipment provided, we adapted the planned techniques for each operation to the resources available, making much greater use of abundant unskilled and semi-skilled labour and adopting more labour-intensive methods than had been envisaged. Much could have been saved, including the purchase of some of the expensive equipment, and perhaps also the assistance of the foreign contractor, if this had been foreseen and allowed for in the plan of operation.

Basically the project suffered from poor planning. Not enough consideration was given to choosing the appropriate techniques. The direct transfer of methods suitable for industrialised countries to a developing country with quite different socio-economic conditions (including factor endowments) was a mistake.

When deciding on the techniques that will be most appropriate for a particular project in a developing country, it is important to take account not only of the technical characteristics of the project but also of the socio-economic conditions in which it will have to be carried out. These conditions naturally vary from one case to another, and I shall attempt here only to suggest a check-list of the considerations to be borne in mind as a guide to project design in a wide variety of circumstances. These, apart from the purely technical features of the project itself, are as follows:

(1) What equipment is available, where else will it be needed and what state of repair is it in?

(2) What is the hire charge of the equipment, using the best estimate of the " shadow " interest rate and realistic depreciation rate? What will be the utilisation rate of each piece of equipment?

(3) How accessible is the project site? How long will it take to bring in heavy equipment?

(4) Are there adequate supplies of spare parts and fuel?

(5) Are experienced equipment operators and drivers available?

(6) Is there a readily available supply of unskilled and semi-skilled labour? How great is the need for employment creation?

(7) Are facilities available, if required, for the housing, feeding and welfare of the labour force employed on the project?

(8) What are the daily wages of the labour force, based not only on the going market wage rates but also on a more realistic " shadow " price for labour?

(9) Are there any engineers, mechanics, supervisors and other technical personnel available and what are their qualifications? To what extent are management skills (as listed below) developed?

(10) Is on-the-job training desirable?

(11) What are likely to be the consequences of completing the project earlier or later than planned?

(12) Will there be follow-on projects? Are there any priorities to be taken into account?

(13) What are the advantages and disadvantages of greater or less participation by the local people in the project? In particular, if they play a greater part is this likely to provide motivation for subsequent upkeep of the project?

Once a project has been correctly planned and a decision taken on the most appropriate techniques, its success or failure will depend largely on the management of every single phase of the plan. Labour-intensive projects may often be rejected because of reluctance of project managers to deal with a large labour force instead of a limited number of skilled equipment operators. Training in project management oriented towards coping with this bias is thus essential along with project-management training in a broad sense and at all levels. The following is a suggested list of what should be included in a project management training programme, mainly focused on infrastructure projects within the field of public works and construction:

(1) General management, including over-all understanding of technical as well as economic aspects of projects, especially cost-benefit analysis and network-planning methodology.

(2) Production management (civil and industrial engineering), including operational management of machines and men (large labour force), maintenance and repair management, management of stores, as well as basic training in the use of work study techniques.

(3) Accountancy and financial management, with special emphasis on cost accountancy and the rate of return on capital investments.

(4) Human resources management, including understanding of the importance of incentives and motivation, attitudes of men towards their work, social welfare, nutrition and health.

The training programme should also include instruction on the employment creation potential of different techniques based on a comparison of labour-intensive and capital-intensive methods in the greatest possible variety of technological and socio-economic circumstances.

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My aim in this paper has not been to express any over-all preference for either labour-intensive or capital-intensive methods; in fact these two expressions can be somewhat misleading. What I am suggesting is that every project must be appraised separately with a view to achieving what I have called the " optimum balance " method. Then, and then only, will it become clear what degree of labour intensity a project should aim at from the very beginning.

APPENDIX

Network diagram of the gravelling operation

Network planning and analysis [1] is one of the most valuable management tools available to the project planner. At the same time it offers the best method of determining where the greatest scope for the use of labour-intensive methods lies. Used carefully, it can ensure the highest degree of labour-intensity feasible.

Operations with " slack " [2] or " float " should be the first to be examined. If a machine would normally be considered for such an operation, the percentage of utilisation of the machine on this operation will be inversely proportionate to the percentage of slack. Unless the machine can be used on other operations, the possibility of " exploiting " the slack by substituting labour-intensive methods should be studied.

To illustrate this the gravelling operation is used once again. A simplified network diagram, showing the construction of 40 kilometres of road by one unit as described in the case study, is presented opposite.

It is enough to examine a single operation to see the point: operation a_3, " opening a quarry " to supply gravel material for the roadlength between kilometre 20 and kilometre 30. The total slack is $48-4-2=42$ days (or $42/44\times 100=95.5$ per cent of the time available). This means that the bulldozer could start work after day 4 and need not have finished before day 48, and thus the percentage of utilisation on this particular operation (looked at for simplification as an isolated operation) would only be $2/44\times 100=4.5$ per cent. As seen in the case study, the operation could be done manually using 144 man-days, which means that 4 men would be able to complete the operation in 36 days (with the help of an agricultural-type tractor for 2 days), reducing the slack to 8 days. The final day of completion of the whole project would not be affected by so doing.

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[1] It would be impossible to explain here how a network diagram is drawn. A large number of books have been published on this subject, of which two may be mentioned: John Dearden and F. Warren McFarlan: *Management information systems: text and cases* (Homewood (Illinois), Richard D. Irwin, 1966); Moder and Phillips: *Project management with CPM and PERT* (New York, Reinhold, 1964). For a fairly simple outline see " Planning training courses by network analysis ", in *Management and Productivity* (Geneva, ILO), No. 30, pp. 15-29.

[2] A technical term used in network planning indicating how much margin or idle time there normally would be on a given operation.

The letters *a*, *b*, *c*, etc., designate the various separate operations, as follows:

- *a.* opening a quarry
- *b.* clearing the road
- *c.* excavating and loading
- *d.* hauling and dumping
- *e.f.g.* spreading, shaping, watering, compacting

Each of these operations is broken down into the work required for 10 kilometres of road (capital-intensive), the successive stages being designated by the subscripts.

The critical path is indicated by the heavy arrows.