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Publication of this paper sponsored by Committee on Soil and Rock Properties and Committee on Tunnels and Underground Structures.

Labor-Intensive Technology: Promises and Barriers

Mathew J. Betz and Ronald Despain

The numerous criteria for technology evaluation in developing countries are discussed with emphasis on labor-intensive appropriate technologies. Historical technologies, current technologies of reduced scale, the adaptation and improvement of indigenous technologies, and the need for research and development in labor-intensive techniques are presented. The technical factors in road construction are investigated as they relate to labor intensity. Special emphasis is given to evaluation of design standards, location criteria, and scheduling. It is possible to combine labor-intensive techniques where appropriate with more-conventional capital-intensive methods. The susceptibility of the various construction components to labor-intensive applications is briefly reviewed. Finally, the barriers to the adoption of labor-intensive techniques in road construction are presented. These include technical barriers; psychological barriers; bureaucratic barriers; educational barriers; managerial barriers; and the general lack of research, development, financing, marketing, and distribution systems to support labor-intensive alternatives. Labor-intensive alternatives are but one in a continuum of technologies. Developing countries will probably retain capital-intensive techniques for primary road projects. Labor-intensive techniques are probably best suited to the construction of feeder and rural-development roads.

APPROPRIATE TECHNOLOGY

During the past half decade, the terms "appropriate technology" and "labor-intensive technology" have become widely used, and the number of publications addressing their numerous aspects has grown.

The term "appropriate technology" can vary broadly in its application. It is currently being applied, not only to the developing countries, but also to Western Europe and the United States. Philosophically, appropriate technology implies that the decision makers should have the sophistication to devise, plan, evaluate, and select from a range of technical solutions to a given problem. Furthermore, it suggests that their selection should be based on a broader range of criteria than has been true in the past. Appropriate technology advocates the use of a greater number of economic indicators than is addressed in the traditional economic-feasibility study and emphasizes the need to include social as well as economic factors.

Stated in another way, appropriate technology could be expressed as the provision of technical solutions that are appropriate to the economic structure of those influenced, appropriate to their ability to finance the activity, appropriate to their ability to operate and maintain the facility, appropriate to the environmental conditions, and appropriate to the management capabilities of the population. There are numerous criteria, and appropriate technology challenges all of them. Not only the engineer, technologist, and economist but also the sociologist, anthropologist, historian, and others need to become involved in the evaluation and selection procedures of technological decision making.

In an extensive review, Eckaus has developed the following criteria for appropriate technology (1):

1. To maximize product output,
2. To maximize the availability of consumer goods,
3. To maximize the rate of economic growth,
4. To reduce unemployment,
5. To encourage regional development,
6. To reduce balance-of-payment deficits,
7. To provide greater equity in income distribution,
8. To promote political development, and
9. To improve the quality of life.

And, although conceding that the list is still far from comprehensive, we add the following:

10. To reduce the population flow to urban centers,
11. To provide an adequate food base for the local or national population,
12. To be as consistent as possible with the indigenous social structure, and
13. To preserve the indigenous cultural continuity and heritage.

It is obvious that these criteria are themselves in conflict. This is the real-world situation where no solution, technical or otherwise, will improve all factors impacted by a project. The strength of this approach is that it can identify both negative aspects and those that can be improved. This should lead to more-rational decision making because the positive and negative aspects can be compared as trade-offs. It presumes, however, that the criteria and the relative importance of each can be agreed on. Paradoxically, this advantage may also be a weakness. It may fail at times because it cannot be all things to all people. Considerable delay, which may in the end be disadvantageous to all, may be encountered in the extensive analysis and evaluation required. The decision making becomes very complex because of the number of criteria involved and of disagreement as to which have priority. Because of its broad definitional base, one can honestly say that, given appropriate conditions, any technology from tool-less hand labor to earth satellites can be appropriate.

LABOR-INTENSIVE APPROPRIATE TECHNOLOGY

One category of appropriate technology is that of labor-intensive appropriate technology. For example, the remaining sections of this paper will address such technologies as related to road construction and maintenance. In the economic sense, these are technologies that look for greater input of labor, often, but not necessarily, unskilled and a corresponding decrease in the requirements for capital investment. The obvious advantages of such technologies are the decrease of the number of underemployed and the reduction in foreign exchange. The underemployment problem in the world need not be documented. Labor-intensive technologies have implications in terms of slowing the migration from rural to urban areas and, perhaps most important of all, in making developing countries as self-sufficient as possible in basic commodities through rural development. We are not so naive as to feel that labor-intensive technology can completely stem the current migrations from rural areas; no such technologies are likely to be that effective or pervasive throughout any developing country. The emphasis should be to consider labor-intensive appropriate technologies as part of the range of alternatives available and possibly to give greater weight to some of the criteria that would tend to encourage and justify experimentation with and implementation of such technologies.

The idea of labor-intensive technologies, especially as applied to rural areas, goes back to the colonial era. Village industries were encouraged in India before the 1930s (2). Gandhi's writings and philosophies were intimately tied to labor-intensive technologies. More recently, the writings of Schumacher have emphasized some of the limitations of capital-intensive development and some of the advantages of labor intensity. It was Schumacher, whose thoughts have had significant impact on the young American reader (3), who coined the term "intermediate technologies" to identify those of moderate capital investment per employee. This led to the development of various intermediate technology groups in Great Britain and elsewhere. It is unfortunate that, at least in the United States, the term intermediate technology has been superseded by the term appropriate technology.

DEVELOPMENT OF LABOR-INTENSIVE TECHNOLOGY

The literature on labor-intensive technologies is a rapidly expanding one. These technologies can be developed from any of four primary sources. First, there is the revival of older technologies. These technologies were used to build the original manufacturing plants and basic infrastructure of the developed countries and were much more labor intensive than is the technology of today. The construction of railroads in the American West is a classic example. There are those who feel that a reintroduction of such technologies to Third World countries is appropriate. Much of the literature of labor-intensive technology, both that directed toward economic development and that directed toward a different life-style, is fundamentally based on this source, which might be called the Whole Earth Catalog approach. It has the advantage of being easily and quickly identifiable and having demonstrated success in the past. Thus, it can produce many good ideas at a very low research cost. It is often the approach of the instant expert, a breed not unknown in this field. It has the disadvantage of lack of depth once the initial inventory has been conducted. It has a very strong psychological disadvantage for the receiving country, which is being advised to use techniques perhaps a century old. It has the technical disadvantages that the tools are no longer manufactured and that maintenance and repair parts that may have been readily available when they were broadly used are not available today. One would have to establish a century-old production and technology base to broadly implement such technology. Where this can be done on a local level with minimal manufacturing and easily maintained tools, it can be effective. If the technology identified has much sophistication, these technical limitations are difficult to overcome. This type of solution should be among the first investigated in any comprehensive research effort, but it should not be overemphasized or become the primary intellectual base.

The second source of labor-intensive technologies is to adapt current technologies to a smaller scale for implementation in a receiving country. This is done daily as new plants and techniques are introduced. Even substantial manufacturing plants are often not to the scale that would be built in the developed world. The adoption of smaller lightweight tractors as opposed to heavier commercial ones is an example.

A third source is the adaptation and improvement of indigenous technologies. The fact that the populations concerned have existed within their geographical location and physical environment for centuries, if not millennia, is often overlooked. The methods and technologies developed have certainly been successful in those conditions. Thus, the folklore methods of doing things may form a fundamental base of knowledge from which to develop improvements and modifications. Furthermore, any new technique or tool must be introduced into the social and cultural environment that exists. This is the same environment that has successfully adopted or adapted the traditional techniques. Why they work and how they work is fundamental to either improving existing techniques or to the insertion of new techniques into the cultural and social milieu. It would seem obvious that the less disruptive a new technique is to its environment (social and cultural), the more likely it is to be readily adopted. This is particularly true in labor-intensive technologies for road construction and maintenance, which apply to large numbers of people in open environments, rather than to limited numbers in the closed environment of a factory.

The fourth source of labor-intensive technologies, probably least used currently, is simply the invention of new technologies that are labor, rather than capital, intensive. The difficulties are substantial. We have established educational and research facilities aimed at the invention and development of tools and techniques that tend to be more capital intensive rather than less so. The difficulties to be addressed in looking at the opposite side of this coin cannot be overemphasized. The concept of small research for small technology is naive. However, it is more than a question of financial resource. It is a question of the entire matrix of the education system from preschool through the Ph.D. In both the developed and the developing countries, training tends to establish biases, capabilities, and value structures that make it very difficult to conceptualize and invent low-capital-investment alternatives. This is not to imply that it cannot or should not be done. If labor-intensive techniques are to be broadly or even moderately effective, such research emphasis must be developed. Most of these techniques require extensive development and implementation projects that are best done in Third World locations.

TECHNICAL FACTORS IN TECHNOLOGY SELECTION

In road construction, labor-intensive projects require the integration of multiple activities, on a relatively large scale and employing many people. Road construction is illustrative of the diverse difficulties encountered when using labor-intensive techniques in large rural development projects. A linkage, normally a road of some type, is a necessity for rural development. Without the physical interconnection of a transportation link, importation of needed commodities and services and export of surplus production is impossible. [This need has been discussed elsewhere (4), as has the construction of low-volume roads (5).]

Most road projects have emphasized the use of capital-intensive heavy equipment, imported from a limited number of developed countries. However, adequate roads were built long before the invention of such equipment. Also, not all roads in developing countries need or should be of a high-quality or a paved type. The Sudan, which instituted a road-building program a few years ago, is about to complete the first paved road from Khartoum to the sea. Is is clear that the Sudan with its large area cannot afford either the cost or the time necessary to develop high-quality roads throughout. Roads can be built in as broad a spectrum of design and quality as any other works of humans.

One of the basic technical factors affecting the attractiveness of labor-intensive technologies in road construction is the original design of the facility. The higher the design standards, the more likely that capital-intensive technology will appear desirable. The overdesign of rural roads in developing countries is probably widespread. The design of penetration and agricultural-access roads to lower standards, including accepting a greater risk of temporary closure, should be carefully evaluated. The selection of a paved design versus an improved gravel facility is often critical. Many of the functions involved in even a simple bituminous-surface-treatment design are not realistically feasible when labor-intensive techniques are used. Such designs usually call for higher-quality base materials and more-uniform compaction standards than does an unpaved facility. As material specifications increase, the likelihood of use of adjacent soil is decreased. This, in turn, increases the need for capital equipment, as efficient methods of transporting material greater than 1 km by labor-intensive techniques are not generally available (5).

The performance of the system, which is exposed to the physical environment and to the abuses of an uncontrolled user group (overloaded lorries being a prime example), is an additional engineering concern. Most engineers feel responsible and consider inadequate performance of roads as a failure. The tendency, therefore, is to overdesign. If the engineers (rather than the real causes) are to be held responsible for the lack of performance, then overdesign will continue to be a problem. There is a myth that, the higher quality the road and the more sophisticated the design, the greater the quality control (i.e., the more mechanized equipment) and the easier and cheaper the maintenance. Over the last 15 years, an expanding amount of research has indicated that, although there is some truth to this in the narrow range, it is misleading in the broad range of design alternatives. In other words, a paved road is not necessarily cheaper or easier to maintain than a gravel road, nor is a gravel road necessarily cheaper or easier to maintain than a dirt road. The local manufacture of road construction equipment is of importance. Such activity has been developed in Kenya through a rural-access road program (6).

The initial location of a proposed facility can bias the technology choice. A direct route between two points generally requires more earth work, involving both excavation and embankments, than would a longer route that takes advantage of the natural terrain. Although the longer route might cost more because of its extra length, the shorter route, because of its technical requirements, may mandate capital-intensive techniques. In other cases, the route might be lengthened to take advantage of locally available materials. This route lengthening could actually decrease the length of haul from material site to building site and thus increase the attractiveness of labor-intensive techniques.

The construction schedule is another variable that can encourage or discourage labor intensity. Labor-intensive techniques require that unemployed or underemployed local labor be available. In the rural situation, there may be relatively little underutilized labor during planting and harvesting seasons. Thus, construction schedules that call for intensive activity spanning either or both of these seasons may require capital intensity. However, time is not critical in most rural road projects, and it should be possible to devise a schedule that supports the use of excess labor.

Road construction represents a collection of different and semi-independent functions, including (but not limited to) site clearance, excavation, hauling, embankment building, compaction, placement of selected material, and grading. There is no reason why a mixture of capital-intensive and labor-intensive technologies cannot be used on a given project. In studying construction of gravel roads in Kenya, one analysis of a variety of construction techniques that ranged from wholly labor-intensive to wholly capital-intensive technology concluded that a combination of labor- and capital-intensive techniques required the minimal amount of capital per person day of work and employed a substantial labor force at a minimal increased total cost (7). Muller (8) has discussed his personal experiences using labor-intensive construction. The project was the construction of 480 km of all-weather gravel road, including drainage and bridges, by capital-intensive methods using mostly imported equipment. The production rate was 1 km of road graveling each 2.3 days at a direct operations cost of approximately $500. Actual experience indicated production rates of 30-70 percent of the anticipated. Increased numbers of laborers were employed when excavators had mechanical problems. Occasionally, these laborers were retained even when the machinery was working, which resulted in increased productivity. Based on this experience, other methods of increasing the labor intensity were devised; Muller found that all operations except hauling (because of the long haul distance from quarry to site) and watering could be performed economically by labor-intensive methods. Maximizing the labor intensity and maintaining the same operational speed (2.3 days/km) resulted in a cost of approximately $550 or about 10 percent higher than the capital-intensive methods. Both Muller's conclusions and those of the International Labor Organization indicate that the direct transfer of capital-intensive technologies into the African social-economic environment is probably not justified. A balance between capital- and labor-intensive techniques would seem to meet current broader criteria.

LABOR-INTENSIVE TECHNIQUES FOR ROAD CONSTRUCTION

Labor-intensive methods of construction are not neces-

sarily limited to the use of the simplest techniques and tools available, e.g., carrying excavation materials in baskets or using hand shovels. The techniques should include the design and construction of new tools and equipment.

In excavation and loading, the traditional techniques of picks, hoes, and shovels can be implemented. Hand-held stretchers or head baskets are effective over short distances and where changes in elevation are small. Somewhat more-sophisticated and more-productive tools can be devised by using teams of labor, draft animals, or machines that develop mechanical advantage (such as those based on the principle of the bicycle). Depending on the soil type and the difficulty of excavation, labor-intensive techniques can be used in immediate conjunction with mechanical excavators. As haul distances increase, more-sophisticated equipment should be devised, but this can still fall far short of modern capital-intensive hauling vehicles. Locally built carts with rubber tires can be drawn by teams of men or draft animals and carry embankment materials significant distances. Small tipping trucks on steel rails may be animal or human powered and are an effective hauling device, although the tracks must be moved as construction progresses. For intermediate distances, the adaptation of the small scraper (possibly made from a half of an oil drum) is feasible. The design for and productive capacity of similar equipment (including carts, wagons, plows, drags, scrapers, fresnos, and wheel scrapers) can be found in older American highway engineering publications (9). The spreading and leveling of road materials is generally not effectively accomplished by hand. Some type of scraper, broom, or drag is necessary but, again, labor, draft animals, or light mechanization can provide the power.

Most engineers feel that soil compaction is the function for which labor-intensive methods have the greatest difficulty in competing with methods involving heavy equipment. Heavy equipment gives rapid compaction that is often significantly higher than can be produced manually. In addition, there is probably greater uniformity of compaction. This does not require, however, that all compaction be done with heavy equipment. Hand compaction can be effective (even in developed countries, it is often used in areas where heavy equipment cannot operate, such as back filling behind retaining walls). Compaction can be achieved by small hand-controlled mechanical compactors, but it can also be accomplished solely by hand. Many feel, however, that hand compaction has serious economic as well as technical disadvantages. A real alternative that should be investigated is the reduction of compaction standards traded off against greater depths of compacted material. It should also be noted that traffic itself can supply considerable compactive capability. For example, a discussion (9) of the construction of sand clay roads in the United States early in the century stated that

> The ordinary method that has been utilized to obtain this result (compaction) has been the mixing and packing due to hooves of animals and wheels of vehicles going over the road. This gives surprisingly good results, but it usually takes several months before the road is thoroughly consolidated and packed. It is necessary, while this packing is going on, that after each rain, the surface be immediately reshaped and crowned.

For a high-quality gravel surface, some type of roller having a significant weight (probably 8 Mg or more) was generally advised.

The haulage of water for construction is usually somewhat more complicated than the haulage of construction materials. Nonetheless, the use of animal-drawn water tanks of local manufacture (e.g., drums on rubber-tired carts) can be effective.

These are just a few specifics that illustrate the feasibility of using more labor-intensive technologies. In addition, as noted by Marsden (10), "New technology should stimulate output in indigenous industries and be capable of being reproduced locally."

BARRIERS TO USE OF LABOR-INTENSIVE TECHNOLOGIES

What are the barriers to the use of labor-intensive techniques? For one, the experts do not agree. Eckaus tends to classify the advantages of Schumacher's proposals under his (Eckaus') criteria of improvement of quality of life and specifically limits them to rural village development. He further states that the advantages of such intermediate technologies are limited and indicates that they fly in the face of major trends throughout the world by resting almost entirely on a village-oriented life-style (1).

Most of the technology available to the Third World is the technology of the developed world. This technology has survived and prospered under a narrow range of solely economic indicators that emphasize minimal cost of production, capital investment, and quality control and are generally based on an economy that has almost full employment and high wage rates. It is not surprising that such an environment encourages high-capital-investment projects.

Project feasibility studies conducted by American or European consultants tend to have a capital-investment bias, intentionally or unintentionally. The bias may be unintentional in that these consultants are trained and experienced in and technically more comfortable with high-capital alternatives. Or, the bias may be intentional because of the realization that the sources of the high-capital construction items are, for the most part, the developed countries. In addition, labor-intensive-technology alternatives may involve fewer expatriates in their implementation and operation (7).

As most development projects are either conducted or channeled through the national government, the selection of projects is greatly influenced by the local bureaucracy. It is clear that, for a given amount of capital to invest, the larger the capital component of each project, the fewer the total number of projects. Thus, from the bureaucratic standpoint, it may be advantageous to have a limited number of projects (which can be realistically followed and controlled) rather than a large number of low-capital-investment projects (which tend to be impossible to control by a central agency).

A country's tariff and tax structures may be another bias toward high-capital projects. These may result in subsidized capital. Such policies tend to undervalue capital investment in terms of other alternatives. Capital may be provided through the central government at low rates or by reduced import duties for foreign machinery, thus subsidizing those who wish to place their resources in a capital investment as opposed to investment in labor components.

Labor-intensive techniques require large numbers of people. The training of these people, their organization and management, becomes a substantial problem. People who have such training and management skills are in short supply in most Third World countries (11). In addition, the developed countries have not provided the organizational structures nor the training tools to support such projects. More imagination is needed in these areas. We suggest consideration of highly sophisticated tools to do this very unsophisticated job. The use of modern, highly portable, audiovisual training techniques may be very effective where the trainees are illiterate. Their audiovisual capabilities may be more acute than

those of a more literate, book-based society.

Because a large number of people are involved, they probably represent a substantial portion of the total indigenous population in a given location. Therefore, the ability to institute and carry through such projects benefits from maximizing the use of the existing social and organizational systems. This calls for a substantial input from sociologists, cultural anthropologists, and other social scientists.

The desire of the private entrepreneur to capitalize is seldom addressed in the literature, other than in terms of lowering unit production cost to maximize profits. Increased capital investment may also increase capacity and improve quality control, which may broaden the potential market. If this is supported by governmental capital subsidization, so much the better from the entrepreneur's standpoint. In addition, one of the factors that is almost never mentioned and may be a consideration, even at a very low level of capitalization, is the fundamental truth that the capital investment belongs to the capitalist. If an individual has given resources, he or she generally can select a technology that will place some of these into capital investment in plant and equipment, some in operational costs, and some in labor costs. There may be a feeling that operational and labor costs are dispersed, whereas investment in plant and equipment is under the control and ownership of the investor. In other words, expenditure in capital tends to be a long-term asset whereas expenditures in operations and labor are not. The importance of this as a psychological bias is probably underrated. The impact of this becomes even greater when the economies have high inflation rates.

The barriers discussed above are basically economic and structural limitations to the implementation of labor-intensive technology. There are others.

A system for innovation in labor-intensive techniques is lacking. There is only a weak technological invention base and little or no incentive for private investment in the invention of low-capital-investment tools. Most Third World countries lack a well-defined research and development laboratory, either in the private or in the public sectors.

There is the absence of the innovation and implementation system represented by the individual firm in the private economy. There tends to be a lack of marketing and distribution systems for those labor-intensive technologies that are used. The weak financial infrastructure to support innovative systems for labor-intensive technologies reflects an absence of private incentives and public interest.

Because of the limitations described above, there would seem to be little incentive for increased emphasis on labor-intensive technologies. The primary justification is the possibility of dispersing economic development by placing some of the emphasis on the number of individuals benefited rather than all of it on the national economic factors.

CONCLUSIONS

The purpose of this paper has been to identify the potentials and problems of labor-intensive technology as applied to low-volume road construction and maintenance. Clearly, because of the multidisciplinary nature of the problems, there is a need for an integrated approach. This is especially true if labor-intensive techniques are to be applied broadly. Although substantial work and much imagination are necessary inputs to the development of new tools, the successful implementation of labor-intensive techniques is fundamentally a people problem; therefore, training, management, social structure, and cultural systems become the four corner posts on which success of the technical activities must rest. The failure of any one will cause failure, or at least substantial impediments to the success, of the others.

Finally, the emphasis on labor-intensive techniques reflects the fundamental belief that the most-valuable resource of any country is its people. The development of this resource cannot be instantaneous. It requires time and patience. More important, it requires opportunity and resources. The use of capital-intensive technologies has led to the development of dualistic economies in many nations. Some would say that this is wrong. These persons feel that development should be entirely focused on the rural development element to improve the quality of life for all of the population simultaneously. A more moderate view would seem appropriate. Modern developing countries wish to become just that—modern. There is a place for the most-advanced 21st-century technologies. There is a place for modern capital-intensive production. As we have emphasized, there is also a place for labor-intensive activities. In this paper, we have identified some of the real barriers, internal and external, technical and social, to greater and more-accelerated application of labor-intensive techniques. Greater efforts by all concerned must be made to encourage and implement these techniques.

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Publication of this paper sponsored by Committee on Low-Volume Roads.