"SOME ASPECTS OF THE USE OF LABOUR-INTENSIVE METHODS FOR ROAD CONSTRUCTION"

By

P. A. GREEN †
&

PETER D. BROWN ‡

CONTENTS

1. Introduction .......... 36
2. System of Analysis .......... 36
3. Construction Methods Available .......... 39
4. Incentives and Supervision .......... 42
5. Productivity & Costing .......... 46
6. Cost Comparisons for Selected Tasks .......... 64
8. Other Factors Affecting Choice of Technology .......... 72
9. Conclusions .......... 73

SYNOPSIS

This Paper to some extent complements that submitted to the Congress by the IBRD (World Bank). Based on field studies carried out on behalf of the IBRD, mainly in India and Indonesia, the Paper summarises some of the more important engineering findings, with particular reference to road construction in India.

The Paper describes the system developed and used to measure and to analyse the productivities and costs of a project, and lists the range of methods available to the engineer for the more important activities and tasks in road construction. It has been found that, once the effects of certain specific parameters have been eliminated, the variation in labour productivity data between different groups of workers and between different sites can be largely explained by variations in incentives and supervision; a relation between these two factors and scatter of productivity data is formulated.

Productivity and cost data for important activities is given for labour, animals and equipment and for intermediate methods using combinations of these three, along with a brief mention of possible ways of increasing productivities investigated, during the study. Costs of alternative methods for selected tasks are compared,

† Partner, Scott Wilson Kirkpatrick and Partners, Consulting Engineers, Basingsloke, U.K.
‡ Assistant Engineer, Scott Wilson Kirkpatrick and Partners.
at typical Indian wage rates, and the concept of a 'break-even' wage is discussed, with particular regard to earthworks, aggregate production and haulage of road materials. The Paper concludes with a brief mention of other factors, including road design, which have an important bearing upon the choice of technology.

1. INTRODUCTION

1.1. Labour-intensive construction methods in road buildings have been widely used in India for many years, but in other parts of the world (excluding the Republic of China) equipment-intensive methods have predominated. The recent and very rapid growth of population in many less developed countries has created a serious unemployment problem, leading politicians, economists, engineers and planners to examine the potential for efficient use of men instead of machines in civil construction.

1.2. This Paper summarises some of the more important engineering findings from a Study of the Substitution of Labour and Equipment in Civil Construction ("the Study") carried out on behalf of the IBRD (World Bank) with particular relevance to road construction in India. By way of cost comparisons based on observations and experiments carried out during the Study, some conclusions are drawn as to which construction tasks are best suited to labour-intensive methods; possible means of improving labour productivity are described briefly, and the role of intermediate technology is identified. Manual and intermediate methods of course have a better chance of success if the project is designed with such methods in mind, and the Paper ends with some notes on the relationship between design and choice of technology.

2. SYSTEM OF ANALYSIS

2.1. In the analytical framework set up in the Study to measure productivity and cost data, a project is usually broken down successively into sub-projects, operations, tasks and activities. A sub-project is a section of work coming under the

---

‡ Words printed in italics the first time they appear in the text have specifically defined meanings in the Study.
control on one site engineer and encompassing one or two seasons' work. *Operations* are jobs which can be carried out independently of one another in time, the important operations in a road project comprising:

- site clearance
- earthworks
- sub-grade improvement (murum or gravel course)
- sub-base construction
- base construction
- surfacing
- drainage works†
- structures (bridges and major culverts)†

A *task* is the smallest description of work which can be performed by an independent group of resources, for example the earthworks operation may consist of two tasks:

(a) excavate soil from borrow to fill, spread and dress, all of which can be done by a gang of labour on the one hand or by a gang of dozers, scrapers and graders on the other;

(b) water and compact fill material, which may require a water tanker and roller operating together.

Tasks may be split into component *activities*, in the case of task (a) above, for example:

- excavate soil
- load (headbasket, wheelbarrow, scraper, etc.)
- haul (i.e., transport or 'lead')
- unload
- spread (including dressing)

2.2. The *productivity* of a task or an activity is the ratio of the *output* to the *input*. The output is the quantity of work done, measured in cubic metres, tonnes, litres or square metres, etc. The input is a measure of the resource-time spent in doing the work, for example man-hours or man-days, specified in terms of either *total time* (TT), *available time* (AT) or *working time*

† Structural and drainage works have not been given much consideration in the Study.
(WT)*. It is convenient to express productivity as its inverse, that is as an input coefficient, e.g.;
- man-hour (WT)/cu.m. or
- dozer-hour (AT)/tonne.

2.3. Productivity of both men and machines is strongly influenced by various conditions which are described as parameters. These fall generally into three categories, the first two of which are measurable:

(a) general parameters, which apply to all tasks;
(b) specific parameters, applying to specific tasks and activities only;
(c) side parameters, which are not readily measurable, or if measurable, are difficult to apply.†

*Total Time* is defined as either the hours during which the resource is involved in the work process, or the hours during which work on site would normally be done. It is generally assumed that the alternative giving the largest number of hours applies. No time outside ‘working hours’, such as night time and official meal breaks, is included in total time unless it is actually used for doing work. Total time divided is into *lost time* and *available time*.

*Lost Time* occasions during total time when production may not be practical or possible are called lost time. Included in this are stoppages due to machine breakdown, severe climatic conditions, strikes, epidemics etc.

*Available Time* (AT) = Total Time (TT) - Lost time (LT).

Available time divided into *working time* (WT) and *non-working time* (NT).

*Non-working Time* is any time during available time when the resource being considered is fulfilling no useful purpose as far as the progress of work is concerned and is temporarily not involved in the work process. Non-Working time includes starting work late, finishing work early or time spent waiting for another resource to complete a piece of work where the wait could have been avoided. Non-working time does not include necessary rest or time spent on ancillary tasks (which are often essential to the construction process) such as fetching water, repairing tools, listening to instructions and walking to the next job site; nor does it include delays to vehicles waiting while loading.

*Working Time* (WT) = Available Time (AT) - Non-Working Time (NT).

† The full list of parameters is given below:

<table>
<thead>
<tr>
<th>General Parameters</th>
<th>Specific Parameters</th>
<th>Site Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>Soil/rock</td>
<td>Health and</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>hardness</td>
<td>nutrition</td>
</tr>
<tr>
<td>Payment method</td>
<td>Loading height</td>
<td>Traditional</td>
</tr>
<tr>
<td></td>
<td>Haul distance</td>
<td>skill</td>
</tr>
<tr>
<td></td>
<td>(lead)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Haul route rise</td>
<td>Local customs</td>
</tr>
<tr>
<td></td>
<td>(lift) or fall</td>
<td>Equipment</td>
</tr>
<tr>
<td></td>
<td>Haul route</td>
<td>condition</td>
</tr>
<tr>
<td></td>
<td>condition</td>
<td>Maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>level Spares</td>
</tr>
<tr>
<td></td>
<td></td>
<td>availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type of work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terrain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rainfall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Altitude</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic interfer-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supervision</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>relations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>contract</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>site</td>
</tr>
</tbody>
</table>
3. CONSTRUCTION METHODS AVAILABLE

3.1. Even the most labour-intensive construction methods employ a little capital in the form of hand tools, while the most equipment-intensive methods require operators. In between the two extremes lie many techniques employing larger amounts of both equipment and labour, so there is no clear dividing line between labour-and equipment-intensive methods. For the purposes of this Paper, however, three categories of method are distinguished:

(1) **Equipment-intensive** methods employ no unskilled labour except in purely ancillary capacity, for instance for dressing of slopes cut by dozer.

(2) **Labour-intensive** methods involve nothing more than hand tools.

(3) **Intermediate** methods employ a certain amount of capital to aid or replace labour in a part of a task which can be least efficiently done by an unaided labourer. They may involve one or more of the following:

(a) **simple equipment**, manually powered, such as hand-operated ropeways and rail systems;

(b) **animals** with or without items of ‘simple equipment’ such as carts;

(c) **mixed resources** where labour and machines work together, for instance hand-loaded trucks or tractor/trailers.

While wheelbarrows are often classified as hand tools, they are treated in this Paper as simple equipment.

3.2. Based on the above definitions, a selection of methods which are technically feasible‡ for the more important activities and tasks in road construction are listed in Table 1. Methods which have little relevance to India are ignored.

---

‡ Note that there is no sharp dividing line between the meanings of technical and economic feasibility. Those methods are ignored which could in theory be used to do a job according to specifications, but which are so uneconomic that no practical man would even consider using them.
## Table 1: Available Construction Methods

<table>
<thead>
<tr>
<th>Activity or Task</th>
<th>Labour-Intensive Methods</th>
<th>Intermediate Methods</th>
<th>Equipment-Intensive Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of soils and</td>
<td>soft soil</td>
<td>Hoe¹</td>
<td>Dozer</td>
</tr>
<tr>
<td>rock</td>
<td>firm soil</td>
<td>Pick</td>
<td>Tracked excavator</td>
</tr>
<tr>
<td></td>
<td>hard soil</td>
<td></td>
<td>Wheeled loader</td>
</tr>
<tr>
<td></td>
<td>soft rock</td>
<td>Crowbar</td>
<td>Scraper with or without</td>
</tr>
<tr>
<td></td>
<td>medium rock</td>
<td></td>
<td>pusher</td>
</tr>
<tr>
<td></td>
<td>hard rock</td>
<td>Hand-drilling and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>blasting</td>
<td></td>
</tr>
</tbody>
</table>

| Loading,         |                          |                      |                             |
| hauling and      |                          |                      |                             |
| hauling and      | 0-50 m                   | Hoe into headbasket  | Dozer                       |
| unloading        | 50-100 m                 | Hoe, wheelbarrow     | Wheeled loader alone        |
|                  | 100-200 m                | Hoe, animals² panniers|                            |
|                  | 200-500 m                |                       | Scrapper with or without    |
|                  | 500-1000 m               | Hoe & head basket or shovel | Wheeled loader or          |
|                  | 1000-2000 m              | into tractor/        | tracked excavator           |
|                  | 2000-5000 m              | trailer, unload      | into dump truck             |
|                  | over 5000 m              | by tipping or        |                             |
|                  |                          | hoe or shovel        |                             |

| Excavation,      | Excavate by hoe, pick or crowbar, | Dozer               |
| loading, hauling | haul by headbasket            |                     |
| and unloading,   | in earthworks in side-long cut in hill roads, |                     |
|                 | mixed soil and soft rock, maximum haul 50 m |                     |

<p>| Spreading soils  | Hoe or rake                | Grader or Dozer     |
| and aggregates² |                          |                     |</p>
<table>
<thead>
<tr>
<th>Loading, hauling and unloading stone materials in quarry, haul distance 0-200 m</th>
<th>Carry by hand</th>
<th>Collect by headpan into</th>
<th>(a) Wheelbarrow (b) Manually operated chute (c) Manually operated aerial ropeway (d) Manually operated rail system</th>
<th>Dozer and wheeled loader alone Dozer, wheeled loader and dumper Dozer, wheeled loader and dump truck Mechanical conveyor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading, hauling and unloading aggregates from quarry to road site, haul distance 1 km upwards</td>
<td>Load by rake and headpan, or by rake or shovel from loading platform or chute into</td>
<td>(a) Tractor/trailer, unload by rake or tip (b) Flatbed truck unload by rake</td>
<td>Wheeled or tracked loader into dump truck</td>
<td></td>
</tr>
<tr>
<td>Production of stone aggregates (i.e., breaking or crushing)</td>
<td>Hammer</td>
<td>Mobile crusher, loaded by hand, stone pre-broken to 100-150 mm</td>
<td>Crushing plant with integral screens and conveyor, loaded by wheeled loader</td>
<td></td>
</tr>
<tr>
<td>Heating and mixing bitumen macadam</td>
<td>Heat chippings and bitumen over open wood fire, mix by shovel or rake</td>
<td>Heat bitumen in tar boiler, heat chippings and mix with bitumen in small or medium sized mechanical mixer</td>
<td>Integrated 'hot' mix plant</td>
<td></td>
</tr>
<tr>
<td>Hauling and laying bitumen macadam surface</td>
<td>Haul by stretcher, lay by hand</td>
<td>Haul by wheelbarrow, lay by hand-propelled screed board with or without rails</td>
<td>Dump truck and paver</td>
<td></td>
</tr>
<tr>
<td>Compaction of earthworks and sub-grade</td>
<td>Hand-propelled mechanical rollers of various types for small quantities Animal-towed sheepfoot roller for large quantity</td>
<td>Self-propelled roller Tractor-towed sheepfoot roller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compaction of base and surfacing materials</td>
<td>Self-propelled roller</td>
<td>Tractor-mounted ('Khamini' type) roller</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. The word 'hoe' is used in the study to describe the back-acting tool used all over India for digging in soft soil and for loading, variously named 'powr ah', 'mamti', etc. For non-cohesive soils, a shovel may be more suitable than the hoe. 2. i.e., mule, donkey or camel. 3. i.e., mule, camel or bullock. 4. Spreading here means only the action of distributing a heap of material evenly over an area: it does not include the transporting of material from a roadside stockpile, which would be described as 'load, haul, unload, spread'. 5. This method is untested.
4. INCENTIVES AND SUPERVISION

4.1. Method of payment and quality of supervision and site organisation have a strong influence upon productivity and hence upon unit costs. To illustrate these influences, and at the same time to provide a framework which allows for the presentation of data with a wide degree of scatter, input coefficients are specified in terms of a range: Line $A$, corresponding to piecework payment with good supervision, and Line $B$, corresponding to daily-paid work with poor supervision.

4.2. Lines $A$ and $B$ are illustrated, for the loading activity, by the lower and upper continuous lines in Fig. 1, the broken lines representing observed data. Roughly speaking, 25 per cent of observed piecework input coefficients fall below Line $A$ and 25 per cent of observed daily-paid input coefficients fall above Line $B$. Average conditions for piecework and daily-paid work can also be expressed as two lines, designated $A^*$ and $B^*$ respectively, Fig. 1.

4.3. For relationships between Line $A$ and Line $B$ condition which affect unit costs have been discovered, empirically, to exist for manual earthworks tasks, and they are believed roughly to hold true for other heavy manual tasks. Generally speaking the ratio of Line $A$ to Line $B$ working time input coefficients is about 0.375 : 1, and the corresponding ratio for Lines $A^*$ and $B^*$ is about 0.57. Pieceworkers (Line $A$, $A^*$) spend more time per day on site and a greater proportion of that time actually working. Their daily earnings are about twice the daily-paid (Line $B$) wage for Line $A$ conditions and about 1.6 times for Line $A^*$. These factors are compiled in Table 2, assuming a ratio of available time to total time ($AT/TT$) of 0.9.$^\dagger$

4.4. It is assumed in Table 2 that Lines $A$ and $A^*$ conditions are associated with contract work, while Lines $B$ and $B^*$ represent departmental labour work. Limited field evidence suggests that a contractor typically adds 70 per cent to his direct costs, including tools, to allow for overheads such as supervision.

$^\dagger$ This ratio has to be determined for each project. The total time does not include Sundays, festive holidays etc. For practical purposes, if labour is paid only for available time days, the concept of total time only enters into calculations for total resource requirements and programming.
finance and profit; while the corresponding figure for departmental work is about 30 per cent.†

---

NOTE: Analytical results for relationship under different combinations of payment method and supervision levels are:

<table>
<thead>
<tr>
<th>PAYMENT METHOD</th>
<th>SUPERVISION LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Daily - paid work</td>
<td>Poor or fair</td>
</tr>
<tr>
<td>2 Daily - paid work</td>
<td>Good or very good</td>
</tr>
<tr>
<td>3 Piecework</td>
<td>Poor or fair</td>
</tr>
<tr>
<td>4 Piecework</td>
<td>Good or very good</td>
</tr>
</tbody>
</table>

Fig. 1. Relationship between working time (WT) input coefficient for loading and the loading height under different combinations of payment method and supervision levels.

† The percentage officially given by organisations in India varies between about 10 and 30; analysis carried out during the study of actual costs related to value of work done by a number of organisations in India indicates that the higher figure is more realistic. Further, it should not be assumed that, because a contractor adds (typically) 70% compared with the 30% addition for departmental work, the latter is more efficient, see foot note to para 6.1.
### Table 2: Typical Factors Associated with Labour-Intensive Construction Methods

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Item</th>
<th>Unit</th>
<th>Piecework</th>
<th>Daily Paid</th>
<th>Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Line A</td>
<td>Line A*</td>
<td>Line B</td>
</tr>
<tr>
<td>1</td>
<td>Daily hours on site</td>
<td>hr(AT)/day(AT)</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Daily working hours</td>
<td>hr(WT)/day(AT)</td>
<td>8</td>
<td>8</td>
<td>5.5</td>
</tr>
<tr>
<td>3</td>
<td>Lost-time factor (AT/TT)</td>
<td></td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>Site factor (WT/AT)</td>
<td></td>
<td>0.89</td>
<td>0.89</td>
<td>0.69</td>
</tr>
<tr>
<td>5</td>
<td>WT/TT ratio</td>
<td></td>
<td>0.80</td>
<td>0.80</td>
<td>0.62</td>
</tr>
<tr>
<td>6</td>
<td>Input coefficient(WT)</td>
<td>man-hr(WT)/Z</td>
<td>1.33y</td>
<td>1.49y</td>
<td>2.67y</td>
</tr>
<tr>
<td>7</td>
<td>Input coefficient (AT)</td>
<td>man hr (AT)/Z</td>
<td>1.12y</td>
<td>1.49y</td>
<td>3.87y</td>
</tr>
<tr>
<td>8</td>
<td>Daily output</td>
<td>Z/man-day(AT)</td>
<td>8.03/y</td>
<td>6.04/y</td>
<td>2.07/y</td>
</tr>
<tr>
<td>9</td>
<td>Daily earnings or wage</td>
<td>Rs/man-day(AT)</td>
<td>x</td>
<td>0.8x</td>
<td>0.5x</td>
</tr>
<tr>
<td>10</td>
<td>Direct unit cost : working labour only</td>
<td>Rs/Z</td>
<td>0.12xy</td>
<td>0.13xy</td>
<td>0.24xy</td>
</tr>
<tr>
<td>11</td>
<td>Direct unit cost : working labour, gang leader (Line B only) and tools</td>
<td>Rs/Z</td>
<td>0.12xy</td>
<td>0.13xy</td>
<td>0.25xy</td>
</tr>
<tr>
<td>12</td>
<td>Total unit cost : Labour, tools, supervision, overheads, etc.</td>
<td>Rs/Z</td>
<td>0.20xy</td>
<td>0.22xy</td>
<td>0.32xy</td>
</tr>
</tbody>
</table>

(Contd)
**Table 2—(Contd.)**

*Notes:*— (1) This Table is mainly based on data from India and it has been developed from experience at several sites. It represents typical factors, although those at any particular site may be a typical in one or more respects.

(2) Values outlined in boxes are assumed to be fundamental; all other factors can be calculated from these fundamental values.

(3) Variables are:
   - $x$ = Typical daily earnings for a pieceworker under Line A conditions.
   - $y$ = Typical input coefficient (WT) for a pieceworker under Line A conditions.
   - $Z$ = Unit of output (e.g., tonne or $m^3$).

(4) Line 11 is calculated from Line 10 by adding 3 per cent for tools (Lines A and B) plus 4 per cent for gang leader (Lines B only).

(5) Line 12 is calculated from Line 11 by adding 70 per cent for supervision, overheads, etc., for Lines A conditions and 30 per cent for Lines B conditions.

(6) Daily earnings include the appropriate proportion of any Sunday or weekly rest day payment.

(7) WT—working time, AT—available time, see Section 2.
4.5. Scatter in data from equipment intensive construction is also defined in terms of Line A and Line B, but these lines have slightly different meanings to those described above for labour. Productivity in working time is mainly a function of operator skill and soil conditions, while daily productivity is also affected by the quality of supervision expressed in terms of the working to available time ratio. Typical factors are listed, for Line A and Line B conditions, in Table 3. For equipment not listed, such as crushers, the productivities have generally been based on maximum rated outputs times a factor of 0.58 (= 0.85 × 0.8) for Line A and 0.39 (= 0.65 × 0.6) for Line B.

4.6. It has been assumed for equipment also that Line A is associated with contract work in which the operators receive a productivity bonus, whereas Line B is associated with direct-labour departmental work. The same overhead factors, viz. 70 per cent and 30 per cent) as those used for labour-intensive construction have been taken, although the general validity of this assumption has still to be verified.

5. PRODUCTIVITY AND COSTING

5.1. Labour Productivity

5.1.1. Labour productivity data are presented in terms of Line A and Line B input coefficients, for a number of activity-parameter combinations, in Tables 4—10 inclusive. By adding appropriate coefficients, it is possible to construct the input coefficient for the majority of manual road construction tasks, except for heating and mixing surfacing materials. However, due allowance must be made for gang balance†, and a ‘gang balance allowance’ of 15 per cent has been added to the sum of activity-level input coefficients in calculating the data for manual earthworks tasks in Fig. 2. Poor gang balance is a frequent cause of low productivity under Line B conditions.

5.1.2. The tabulated productivity data are based on observations taken during the Study, mainly in India and Indonesia. They are expressed in terms of working time, and allowance should be made for non-working time. With the exception of

† Gang balance: that is the distribution of activities within a task so that all men in a gang can work at much the same pace, without undue time lost while one has to wait, say, for a headbasket to be filled or for a hauler to return with an empty basket.
### Table 3: Typical factors associated with Equipment-Intensive construction methods

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Average Productivity as % Caterpillar Ideal&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Assumed Factors&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Productivity as % Caterpillar Ideal&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line A</td>
<td>Line B</td>
<td>Line A</td>
</tr>
<tr>
<td></td>
<td>Operator&lt;sup&gt;3&lt;/sup&gt;</td>
<td>WT/AT&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Soil</td>
</tr>
<tr>
<td>Wheeled loaders</td>
<td>65</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Tractors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dozers</td>
<td>42.5</td>
<td>0.85</td>
<td>0.8</td>
</tr>
<tr>
<td>Scrapers</td>
<td>40</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

**Notes:**
1. The 'ideal' (best) productivity for various types of plant and conditions is given in the Caterpillar Handbook. Assumed productivities are expressed as a percentage of this ideal.
2. The Handbook discusses many factors which can influence productivity, but three important general ones are operator efficiency, job efficiency and soil.
3. The operator factor is assumed to be similar to operator efficiency in the Caterpillar Handbook.
4. WT—working time, AT—available time, see Section 2.
5. The Working Time/Available Time ratio is assumed to be similar to the job efficiency factor in the Caterpillar Handbook. It is a function of site supervision and organisation.
### Table 4: Productivity Data for Manual Excavation Using Hand Tools

<table>
<thead>
<tr>
<th>Excavation Parameter (Soil Type)</th>
<th>Material Type</th>
<th>Input Coefficient Man-hour (WT)/cu.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cohesive Soil</td>
<td>Non-Cohesive Soil</td>
</tr>
<tr>
<td>0</td>
<td>Very soft</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>Very loose</td>
</tr>
<tr>
<td>2</td>
<td>Soft</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Firm</td>
<td>Loose</td>
</tr>
<tr>
<td>4</td>
<td>Stiff</td>
<td>Compact</td>
</tr>
<tr>
<td>5</td>
<td>Very Stiff</td>
<td>Dense</td>
</tr>
<tr>
<td>6</td>
<td>Hard</td>
<td>Very dense</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>Soft</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>Medium</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>Hard</td>
</tr>
</tbody>
</table>

### Table 5: Load Height Correction for Excavate/Load

<table>
<thead>
<tr>
<th>Loading Height (m)</th>
<th>Excavate-Load Input Coefficient Correction Man-hour (WT)/cu.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line A</td>
</tr>
<tr>
<td>0.3</td>
<td>0.04</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>0.08</td>
</tr>
<tr>
<td>1.0</td>
<td>0.16</td>
</tr>
<tr>
<td>1.5</td>
<td>0.26</td>
</tr>
<tr>
<td>2.0</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**Notes to Tables 4 and 5:**
1. *Excavate* in this context means loosen or break up in-situ soil or rock with hand tools and remove a distance not more than 1 metre.
2. The productivity data given above for *excavate* are also applicable for the combined activities *excavate-load*, but only if these are performed in the same physical action and only if the loading height is zero.
3. When loading height is not zero, a correction to be added to the input coefficients given above can be obtained from the *excavate-load* data listed in Table 5, which is based on observations measured in tonnes and converted at an assumed in-situ soil density of 1.76 tonne/cu.m.
4. All negative loading heights may be taken as —0.3 m.
5. Output in cu. m is measured in-situ prior to excavation.
6. WT — working time.
### Table 6. Productivity Data for Haul and Unload Using Manual Methods

<table>
<thead>
<tr>
<th>Equivalent Haul Distance (m)</th>
<th>Input Coefficient, man-hour (working time)/cu.m.</th>
<th>By headbasket shoulder yoke or similar means</th>
<th>By wheelbarrow ('scooter wheel' type)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line A</td>
<td>Line B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>.19</td>
<td>1.02</td>
<td>.29</td>
</tr>
<tr>
<td>10</td>
<td>.30</td>
<td>1.28</td>
<td>.33</td>
</tr>
<tr>
<td>15</td>
<td>.41</td>
<td>1.54</td>
<td>.36</td>
</tr>
<tr>
<td>20</td>
<td>.53</td>
<td>1.81</td>
<td>.40</td>
</tr>
<tr>
<td>25</td>
<td>.64</td>
<td>2.07</td>
<td>.44</td>
</tr>
<tr>
<td>30</td>
<td>.75</td>
<td>2.34</td>
<td>.48</td>
</tr>
<tr>
<td>35</td>
<td>.87</td>
<td>2.60</td>
<td>.51</td>
</tr>
<tr>
<td>40</td>
<td>.98</td>
<td>2.86</td>
<td>.55</td>
</tr>
<tr>
<td>45</td>
<td>1.10</td>
<td>3.13</td>
<td>.59</td>
</tr>
<tr>
<td>50</td>
<td>1.21</td>
<td>3.39</td>
<td>.63</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
<td>.67</td>
</tr>
<tr>
<td>60</td>
<td>1.44</td>
<td>3.92</td>
<td>.70</td>
</tr>
<tr>
<td>65</td>
<td>1.55</td>
<td>4.18</td>
<td>.74</td>
</tr>
<tr>
<td>70</td>
<td>1.66</td>
<td>4.45</td>
<td>.78</td>
</tr>
<tr>
<td>75</td>
<td>1.78</td>
<td>4.71</td>
<td>.82</td>
</tr>
<tr>
<td>80</td>
<td>1.89</td>
<td>4.98</td>
<td>.86</td>
</tr>
<tr>
<td>85</td>
<td>2.00</td>
<td>5.24</td>
<td>.89</td>
</tr>
<tr>
<td>90</td>
<td>2.12</td>
<td>5.50</td>
<td>.93</td>
</tr>
<tr>
<td>95</td>
<td>2.23</td>
<td>5.77</td>
<td>.97</td>
</tr>
<tr>
<td>100</td>
<td>2.34</td>
<td>6.03</td>
<td>1.01</td>
</tr>
</tbody>
</table>

**Notes:**

1. Equivalent haul distance is the horizontal distance centre of borrow to centre of fill, plus 10 × (vertical distance centre of borrow to centre of fill).
2. *Haul-unload* includes pick-up-load, haul laden, unload, haul unladen and necessary rest only.
3. Figures are calculated for soil with in-situ density 1.76 tonne/cu. m.
4. Output is cu.m. measured in-situ in the borrow area.
### Table 7. Productivity Data for Loading and Unloading Using Hand Tools

<table>
<thead>
<tr>
<th>Loading or Unloading Height (m)</th>
<th>Input Coefficient Man-hour (Working time)/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line A</td>
</tr>
<tr>
<td>-0.3</td>
<td>0.20</td>
</tr>
<tr>
<td>0</td>
<td>0.22</td>
</tr>
<tr>
<td>0.5</td>
<td>0.26</td>
</tr>
<tr>
<td>1.0</td>
<td>0.31</td>
</tr>
<tr>
<td>1.5</td>
<td>0.37</td>
</tr>
<tr>
<td>2.0</td>
<td>0.44</td>
</tr>
</tbody>
</table>

**Notes:**

1. **Loading or unloading** means moving broken-up earth, rock or other loose materials into or out of a haulage vehicle by hand or with hand tools (not, for example, emptying baskets or barrows).
2. All negative loading heights may be taken as -0.3 m.

### Table 8. Productivity Data for Manual Spreading in Earthworks

<table>
<thead>
<tr>
<th>Haulage Mode</th>
<th>Spreading Input Coefficient man-hour (working time)/cu.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line A</td>
</tr>
<tr>
<td>Head basket</td>
<td>0.17</td>
</tr>
<tr>
<td>Wheel-barrows</td>
<td></td>
</tr>
<tr>
<td>Animals</td>
<td>0.25</td>
</tr>
<tr>
<td>Animal carts</td>
<td></td>
</tr>
<tr>
<td>Trailers</td>
<td>0.33</td>
</tr>
<tr>
<td>Trucks</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. **Spreading** means distribute deposited loose soil in a uniform layer 200-400 mm loose thickness, breaking up any large lumps and removing organic matter.
2. Line A, Line B refer to conditions for associated haulage—spreading itself may be daily paid.
3. Output in cu. m. is measured in-situ in the borrow area.
### Table 9. Productivity Data for Manual Spreading in Roadworks

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Layer Thickness or Rate of Spread</th>
<th>Spreading Input Coefficient, Man-hour (working time)/Unit</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Line A</td>
<td>Line B</td>
</tr>
<tr>
<td><strong>Bases and Sub-bases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel sub-base</td>
<td>100 mm</td>
<td>0.25</td>
<td>0.4</td>
</tr>
<tr>
<td>Crushed rock base and sub-base</td>
<td>100 mm</td>
<td>0.25</td>
<td>0.4</td>
</tr>
<tr>
<td>Laterite, murum, etc., for water-bound macadam (WBM)</td>
<td>60 mm</td>
<td>0.45</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Surfacing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bituminous macadam</td>
<td>20-25 mm</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Bituminous macadam</td>
<td>40-80 mm</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Asphalitic concrete overlay</td>
<td>40-50 mm</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Sand-bitumen</td>
<td>1.5 mm</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Seal coat</td>
<td>4 mm</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Chippings for surfacing</td>
<td>20 kg/m²</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Liquids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>0.3-0.8 l/m²</td>
<td>.015</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>..</td>
<td>.003</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. **Spreading** does not include associated loading and hauling from stockpiles or elsewhere.

2. Line A conditions have not been observed for some types of work. It is suggested that the input coefficients may be taken as one-half those given for Line B conditions.
Table 10. Productivity Data for Production of 50 mm Aggregate and 10 mm Chippings Using Hammers

<table>
<thead>
<tr>
<th>Output Material</th>
<th>Input Coefficient for Manual Breaking Man-hour (working time)/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line A</td>
</tr>
<tr>
<td>Production of 50 mm aggregate</td>
<td></td>
</tr>
<tr>
<td>reduction factor $4^1$</td>
<td>.</td>
</tr>
<tr>
<td>Production of 10 mm chippings</td>
<td></td>
</tr>
<tr>
<td>reduction $10^2$</td>
<td>.</td>
</tr>
</tbody>
</table>

**Notes:**

1. The reduction factor is the ratio of mean input size to mean output size.
2. Rock is assumed to be hard, requiring blasting for excavation (e.g., black basalt).

5.1.3. Considerable differences in productivity were noted between tools of different designs and qualities in use on the same sites, for example stone-breaking hammers. Some tools specially designed by contractors' labourers gave unusually high productivities, for instance a heavy crowbar sharpened to a knife-edge and a 'half-pick' made from an old vehicle leaf-spring, both used for excavation of fairly stiff soil.

5.2. Labour Costs

5.2.1. Cost comparisons given in this Paper are based on an unskilled daily wage rate of Rs 4.5 for Line B conditions. It can be seen from Line 9 of Table 2 that the corresponding daily piece-work earnings are Rs 9 where supervision is good (Line A), with an average of Rs 7.2 (Line A*). Plant operators are assumed to earn three times as much as an unskilled daily-paid worker.

5.2.2. It should be noted that the *relative* costs of tools and equipment will decline if wages rise faster than the general level.
of prices, thus making it increasingly worthwhile to employ small amounts of capital to increase labour productivity.

5.3. Simple Equipment

5.3.1. Experiments were carried out during the study using various types of simple equipment; the conclusions are given

![Graph showing input coefficients for labour in the earthworks tasks on level ground.](image)

**Fig. 2.** Input coefficients for labour in the earthworks tasks on level ground.
briefly below, due allowance being made for the cost of equipment and for setting it up and moving it periodically.

5.3.2. Traditional kinds of wheelbarrow with plain bearings gave no advantage over headbaskets, but the 'scooter-wheelbarrow' of 100 kg capacity, having a pneumatic tyred wheel mounted on ball bearings, gave a substantial increase in productivity, Fig. 2. Haulage over fairly level ground, with no more than 2 m lift, is cheaper by wheelbarrow for distances above about 20 m for Line B and 30 m for Line A. As the lift increases, so does this 'break-even' haul distance, which appears to be in the region of 60 to 100 m for a lift of 6 m. An experiment using a 5 hp high-speed winch† to haul barrows through a lift of between 5 and 7 m up a 1-in-2 slope gave preliminary indications that the break-even haul distance between head-baskets and wheelbarrows could be reduced to some 30 or 40 m, after allowing for the cost of the winch. Experiments with other forms of wheelbarrow are continuing.

5.3.3. Systems using hand-propelled wagons running on fixed rails can significantly reduce unit costs of the earth-work tasks (excavate/load/haul/unload/spread) compared with head-basket haulage where the haul distance is greater than 50 m, but such systems are still not competitive with wheelbarrows over the distances tested (up to 100 m).

5.3.4. Manually-operated fixed-rail systems, gravity chutes and aerial ropeways can reduce the unit costs of the task of transporting stone products in quarries by 50 per cent or more, compared with headpan haulage. The greater the haul distance the larger the advantage. To effect any useful cost saving the minimum haul distance appears to be about 30 m, and the minimum quantity moved in each set-up position (excluding minor adjustments) needs to be of the order of several hundreds of tonnes. Ropeways are particularly useful where there is a large rise or fall, since they obviate the need for men to carry their own weight up and down hills.

5.3.5. An improved design of bitumen macadam heating/mixing tray on one site reduced heating times by between 25 and 50 per cent, and firewood consumption per tonne of mix by 40 per cent.

† Speeds in practice were in the region of 50—100 m/min.
5.4. Animals

5.4.1. The principal use of animals in civil construction is for medium distance haulage (say 100–1000 m) in earthworks, using either panniers or carts. Panniers are effective for shorter hauls, particularly where there is a large rise, as in the final portion of a high embankment. Carts begin to become effective for hauls of around 100 m, and are most useful over fairly flat terrain. The work of excavation, loading, unloading and spreading is invariably done by labour, sometimes aided by a certain amount of tipping action where carts are used.

5.4.2. The design of the cart is of great importance. The most successful carts are built up on old truck wheels; they make use of two components of modern industrial origin, the roller bearing and the pneumatic tyre, and can thus be regarded as true examples of ‘intermediate technology’.

5.4.3. Unfortunately the available productivity data for animal haulage are somewhat unsatisfactory, especially in the coverage of the gang balance between labour and animals. Gang balance is often far from ideal since the animals usually work in very small groups. Another problem has been to establish the proper cost of feeding animals, which often feed wholly or partially on land neighbouring the site. Fig. 3 gives input coefficients for the haul and unload activities, which are not affected by the gang balance. Since the owners of all animals observed were being paid piece rates the animal data probably corresponds to something like Line A* conditions (see para 4.2). Data for manual excavation, loading and spreading can be taken from Tables 4, 5, 7 and 8. Table 11 gives estimated animal and cart costs; these comprise, in order of importance, food, cost of cart, animal purchase and veterinary costs.

5.5. Capital Equipment

5.5.1. Equipment productivities used in the analyses in sections 6 and 7 are listed in Table 12. They are expressed in terms of available time, and were obtained in most cases by applying the appropriate factors from Table 3 to the ‘ideal’ productivity given in the Caterpillar Performance Handbook.
Table 11. Estimated Rates for Animals and Carts in India

<table>
<thead>
<tr>
<th>Resource</th>
<th>Hourly Rate, Rs/hr (available time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camel</td>
<td>2.1</td>
</tr>
<tr>
<td>Mule</td>
<td>1.1</td>
</tr>
<tr>
<td>Donkey</td>
<td>0.7</td>
</tr>
<tr>
<td>Camel with cart</td>
<td>2.5</td>
</tr>
<tr>
<td>Mule with cart</td>
<td>1.4</td>
</tr>
<tr>
<td>Ox with cart</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Note: Effective haul length = horizontal haul distance + 10:\( \div \) (Vertical rise)

Fig. 3. Productivity of animals for the haul and unload activities

5.5.2. Table 13 outlines the method of calculating equipment hire rates; these are expressed as ‘hourly usage charges’, excluding operator, and are made up of five main components:

- depreciation, including interest payments
- tax and insurance
- maintenance, excluding tyres
- tyre cost
- fuel and oil

\{ Hourly Rental Charge POL cost \}
<table>
<thead>
<tr>
<th>Item</th>
<th>Activity1 or Task</th>
<th>Conditions &amp; Parameters</th>
<th>Input Coefficient machine²-hr(AT)/1000 cu.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Line A</td>
</tr>
<tr>
<td>Dozer</td>
<td>D7 180 hp</td>
<td>ELHU Soft rock in mountain road, haul 15 m</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>-do-</td>
<td>-do- haul 90 m</td>
<td>38.8</td>
</tr>
<tr>
<td></td>
<td>ELHUS</td>
<td>-do- Firm soil, bulk fill haul 15 m</td>
<td>5.05</td>
</tr>
<tr>
<td></td>
<td>-do-</td>
<td>-do- haul 90 m</td>
<td>17.7</td>
</tr>
<tr>
<td></td>
<td>-do-</td>
<td>-do- extra for stiff soil</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>-do-</td>
<td>-do- extra for very stiff soil</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>-do-</td>
<td>-do- extra for hard soil</td>
<td>1.1</td>
</tr>
<tr>
<td>Motor scraper</td>
<td>621 11 m³</td>
<td>ELHUS Firm soil, bulk fill haul 200 m</td>
<td>7.51</td>
</tr>
<tr>
<td></td>
<td>-do-</td>
<td>-do- haul 600 m</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>EL</td>
<td>-do- any haul length</td>
<td>2.96</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>-do- Soil, gravel</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>-do- aggregates</td>
<td>3.13</td>
</tr>
<tr>
<td>Dozer, D8, pushing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>621 scraper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grader</td>
<td>12F</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dozer</td>
<td>D8 1 No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheeled loader</td>
<td>988 1 No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dump truck</td>
<td>769B 2 No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dozer</td>
<td>D8 3 No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheeled loader</td>
<td>988 3 No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dump truck</td>
<td>769B 8 No.</td>
<td></td>
</tr>
</tbody>
</table>

(Contd.)
<table>
<thead>
<tr>
<th>Item</th>
<th>Activity or Task</th>
<th>Conditions &amp; Parameters</th>
<th>Input Coefficient machine²-hr(AT):1000 cu.m.</th>
<th>Line A</th>
<th>Line B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 12—(Contd.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor (Hauling 5-t trailers)</td>
<td>50 hp LHU</td>
<td>-do- aver. speed 12 km/h, haul 1.0 km</td>
<td>97</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>Tractor (Hauling 3-t trailers)</td>
<td>35 hp LHU</td>
<td>-do- aver. speed 12 km/h, haul 1.0 km</td>
<td>774</td>
<td>1287</td>
<td></td>
</tr>
<tr>
<td>Crushing plant</td>
<td>50-60 t/hr</td>
<td>P 50 mm output (reduction factor 4)</td>
<td>50 mm output (reduction factor 20)</td>
<td>24.5</td>
<td>42.7</td>
</tr>
<tr>
<td>Mobile crusher</td>
<td>6-8 t/hr</td>
<td>P 50 mm output (reduction factor 4)</td>
<td>36.8</td>
<td>64.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P 10 mm output (reduction factor 20)</td>
<td>276</td>
<td>481</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. E—Excavate
2. Cu.m. measured in borrow pit.
   L—Load
   S—Spread
   H—Haul
   P—Produce
   AT—available time, see Section 2.
The analyses in sections 6 and 7 are based on slightly lower equipment rates, based on more optimistic assumptions as to repairs, tyre life and other factors: the rates are listed in the right hand column of Table 13.

5.6. Mixed Labour and Capital Equipment

5.6.1. Most items of capital equipment have very much larger rates of production than labour and it is often difficult to balance men and machines so that the latter are employed effectively. When machines are significantly under-utilised their hourly usage rates are of course higher than those quoted in Table 13.

5.6.2. Hand-loading of trucks is often uneconomic, involving large losses through vehicle loading delays. Indian contractors have answered this problem by developing another example of ‘intermediate technology’; the re-use of aged trucks which have served their useful lives as fast, road-going vehicles. They are therefore cheap to buy, but can still give several years’ useful service to an operator with the necessary time, skills, second-hand parts and so on. The estimated usage charge for such a truck, carrying a reduced payload of 5 tonnes, is about Rs 20 per hour, against Rs 36 per hour estimated for a new Indian made vehicle of the same capacity. To minimise vehicle waiting-time during loading, the owners often operate with loading parties of up to 16 men.

5.6.3. Another means of reducing costs of loading delays is to use a tractor with two or more trailers: one trailer is loaded while the other is being hauled and vice versa. To be successful such an operation needs to be very carefully organised; the equipment must be of the right type and in good mechanical order; two-wheel trailers should be used except for virtually level hauls, for better traction; hydraulic hooks must be operational; and, haul routes kept in good condition.

5.6.4. Productivity and usage charges for trucks, tractors, and trailers is given in Tables 12 and 13, while Fig. 1 can be used for labour loading productivity.

5.6.5. The possibility of developing smaller machines, as a solution to the discrepancy in scale between existing equipment
### Table 13. Equipment Hire Rates

<table>
<thead>
<tr>
<th>Resource Description</th>
<th>Latest Estimates</th>
<th>July 1976</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delivered Cost¹</td>
<td>Total Tyre Cost²</td>
</tr>
<tr>
<td></td>
<td>Rs 000</td>
<td>Rs 000</td>
</tr>
<tr>
<td>Scraper, motorised</td>
<td>621B struck</td>
<td>1420</td>
</tr>
<tr>
<td>Dozer</td>
<td>D7F</td>
<td>934</td>
</tr>
<tr>
<td>Dozer</td>
<td>D8H</td>
<td>1340</td>
</tr>
<tr>
<td>Grader</td>
<td>12G</td>
<td>670</td>
</tr>
<tr>
<td>Tracked excavator</td>
<td>931 62hp</td>
<td>270</td>
</tr>
<tr>
<td>Wheeled loader</td>
<td>910 65hp</td>
<td>330</td>
</tr>
<tr>
<td>Wheeled loader</td>
<td>988 325hp</td>
<td>1410</td>
</tr>
<tr>
<td>Truck, dump</td>
<td>769B 35t</td>
<td>1520</td>
</tr>
<tr>
<td>Truck, tipping</td>
<td>7-8t 6cu.m</td>
<td>150</td>
</tr>
<tr>
<td>Truck, flatbed</td>
<td>7-8t 6cu.m</td>
<td>110</td>
</tr>
<tr>
<td>Farm tractor</td>
<td>30hp</td>
<td>52</td>
</tr>
<tr>
<td>Farm tractor</td>
<td>50hp</td>
<td>70</td>
</tr>
<tr>
<td>Tipping trailer</td>
<td>3t 2cu.m</td>
<td>17</td>
</tr>
<tr>
<td>Tipping trailer</td>
<td>5t 3.5cu.m</td>
<td>19</td>
</tr>
<tr>
<td>Wheelbarrow</td>
<td></td>
<td>0.36</td>
</tr>
<tr>
<td>Roller, self-prop. steel wheeled</td>
<td>8-10t</td>
<td>190</td>
</tr>
<tr>
<td>Mobile crusher/granulator</td>
<td>6-8t/hr</td>
<td>89</td>
</tr>
<tr>
<td>Crushing plant</td>
<td>50-60t/hr</td>
<td>800</td>
</tr>
</tbody>
</table>

(Contd.)
Notes to Table 13

1. Delivered Cost = Initial Cost + Shipping Cost + Duty
   - Initial Cost:
     (a) Free on board in U.S. port, approximate January 1976 price (source: Caterpillar Co.) for scraper dozers, grader, tracked excavator ('traxcavator') 988 loader, 769B truck, @ US $1 = Rs. 8.9;
     (b) 910 U.K. FOB price, June 1976 @ £1 = Rs. 16;
     (c) 6 cu.m. flat and tipping trucks and roller, Indian price 1976;
     (d) Tractors and trailers, U.K. FOB prices, early 1976 @ £1 = Rs. 18;
     (e) Wheelbarrow, Indian delivered price, 1976;
     (f) Mobile crusher, crushing plant, estimated prices.
   - Shipping Cost:
     (a) Actual cost (source IBRD) for scraper, dozers, grader, tracked excavator, 988 loader, 769B dump truck, @ US $1 = Rs 8.9;
     (b) Other imported items, 10% initial cost assumed;
   - Duty:
     Customs and/or excise duty (combined) 10% of initial cost (FOB)

2. Tyre Cost:
   - (a) U.S. prices (early 1976) for scraper, grader, 988 loader 769B truck @ US $1 = Rs. 8.9;
   - (b) 910 loader, tractors and trailers, U.K. prices @ £1 = Rs 18;
   - (c) Flat and tipping trucks, estimated prices.

3. Tyre Life:
   Estimated on basis of Caterpillar Handbook, assuming average conditions for all equipment.

4. Utilisation = annual working season (days) x nominal day (hr) x lost time factor (t).
   In this case: 192 days x 8 hrs (AT)/day.
   t = 0.8 for dozers, towed scrapers and rollers, tractors, trailers and crushers, 0.65 for all other items.

5. Repair Factor: Estimated so as to give total maintenance cost during machine life of about 100 per cent of depreciable cost for heavy equipment. 0.10 assumed for motorised wheeled vehicles, 0.05 for towed equipment, 0.12 for tracked vehicles.

6. Fuel & Oil: Source: Caterpillar Co. for Caterpillar equipment, consumption for other items estimated on basis of hp.

7. Depreciation = (Delivered Cost less Total Tyre Cost) x Capital Recovery Factor (CRF) ÷ Utilisation
   - CRF = \( \frac{i(1 + i)^N}{(1 + i)^N - 1} \)
     \( i \) = Interest Rate expressed as a fraction, assumed in table as 0.12 (12 per cent pa).
     \( N \) = Operating Life in years ÷ Utilisation
     = Economic life ÷ Utilisation

8. Tax/Insurance: this is assumed to average 3 per cent of initial cost.

9. Maintenance Charge:
   (Delivered Cost less Total Tyre Cost)
   x Repair Factor ÷ 1000

10. Hourly Rental Charge:
   sum of Depreciation, Tax/Insurance, Maintenance and Tyre Charges: sums may not be exact due to rounding.

11. Fuel cost: assumed to be diesel in all cases, a: Rs 1.4 per litre.

12. Oil Cost: assumed to be Rs 7.1 per litre.

13. Hourly Usage Charge:
   Sum of Hourly Rental, Fuel and Oil Charges: sums may not be exact due to rounding.

14. Hours: defined in terms of Available Time (AT) in all classes.
and labour looks unpromising. Below a certain threshold horsepower the energy required to shift a given amount of material appears to rise steeply, a phenomenon illustrated in Fig. 4, which has been prepared from Caterpillar productivity information.

![Graph showing energy input for earthmoving by bulldozer]

**NOTES:**
1. Energy calculated on basis of machine-hour (Available Time)/m³ x 60% rated engine power (kw)
2. The energy does not include any used to make the machine, transport fuel etc.

**Fig. 4.** Energy input for earthmoving by bulldozer

The theoretical basis for the existence of the threshold may be that a certain minimum force is required to cut the soil. Before any definite conclusion can be drawn, however, further work needs to be done to determine:

(a) whether the pattern shown in Fig. 4 has general validity; and

(b) if so, does the increase in unit energy costs for smaller machines outweigh any advantage which they may have in terms of better utilisation on small-scale works?

**5.7. Organisational Improvements**

5.7.1. Productivity of both labour and equipment can often be increased by some re-organisation on site, and a number of examples are given below:
(1) In the work of manual excavation in side-long cut for a hill road there is a tendency towards excessive double handling of material and interference between excavators and loaders. In one example, the use of a bench method of excavation in combination with wheelbarrows for haulage, as depicted in Fig. 5, tripled labour productivity and halved costs.

![Diagram](image)

<table>
<thead>
<tr>
<th>DAY</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXCAVATION</td>
<td>A-1</td>
<td>A-2</td>
<td>B-1</td>
<td>B-2</td>
<td>C-1</td>
<td>C-2</td>
<td>D-1</td>
<td>D-2</td>
<td>E-1</td>
<td>E-2</td>
<td>F-1</td>
<td>F-2</td>
<td></td>
</tr>
<tr>
<td>HAULAGE</td>
<td>A-1</td>
<td>A-2</td>
<td>B-1</td>
<td>B-2</td>
<td>C-1</td>
<td>C-2</td>
<td>D-1</td>
<td>D-2</td>
<td>E-1</td>
<td>E-2</td>
<td>E-2</td>
<td>F-1</td>
<td>F-2</td>
</tr>
</tbody>
</table>

*(Spoil heap material from A-1 etc.)*

**SCHEDULE OF EXCAVATION AND HAULAGE**

Fig. 5. Bench method of excavation in side-long cut

(2) A large increase in labour productivity was obtained by reorganising a stone quarry (i) to separate activities of excavation and collection and (ii) to ensure that blasting takes place outside normal working hours.

(3) It has sometimes been observed that production from mobile stone crushers is lost because the jaws are not kept filled 100 per cent of the time. Such a state of affairs can be remedied by rationalising the layout of the feed stockpile and the labour gang, so as to allow a plentiful supply of stone to the crusher and to create a platform for gravity feeding.

(4) Use of ramps, platforms and chutes can increase the rate of loading vehicles by between 25 and 50 per cent, with a corresponding reduction in manpower input. The cost of preparing the installation is generally justified if the quantity of material to be handled exceeds a figure of between 200 and 1000 tonnes, the precise value depending upon the nature of the job.
6. COST COMPARISONS FOR SELECTED TASKS

6.1. In this section costs of various methods of carrying out certain important road-building tasks are compared, using the factors listed in Tables 2 and 3 and the productivity and cost data given in Tables 4 - 13 inclusive† and para 5.2.1. As noted in para 5.2.2., the conclusions would vary if the relationship between wage rates and equipment rates were to change. All costs are expressed as ‘Total Production Costs’, including supervision and other overheads.

6.2. Fig. 6 shows the costs of the cut-to-spoil earthworks task (excavate/load/haul/unload) in soft rock in side-long cut,

![Graph showing total production cost/haul distance relationships for the earthworks task in cut-to-spoil](image)

**NOTES.**
1. Task includes excavation, load, haul, and unload.
2. Excavation is in soft rock.
3. Total production cost includes overheads and supervision.
4. Assumed unskilled labour daily wage (Line B) Rs 4.5, daily piecework earnings (Line A) Rs 9.

Fig. 6. Total production cost/haul distance relationships for the earthworks task in cut-to-spoil

† It should be remembered that Line A represents relatively good piecework productivity while Line B represents rather poor daily-paid productivity, so the results for the two sets of conditions should not be compared. Line 12 of Table 2 suggests that for labour intensive methods the average total production costs of work by piecework and daily-paid labour are in the ratio of 0.85 : 1.
USE OF LABOUR-INTENSIVE METHODS FOR ROAD CONSTRUCTION

typical of hill road construction, by:

1. D7 dozer
2. Hand excavation and loading with headbasket haulage
3. Hand excavation and loading with wheelbarrow haulage.

The cost by dozer is greater than that by the optimal labour-intensive method for all haul distances, the relative disadvantage of the dozer rising sharply with distance.

6.3. Fig. 7 combines cost data for a large variety of haul methods for the earthworks task, consisting of excavate/load/

\[ \text{TOTAL PRODUCTION COST (Rupees per cu m)} \]

\[ \text{HAUL DISTANCE (m)} \]

NOTES: 1. For details of task and methods see text para. 6.2.
2. (A) = Line A, (B) = Line B
3. Total production cost includes overheads and supervision.
4. Assumed unskilled labour daily wage (Line B) Rs 4.5, daily
   piecework earnings (Line A) Rs 5.

Fig. 7. Total production cost/haul distance relationships for the earthworks task in borrow-to-fill
haul/unload/spread, in average (firm) soil in relatively flat terrain typifying both low and high embankment construction roads in plains. Details of methods are as follows:

1. D7 dozer for all activities.
2. Cat 621 motor scraper, D8 pusher, 12G grader.
3. Cat 769B (35-tonne) dump truck, 988 wheeled loader, excavation by D8 dozer, spreading by 12G grader.
4. Headbasket and labour.
5. Wheelbarrow and labour.
6. 35 hp tractor and 3-tonne tipping trailers, manual excavation, loading and spreading.
7. Mule with panniers and labour.
8. Mule-cart and labour.
9. Camel-cart and labour.
10. Second-hand truck of 5-tonne capacity and labour.

For methods 7 and 8, no daily-paid data are available. Data for methods 9 and 10 are based on observations at one site only and are intended merely to indicate the sort of costs which can be produced by efficient contract working with camels and old trucks.

6.4. The conclusion from Fig. 7 is that labour-intensive methods, using headbaskets or wheelbarrows as appropriate, are cheaper than machines up to around 150 m. Under piece-work conditions, however, animal-carts can be cheaper than both labour and machines for distances in the region of 100 m and upwards, while second-hand trucks can also be economical above about 200 m. Where animal-carts and second-hand trucks are not available, as is usually the case with daily-paid direct labour, a comparison of Line B costs indicates that tractor/trailers can work economically over haul distances greater than about 200 m.

6.5. Analysis similar to the above were done for transport (load: haul/unload) of stone and soils by road, between 1 and 10 km, for four methods:

1. 50 hp 5-tractor, tonne tipping trailer, hand-load.
2. 7-tonne flatbed truck, hand-loaded and unloaded.
3. 7-tonne tipping truck, loaded by Cat 910 wheeled loader.
4. For Line A only, 5-tonne capacity second-hand trucks, hand-loaded and unloaded.
Use of labour-intensive methods for road construction

Under Line B conditions, the fully mechanised method (3) appears to be the cheapest, but tractor/trailers are only marginally more expensive up to 4 km, and costs by flatbed truck closely approach the mechanised method at distances over 4 km. Under Line A conditions hand-loaded second-hand flat trucks are the cheapest method over all distances, while the use of hand-loaded new vehicles is still competitive with the other methods for hauls greater than 2 km.

6.6. Table 14 gives comparative costs of producing aggregates for WBM (50 mm) and for 10 mm chippings. The figures are based on 200 mm size input stone for WBM, 100 mm for chippings.

7. Break-even wage rates

7.1. In assessing the economic feasibility of labour-intensive methods it is helpful to use the concept of the break-even wage for unskilled labour. This is defined as that wage at which the cost of carrying out a task by labour is equal to the cost by

Table 14. Comparative Costs of Aggregate Production

<table>
<thead>
<tr>
<th>Method</th>
<th>Total Production Cost, Rs/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 mm output</td>
</tr>
<tr>
<td></td>
<td>Line A</td>
</tr>
<tr>
<td>1. 50-60 tonne/hr crushing plant loaded by tractor</td>
<td>15.4</td>
</tr>
<tr>
<td>2. 6-8 tonne/hr mobile crusher loaded by hand</td>
<td>12.5</td>
</tr>
<tr>
<td>3. Hand-breaking</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Notes: (1) Daily wage for daily-paid labour (Line B) Rs 4.5, daily earnings for pieceworkers (Line A) Rs 9.

(2) Total production costs include supervision and other overheads.
equipment, for a given set of equipment hire rates. Algebraically, comparing any two methods,

$$ W = \frac{E_1 - E_2}{l_2 - l_1} $$

where $W =$ break even wage

- $E_1 =$ equipment cost for method 1
- $l_1 =$ labour input (man-days) for method 1 per unit of output
- $E_2 =$ equipment cost for method 2
- $l_2 =$ labour input (man-days) for method 2

The greater the value of $W$, the more advantageous is the substitution of labour for equipment.

7.2. The concept of a break-even wage is explained graphically in Fig. 8, which plots the total production cost (including overheads) against the wage rate for an example task. As in the cost comparison graphs, Lines A and B are used to represent scatter in the data (see footnote to para 6.1). Since Line A pieceworkers earn about twice as much as corresponding Line B

![Fig. 8. Break-even wage rates for the earthworks task with 60 m haul distance and average soil](image-url)
daily-paid workers (Table 2, line 9) the wage scale for the former in Fig. 8 is twice that for the latter. The break-even wage rates under ‘like’ conditions are represented in Fig. 8 by the two circles labelled $A_1 A_2$ and $B_1 B_2$, for Line A and Line B conditions respectively. The two crosses labelled $A_1 B_2$ and $B_1 A_2$ represent the break-even wages under ‘unlike’ conditions, which are particularly favourable in the first case to method 1, in the second to method 2.

7.3. Under comparable ‘like’ conditions, the break-even wage rate varies between Rs 8/day for Line B to Rs 21/day for Line A, this last figure corresponding to an environment in which wages for daily paid labour are Rs 10.5/day.

7.4. The graphs in Fig. 8 refer to the earthworks task (excavate/load/haul/unload/spread) for 60 m haul distance up to a 2 per cent grade and average (firm) soil. Clearly for other tasks, or for the same task but with different haulage or excavation parameters, the cost functions and consequently the break-even wage rates will be different. For example, soil hardness has a more pronounced effect on manual excavation than upon excavation by machine, with the result that the break-even wage decreases with increasing soil hardness.

7.5. Table 15 lists the break-even wage rates for both ‘like’ ($A_1 A_2$ and $B_1 B_2$) conditions and for ‘unlike’ ($B_1 A_2$ and $A_1 B_2$) conditions for all the task method combinations compared in section 6, excepting animal methods and contractors’ second-hand trucks. Method 1 in Table 15 represents the equipment-intensive method, Method 2 is labour-intensive or intermediate. For only three of the tasks listed does the break-even wage rate under ‘like’ conditions fall below the level of Rs 5 per day for daily paid workers ($B_1 B_2$) or below Rs 9 per day for piece workers ($A_1 A_2$); these tasks are earthworks for 960 m haul, 5 km haul of road material and production of 10 mm chippings. In the first two cases under Line A conditions (i.e. generally contract work) the use of second-hand trucks by contractors has been calculated independently to raise the break-even earnings to over Rs 12 per day.

7.6. To demonstrate the meaning of break-even wage rates for a complete project or sub-project, the methods of analysis †
### Table 15: Break-even Wage Rates for Selected Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Method(^1) 1</th>
<th>Method(^1) 2</th>
<th>Break-Even Wage Rate (Rupees/day)(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(B_1B_2)</td>
</tr>
<tr>
<td><strong>Earthworks Borrow-to-Fill</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(excavate, load, haul, unload, spread)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 m haul</td>
<td>Dozer</td>
<td>Labour, headbasket</td>
<td>5.5</td>
</tr>
<tr>
<td>60 m haul</td>
<td>Dozer</td>
<td>Labour, wheelborrow</td>
<td>8</td>
</tr>
<tr>
<td>120 m haul</td>
<td>Motor, Scraper, dozer pusher, grader</td>
<td>Labour, wheelborrow</td>
<td>7.5</td>
</tr>
<tr>
<td>240 m haul</td>
<td>Dozer, wheeled loader</td>
<td>Labour, tractor/trailer</td>
<td>6.5</td>
</tr>
<tr>
<td>480 m haul</td>
<td>dump truck</td>
<td>Labour, tractor/trailer</td>
<td>7</td>
</tr>
<tr>
<td>960 m haul</td>
<td></td>
<td>Labour, tractor/trailer</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Earthworks, Cut-to-Spoil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(excavate, load, haul, unload)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 m haul</td>
<td>Dozer</td>
<td>Labour, headbasket</td>
<td>6</td>
</tr>
<tr>
<td>20 m haul</td>
<td>Dozer</td>
<td>Labour, headbasket</td>
<td>6.5</td>
</tr>
<tr>
<td>40 m haul</td>
<td>Dozer</td>
<td>Labour, wheelbarrow</td>
<td>7</td>
</tr>
<tr>
<td><strong>Road material Haulage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(load, haul, unload)</td>
<td></td>
<td>Labour, wheeled loader</td>
<td>8</td>
</tr>
<tr>
<td>1 km haul</td>
<td>tipping truck,</td>
<td>Labour, tractor/trailer</td>
<td>0.2</td>
</tr>
<tr>
<td>5 km haul</td>
<td></td>
<td>Labour, flatbed truck</td>
<td>..</td>
</tr>
<tr>
<td><strong>Aggregate Production</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 mm size</td>
<td>6-8 tonne/hr crusher</td>
<td>Labour</td>
<td>6</td>
</tr>
<tr>
<td>50 mm size</td>
<td>50-60 tonne/hr crusher</td>
<td>6-8 tonne/hr crusher</td>
<td>9</td>
</tr>
<tr>
<td>10 mm size</td>
<td>6-8 tonne/hr crusher</td>
<td>Labour</td>
<td>2.5</td>
</tr>
<tr>
<td>10 mm size</td>
<td>50-60 tonne/hr crusher</td>
<td>6-8 tonne/hr crusher</td>
<td>9</td>
</tr>
</tbody>
</table>

Notes:
1. For details of methods, see:
   - para. 6.3. for earthworks borrow-to fill,
   - para. 6.2. for earthworks cut-to-spoil,
   - para. 6.5. for road material haulage,
   - para. 6.6. for aggregate production.

2. For figures are expressed in terms of the daily-paid wage rate. Corresponding piece rate earnings are given in brackets.
and productivity and cost assumptions described in this Paper were applied to two stretches of NH-12, which is presently being constructed between Bhopal and Jabalpur. One stretch is a plain section incorporating the earthworks in the approach to a major bridge; the other lies partly through hill country or "Ghat".

7.7. Analysis showed that, if compaction and water haulage are excluded, three major operations contribute 50 per cent of the project cost, namely (i) earth works, (ii) excavation and haulage of murum, and (iii) production and haulage of aggregate for WBM. (Of the balance 50 per cent, structures comprise 35 per cent, and surfacing, including bitumen cost, compaction and water haulage the other 15 per cent). The break-even wage rates for the various tasks making up these three major operations, for both the stretches of road, range from Rs 3.5 - 7 per day for daily-paid workers under Line B conditions, and from Rs 11 - 23 per day for pieceworkers under Line A conditions, with 'project level' averages of Rs 5.5 and 16 per day respectively.

7.8. These rates correspond fairly closely with those in Table 15. The main differences between the assumptions underlying Table 15 and the factors applying specifically to the NH-12 project (the last two of which have a cancelling effect) were that in the latter case:

(1) Second-hand trucks are assumed for Line A 'labour intensive haulage', but not for Line B (see Fig. 7 and Table 15).

(2) Under Line B conditions it was assumed that wheelbarrows are not used, since local female labour refuse to use them.

(3) Labour productivity was reduced by some 10-20 per cent to allow for family labour.

(4) Heavy equipment charges were increased by 20 per cent on account of remoteness.

7.9. The conclusion from the analysis in this section is that it is economic to build roads in India by direct labour, using manual and intermediate methods, wherever daily-paid labour wage rates lie before about Rs 5 per day, even with relatively poor organisation. Where daily wages lie about this figure, to justify manual methods on a cost basis, either supervision must be improved or incentives applied. In the absence of both these possibilities, the least cost solution will require progressive substitution of equipment as wages rise, starting with those tasks which have the lowest break-even wage rates.
8. OTHER FACTORS AFFECTING CHOICE OF TECHNOLOGY

8.1. This section briefly mentions a number of important factors affecting the choice between manual and mechanical methods. Most of these factors are related to the design of the road especially to the materials specifications.

8.2. In many respects it is evident that Indian roads are already designed with manual methods in mind. Thus the widespread use of WBM instead of smaller-sized aggregates and the minimising of haulage in earthworks by moving soil perpendicular to, rather than parallel to, embankments both represent designs which lend themselves to hand methods.

8.3. It is in the fields of surfacing and compaction that the least economic opportunity for labour-intensive methods arises. Hand-breaking of chippings has a very low break-even wage rate (see Table 15); and existing quality standards generally require the use of a paver to lay surfacing materials, and of a roller weighing several tonnes for most road compaction tasks. Large surfacing and compaction equipment, when used in conjunction with manual methods for other tasks, tends to be much too large for the scale of job and often suffers from gross underutilisation†. There is therefore scope for reducing the equipment element of road construction costs by relaxing standards of compaction and surface finish, wherever feasible.

8.4. Finally, use of labour rather than machines can sometimes reduce the total quantity of work in a project; for example:

(1) Boulders can be picked out by hand from excavated soil and re-used for aggregates.

(2) Labourers are able to exploit the fissures of some kinds of medium hard rock so as to excavate it without blasting, whereas such rock cannot readily be ripped.

(3) In hill cutting, labour can excavate to finer tolerances than can machines, so that the volume of excavation is reduced, and, incidentally, the slopes are more cleanly dressed.

(4) On high embankments, with hauls from lateral borrow areas, labour and animals have the advantage of being able to climb up in a fairly direct path, while machines need to make long detours up ramps.

† Ratios of working to available time of 20 per cent are not uncommon.
9. CONCLUSIONS

9.1. The break-even wage rate for most road construction tasks lies somewhere between Rs 5 and 20 per day, tending towards the lower values where organisation is poor and where labour is daily-paid, and towards the higher values where organisation is good and piecework is in operation. In India where wage rates, or daily earnings for pieceworkers, generally lie between Rs 2.5 and 10, labour-intensive methods of road construction are generally economical and they often have the additional merit of reducing the quantity of work needing to be done. Labour and animal methods have particular advantages in earthwork haulage up to about 500 m and in stone breaking down to a size of about 25 mm.

9.2. It is nevertheless possible to obtain substantial increases in the productivity of labour-intensive methods by organisational means such as:

(a) the detailed planning, at site level, of labour-intensive works, for example to avoid interference between activities, to ensure orderly arrival of materials and vehicles on site, to avoid double handling of materials, to schedule earthworks early in the season when the earth is soft, etc.; and

(b) improved supervisory and organisation on site, with particular attention to gang balance, along with the establishment of some type of incentive payment scheme.

9.3. In the field of tools and small-scale equipments, the following conclusions were drawn:

(1) Significant increases in manual productivity can be achieved by the use of appropriate, well-designed hand tools and by their proper maintenance.

(2) Wheelbarrows with ball bearings and pneumatic tyres are clearly less costly than headbaskets for hauls of more than 20–30 m, as long as the rise is not more than about 2m; as the rise increases so does the break-even haul distance, but a suitably designed winch may solve this problem.

(3) None of the rail systems devised could improve upon the performance of the wheelbarrow in the earthworks task and have, at best, limited application in this type of work.

(4) Tractor-trailers are probably superior to hand-loaded trucks for haulage on fairly level ground up to between 2 and 5 km where the work is organised on a departmental basis; but the former are unlikely to become competitive with contractors' second-hand trucks, nor, for distances below about 1 km, with animal carts.
(5) Manually operated rail systems, ropeways and chutes can have value for hauling stone products in quarries.

(6) Scaled down versions of conventional earth-moving machines are unlikely to be economical for large scale applications.

9.4. India already possesses a thriving ‘intermediate technology’, based not on small-scale machinery so much as on the use by small contractors of certain industrially produced components such as roller bearings and pneumatic tyres, and the re-use of worn-out industrial products such as old trucks and vehicle wheels.

9.5. There are certain tasks where a certain equipment input is at present inevitably required, for instance high quality compaction and surfacing work, long distance haulage (more than about 1 km) and production of chipping smaller than 20 mm. It is sometimes possible, however, to employ some labourers on such tasks by using suitable types of equipment, such as hand-loaded trucks or crushers; and continuation of present research into quality and material requirements for earthworks, base and surfacing materials may eventually permit alternative road designs which reduce the need for these tasks.

ACKNOWLEDGEMENTS

The Authors wish to thank the following persons for their help throughout the duration of the Study in India, without whose help the Study could not have been a success: Shri J. S. Marya and Shri S. L. Kathuria of the Ministry of Shipping & Transport (Roads Wing), Shri J. S. Bali, Secretary of the Border Roads Development Board, the Director General, Border Roads, and the many engineers on his staff who gave such valuable assistance in both office and field. We should also like to thank the numerous other engineers who assisted the Study for shorter periods in various parts of the country, including a considerable number of the engineering staff under the direction of Shri B. G. Naik, Engineer-in-Chief of the M.P., P.W.D. in Bhopal.
DISCUSSIONS
Shri J. S. Marya (Chairman's Opening Remarks)

Before I read out my introductory remarks, I would just wish to say a few words about the background of this study. It was around the year 1973 when we had the first communication from the World Bank showing great interest in undertaking a scientific study of this nature in this country as India occupied a very important position in regard to the labour-intensive techniques in civil engineering profession. The Government of India welcomed this offer and readily agreed.

The study has been carried out by the Bank with their consultants in close collaboration with the various organisations of the Government of India including the Roads Wing of our Ministry, the Border Roads Organisation and the Irrigation Ministry. Conclusions of this study which are a result of almost three years' work have been reported in a large number of technical memoranda and study reports. Papers for the Panel Discussion, based on these documents are going to provide us a good opportunity of exchanging our ideas on this important subject.

In the light of the historical background explained by me, I have great pleasure in welcoming you all to this Panel Discussion. I am sure you will all agree that the discussion is on one of the most topical subjects engaging our attention today. It is not infrequent that engineers, engaged in planning and construction of civil works are posed with the question of appropriate technology for the construction of a road, canal or a bridge structure. Choice can be between equipment-intensive methods, labour-intensive methods, or a blend of the both. Final selection is governed invariably by several considerations. First is the economic feasibility, or the selection of the cheapest method. Second is the employment, which cannot be ignored in developing countries where unemployment is generally chronic. As a matter of fact, in developing countries, civil constructions like roads and minor irrigation works figure high in the development programme especially because of their potential to generate additional employment.

At the same time, there are also other important factors to consider, for instance technical feasibility, project size, schedule
of completion, etc. In many circumstances, use of machinery may be more economical because of the sheer size of the job or the tight programme of work. Between the two extremes, no doubt there are several intermediate situations.

Since the circumstances can be so varying, it is but understandable that opinions about the selection of the optimum technology should differ so widely. In literature, one finds staunch proponents of manual labour as well as equipment. Amidst this continuing controversy, it is welcome indeed that the World Bank pioneered the first-ever scientific study about the viability of the various construction methods so that doubts and difference of view in this regard could be resolved one way or the other.

The World Bank study consisted of several phases. An initial literature survey formed Phase I of the study. As a follow-up, the Bank undertook Phase II study in which factual data about the productivity of both labour-intensive and equipment-intensive methods was collected in India and Indonesia. This study extending over a year was completed towards the end of 1973. The Ministry of Transport (Roads Wing) assisted the Bank in this phase by way of requesting the States concerned to provide the required facilities. Subsequently, the Bank initiated further studies in India with the objective of exploring, firstly the means by which labour productivity at the task level could be increased, and secondly how the techniques and tools thus developed could be used in combination with labour on full-scale projects. The first part of this study, known as Phase III-A was completed in mid 1974 with the collaboration of the Border Roads, while the second part, i.e., Phase III-B was completed only recently on National Highway No. 12 in Madhya Pradesh.

Because of this link with Madhya Pradesh, I am really glad that we are having a Panel Discussion on the subject in Bhopal itself. While providing an excellent opportunity for dissemination of the findings, I am sure the subsequent discussions will lead to a better appreciation of both sides of the picture. To my mind, both manual methods and machines are indispensable to developing countries. Primary question is to what extent the two should be blended together under different situations. Discussion today should provide us with some answer.
Discussions this afternoon will centre around two Papers. The first Paper is by Shri Sud, Dr. Harral and Shri Coukis of the World Bank while the second is by Sarvashri Green and Brown of the consultant firm who actually did the field work for the study. In turn, these Papers are based on a series of detailed reports separately brought out by the Bank.

Before we have open discussion, the authors will introduce their Papers and the Reporter of the Panel Discussion will present a brief resume on the topic for channelising discussions.

First I call upon Dr. Harral to introduce his Paper.

Dr. Clell G. Harral (Author’s Introductory Remarks)

It is indeed an honour to appear before you this morning. It is an added pleasure to see so many old friends in the audience who have worked with us in this study and earlier endeavours over the years. I must express the deep appreciation of the World Bank and the nine Governments who have donated financial support to this large research study to Shri Marya and to his predecessor in the Central Roads Wing, Shri S. N. Sinha, to the Border Roads Organisation, to the Central Water Commission and to the several State Governments who have released their personnel in support of the study and provided generally the support and co-operation without which this study would have been impossible. I only wish that time permitted me to cite each and every one by name, but that is impossible. Please accept our heartfelt thanks.

Mr. Chairman, unemployment and under-employment of human resources is a problem of grave proportions to mankind not only in India but in much of the rest of the World, and particularly in many of the economically most deprived countries which are the proper focus of the World Bank and other international and bilateral development agencies. It is generally acknowledged that productive employment opportunities must be created for large segments of the population to foster economic growth with distributional equity. In this regard, it has been increasingly questioned in recent years whether the highly capital-intensive technologies developed in the labour-scarce, capital rich economies of Europe and North America are appropriate to the labour-abundant, capital-scarce economies of Asia, Africa and much of Latin America.
In no sector has this question been more frequently raised nor more fiercely debated than in civil construction. It is easy to understand why this is so. In civil construction there exists a pronounced dichotomy between traditional labour-intensive methods and modern capital-intensive technology. One machine costing a million rupees or more can displace a thousand labourers. Moreover, civil construction constitutes a major portion of the real domestic capital formation in developing countries and a very significant part of lending by the World Bank and bilateral aid agencies.

Thus since 1971 the World Bank in conjunction with several Governments and other agencies has been engaged in a major study to investigate the engineering and economic feasibility of labour-intensive and intermediate technologies in civil construction. Our initial study, completed in 1971, comprised a review of the existing literature, PWD records, military manuals, etc., going back as far as the mid-nineteenth century in some cases—and discussions with many engineers, contractors and Government officials with experience in many countries. As history provides ample proof, there was widespread agreement on the technical feasibility of labour-intensive methods for almost all activities, (the primary exceptions being long distance haulage and compaction and finishing to the high tolerance standards we have come to expect in modern high quality highway and airport pavements). However, the economic feasibility of these age-old techniques compared to modern machinery presented a major controversy.

Economic feasibility depends critically on the relative productivity rates of men and machines as well as the relative prices of the two basic inputs. The limited evidence we were able to amass on productivity rates displayed enormous variability—more than 1,000 per cent in the case of some of the most important activities, and it was not possible to explain why with the evidence then in hand. Certainly there are many parameters which affect productivity dramatically—physical parameters (such as the hardness of the soil, its moisture content, the height of lifts, the length of haul, ambient temperatures), managerial and social (such as work organisation, incentives, attitudes toward manual work and the health and nutrition of the labour). Thus we found that the two very qualified consulting groups we had working with us, using the same evidence, arrived at contradictory conclusions about the economic feasibility of labour-intensive
methods: one found it economically feasible to substitute labour for almost all equipment in low wage economies and the other found labour non-economic in the majority of construction activities even in the most labour abundant economy. Because of the limited amount of hard evidence and the large element of the analysis which necessarily had to be conjectured, it was possible to compose equally convincing (or unconvincing) arguments on either side of the issue.

Subsequent phases of the study therefore focussed on primary observations of ongoing construction activities in India and Indonesia. Work inputs, outputs and the associated parameters describing site conditions were carefully recorded.

The work concentrated on labour-intensive and intermediate techniques, for which the least information was available, and ultimately many experimental methods which were devised. Altogether in Phase II and Phase III observations were taken at some 42 sites, 24 in India and 18 in Indonesia, including roads, irrigation canals, dams, quarries and an airport. Altogether more than 35,000 man-days of work were observed. This is I think principal contribution of the World Bank study: we have gained much new scientific evidence on the productivity of labour and intermediate techniques of construction under widely varying circumstances.

For all practical purposes, the evidence is now adequate and we know that labour-intensive methods are economically feasible in many circumstances. Certainly they appear to be appropriate for the majority of civil construction works in India, and they could be economical in many other countries where they are not currently being practised. You have the summary of the findings before you and I need not repeat them all here.

However, there are a few points that I would like to emphasise briefly. By and large we have been impressed with the manner in which labour methods are used in India, and certainly we have learned much from you. However, there is scope for improvement which is suggested by this study and I hope that you can take advantage of it. There is an important potential for improved tools and simple equipment, such as wheelbarrows, which is not being exploited. (It is a source of amazement to me that, in a country which produces railway
Discussion on

Locomotives and bulldozers, it is not possible to buy a properly designed and constructed wheelbarrow—which our studies have demonstrated on work in India can be of widespread use.) Possibly there is a role here for the IRC in working with your industrial ministries or manufacturers' associations in developing standard specifications. Similarly, our study suggests that providing improved incentives to PWD staff as well as contractors to increase the speed and the quality of construction might have as dramatic an effect as wage incentives have been shown to have on the labourers' productivity. Something should be done, indeed must be done, to improve the speed of construction. Long delays in project completion constitute enormous non-productive investments in inventory of uncompleted works for which society receives no benefit. It is an important and unanswered question whether labour-intensive methods necessarily take larger time than equipment-intensive methods; but it is undoubted that much could be done to speed the progress. Better to concentrate resources and finish a smaller programme quickly so that someone can be benefitting, rather than spread resources so widely that no one benefits for many years. Finally, Mr. Chairman, I would like to call attention to the important results on the relationship of productivity to the health and nutritional status of the work force. It is improving the welfare of some of the most disadvantaged of our fellow men that concerns us, but, as if this were not enough in its own right, we have shown that this humanitarian goal also makes good business sense because a well-fed, healthy worker is a much more productive worker. I hope that in this area, as well as in other facets, our study will be of help to you in helping civil construction serve society better.

Thank you, Mr. Chairman, in bearing with me through these rather lengthy introductory remarks. I thank all of you once again for the privilege of addressing this distinguished group and I thank especially those of you who contributed so much to the success of our study.

Shri P. A. Green (Author's Introductory Remarks)

Before giving my introductory remarks I would like to express my thanks to the IRC and to your distinguished Chairman, Shri J. S. Marya, for giving me the opportunity to present the engineering findings of the World Bank study. I do so with considerable trepidation because I know that many of you have
had far more experience with using labour-intensive methods than I have had. I intend in these brief introductory remarks to summarise the results of our research in a little more detail than was possible in the Paper by myself and Shri P. D. Brown.

Firstly, working on the study over the last three years has brought home to me the fact that labour-based work is far from a simple subject. Indeed, in the interaction of technical, managerial, social and economic factors, labour-based work can be as complicated as any equipment-intensive project. The engineer who can resolve these problems successfully can truly claim to be using his skill for the benefit of his fellow men.

Secondly, the results of a study has, of necessity, to be expressed in general terms for a 'typical' project, but such a project does not exist. Every site has its peculiar conditions which will possibly result in differing conclusions to the general ones expressed by me. However, only by considering generalities can we attempt to recognise those underlying factors which to a greater or lesser extent, apply to every project.

All engineers have a choice, firstly in carrying out the design and secondly in the methods to be used for constructing the project. However, we all tend to restrict our choice within the technology with which we are most familiar, now we find that where labour is abundant the first question to be asked is what part of the technology spectrum is appropriate. Once we have decided that issue we can go on to examine in more detail the alternative ways of doing parts of the project, depending on the relative costs of men, tools and simple equipment. The mechanics of such an examination are by no means straight forward, and cost comparisons have to be done very systematically to ensure, as far as possible, that like is being compared to like.

With labour-based methods the quality and maintenance of tools and simple equipment is very important. We have observed that this is one aspect which has received little attention and, consequently, the quality of tools in use is extremely low. There is clear evidence that the extra cost of top quality tools and good maintenance is more than recovered by (i) a longer life for the tools and (ii) in increased production.
Another factor which is overlooked in most labour-based projects is that of planning. In some respects more planning is needed than that required for equipment-intensive construction. Several carefully monitored studies have shown that careful attention to details can result in significant cost savings.

We all appreciate that good supervision and incentives (both monetary and others) is important, but it has not been possible in the past to quantify these factors. However, as a result of the study we now feel confident that we can put values to them. For example, in Table 2 we have found that piecework labour in a well organised contractor's operation (Line A) produces, typically, about four times the daily output of daily paid labour working for a poorly organised force account organisation (Line B). If we consider averages (Line A* and B* in Table 2) we can see that, for example, a contractor using piecework can achieve total unit costs about 85 per cent of those for a force account organisation using daily paid labour.

One important question that needs to be asked in the use of contractors and the piecework method of payment is who gets the benefits. On this we have found that generally every one gains. The labour has higher daily earnings in return for significantly higher output; the contractor makes some profit (which may be regarded as management incentive for working hard and taking financial risks); and the nation gains by having the job done cheaply. This equation is carefully balanced and attempts to upset this balance, e.g. by trying to reduce the contractors' profits or by the contractor not passing enough of the earnings (from increased productivity) to the labourers, may prove to be counter productive.

I am looking forward with great interest to hearing your views on this and the other matters raised in our Papers.

Shri R. P. Sikka (Reporter)

Provision of gainful employment to large population bodies remains a burning problem for the developing countries. Civil construction, with its potential for labour-intensive techniques and high degree of employment, has always figured prominently in the developing world as an important avenue for resolving the problem of unemployment. While this has been so, doubts have
continued to persist whether the labour-intensive methods were really economical compared to equipment-intensive techniques, or had an edge purely from the angle of creating additional employment. Very few studies on scientific basis had been undertaken earlier to examine this issue. It is welcome indeed that the World Bank, which has a large lending programme for civil construction in developing countries, came forward to pioneer an in-depth study about the viability of the labour against the background of the different economic and technical factors so that the doubts in this regard could be resolved.

Major portion of the World Bank study was carried out in India between 1972-76. It is natural as such that Indian engineers and contractors should have deep interest in its results. It is for this reason that this topic has been brought before the open forum of the Indian Roads Congress so that the large body of practising engineers and contractors could benefit through further exchange of views.

For today’s Panel Discussion, two Papers have been presented, one by Sarvashri Sud, Harral and Coukis of the World Bank and the other by Sarvashri Green and Brown of the Consultant firm who actually did the field work of the study. In this brief note, some of the important aspects covered by the above Papers are touched upon for the purpose of channelising discussion.

Economic feasibility of labour-intensive technologies

Economic feasibility is an important parameter influencing the selection of the appropriate construction method. For highlighting the feasibility of different methods, the concept of break-even wages was adopted in the study. Table 15 of the Paper by Green and Brown summarises the finding for selected tasks on this basis. It shows that for most of the tasks, labour intensive methods are competitive for the base daily unskilled labour rates of the order of Rs 6-8. With good supervision and a system of incentives, the basic daily wage could however be as high as Rs 20.00 to be competitive with equipment methods. This is quite gratifying for the developing countries.

A point about cost comparison however deserves attention, in that while the productivity of labour-intensive methods was actually observed, that of equipment-intensive ones is based
essentially on manufacturers' manuals and hand-books. With this procedure, the danger of under-estimating or playing up the equipment productivity leading to a distorted comparison cannot be ruled out. For example, conclusions of the Phase-II study mentioned in para 4 of the Paper by Sud, et al, were based on very high productivity rates and low operation costs for the equipment. The same labour intensive methods, however, came out triumphant when the equipment productivity was scaled down by 50 per cent and the operation cost of machines brought up to a realistic level — vide World’s Bank’s Tech. Memo. No. 3. The present Papers assume yet another set of figures. While operation costs have been retained at a reasonable level, productivity figures of machines have been revised somewhat upwards. Taking the case of bull-dozers, productivities assumed as a percentage of the ideal capacity given in Caterpillar Handbook were 50 per cent in Phase-II Report (1974), 25 per cent in Tech. Memo. No. 3 (June, 1975) and 31 to 54 per cent in the present Papers. In a similar study completed by the International Labour Organisation in Philippines recently, the corresponding figures range from 20 to 35 per cent.

This goes to show that so long reliable figures of equipment productivity under conditions representative of the developing countries are not available, any exercise in comparing and rating the two rival techniques will remain incomplete. If the assumptions involved are subject to discretion, then any change in the values could have a radical effect on the results. To plug the gaps hindering a more realistic comparison, it may be worthwhile to collect additional data about output of machines under prevailing conditions at a few selected construction sites. If the actual productivities turn out to be really very low, perhaps there may be a case for examining the ways and means to improve the situation.

**Choice of Technology — Man vs. Machine**

Economic feasibility is an important factor in the choice of appropriate technology. This has been amply covered in the two discussion Papers. But there are several other parameters peculiar to the developing countries which have a strong bearing on the overall comparison. Some of these factors are discussed briefly in Paper by Sud, et al, but the emphasis is mainly on problems of labour utilisation. There are other factors too which need to be looked into in the light of the socio-economic conditions of the country before the optimum solution is struck.
STUDIES ON LABOUR-SUBSTITUTION IN HIGHWAY CONSTRUCTION

Firstly, it is the availability of capital equipment and spares. India is in the happy position of manufacturing most of the essential equipment already, though some of the other developing countries may not be so fortunate. This raises the problem of imports involving valuable foreign exchange and possible idling of machines due to non-availability of spares in time. Such factors are difficult, if not impossible, to quantify when attempting a fair comparison. One would have to keep in view the initial capital cost of the equipment, idle time involved (due to shifting of machines from one place to another or some other reason) and the problem of creating maintenance facilities at dispersed places.

Another important factor is the project size and type. Paper by Sud, et al, concentrates mainly on major projects and expresses good deal of concern about the adoption of labour-intensive techniques, in particular the problem of mobilisation of labour. Position in developing countries is rather to the contrary, with small works on feeder and secondary roads dominating the highway scene, for which the use of equipment and its mobilization will be found usually manageable and more expensive. Even for major jobs, closer examination may show that labour-intensive techniques are applicable for several of the component tasks.

Some works, because of sheer size or technical requirements, can be executed by equipment-intensive methods along with no other alternative. Asphaltic concreting of roads, mass production of aggregates, major river valley projects, and other works which have to be completed within a tight time schedule, fall under this category. Still there are several projects of intermediate character where mobilisation of labour should lead to no serious problems. For relatively small and dispersed works like feeder road construction, most of the tasks are amenable to labour-intensive methods without loss of quality or efficiency.

One criticism levelled against labour techniques is the delay in completion of the projects. It is important to underscore that in developing countries project completion periods are invariably linked with budgetary allotments every year which may sometime be restricted. Because of this element, there might have been instances of delay in completion of projects but this cannot be fully attributed to the adoption of labour-intensive methods. From economic angle too, the benefits foregone because of the delays may not be so substantial as to upset the balance.
On the contrary, occasionally there may be added benefits like reduction in the total quantity of work as listed in para 8.4 of the Paper by Green & Brown.

Availability of labour in agricultural season has been cited as a particular problem with labour-intensive methods. In labour-abundant economies, as in the developing countries, this factor should not be found insurmountable if one considers the break-even earnings of the order of Rs 20 per day for a piece work unskilled labourer — see table 15 of the Paper by Green and Brown. For daily earnings of this magnitude it should well be possible to draw adequate labour force even in the busy agricultural season. From economic angle, this aspect could be analysed by using the social opportunity cost of labour instead of market wages. This type of exercise was done by the I.L.O. in the Philippines study and the results still favoured labour-intensive methods.

Intermediate Methods

The discussion Papers have identified some intermediate techniques using small tools or animal power. Methods using mules, animal-drawn carts, wheelbarrows, hand operated rope-ways etc. have been classed under this group. Most of these are being practised in India and other developing countries. Choice among these is dictated by the type of work, the haulage distance involved, and site conditions. For example, wheelbarrows can be successful only on relatively level and firm ground; mules are better suited where steep inclines are involved; animal carts require a firm track and should have longer haulage routes for negotiating level differences. Each case will therefore require individual attention before the optimum construction method is chosen. The inter se rating of the different methods as given in Figure 7 of the Paper by Green and Brown may be taken as a broad guide, but cannot be generalised.

Incentive Wage System and Supervision

It is recognised that methods of payment and quality of supervision have a strong influence on the productivity and unit cost of labour-intensive techniques. The Bank studies have thrown considerable light on this aspect. Compared to the case of daily wage payment and poor supervision, incentive payment method with good supervision can increase the productivity by more than \(3\frac{1}{2}\) times. The daily earnings of labour go up by two
times and yet the total cost of work would be less by about 40 per cent. The result is that labour intensive methods with incentive wage payment and good supervision can be competitive even at a daily earning of about Rs 20 for an unskilled worker.

Supervision includes motivation of labour and proper organisation and management of the operations to ensure gang balance, avoidance of double handling and the like. In view of the large benefits, it seems essential that the task level supervisors are properly and adequately trained for the job they are expected to handle. Construction authorities in India will have to pay a good deal of attention in the future to training of supervisors in labour mobilisation for best results to flow from the use of labour intensive methods.

**Health and Nutritional Aspects**

Health and nutritional standard of labour is an important factor affecting labour productivity and it is gratifying to note that the World Bank study has drawn attention to this aspect. More often than not, this factor is completely overlooked by the employers. To take the best out of the man, it is essential that he must have the requisite food, clothing, shelter and medical facilities. Project authorities and contractors employing labour should seriously consider providing these essential requirements of food, shelter etc. in kind as an indirect incentive.

**Conclusions**

The World Bank study has been useful in generating a large volume of data in giving broad indications about the technical and economic feasibility of the different methods of construction. It has also served to reassure developing countries that the labour-intensive techniques adopted by them in civil construction are economically viable and that their competitiveness could be improved further through simple devices relieving the muscle power, better organisation of operations and adoption of incentive system of wages.

For general application in different situations it would no doubt be advantageous to produce documents in the form of guidelines about the selection of appropriate technology in civil construction. As regards road construction, it is hoped this task
will be taken up by concerned committees of the Indian Roads Congress keeping the deliberations of the Panel Discussion in view. For river valley projects, equipment-intensive methods are currently preferred. Yet there are works of smaller magnitude, e.g. excavation for irrigation minor etc. where labour-intensive technologies may be more appropriate and economically viable. The Ministry of Agriculture and Irrigation in due course may perhaps like to bring out an advisory manual of instructions for application to such works.

SALIENT POINTS FOR DISCUSSION

1. Means of improving labour productivity.
2. Application of incentive wage system—merits and demerits.
3. Inputs for labour—provision of essential requirements like food, clothing, shelter and medical facilities in kind as an indirect incentive.
5. Training requirements of site supervisors.
6. Improving productivity through application of intermediate technology and development of small tools.
7. Social desirability of employing labour-intensive techniques even when the market wage is higher than the break-even wage.
8. Problems associated with labour mobilisation, particularly for major works and in the peak agricultural season.
9. Equipment productivity under situations prevailing in developing countries, and ways of increasing the same.
10. Application of labour-intensive technology in river-valley projects.

Brig. R. C. Nayar

We are one of the biggest users of manual-intensive methods as well as machine-intensive methods. We have already tried to implement all these recommendations before coming to this forum for discussion. The authors have given some concrete recommendations in respect of excavation of earth, haulage of earth and sand, haulage of stone and aggregate, crushing of stones etc. and performance of tools, implements and wheelbarrows. Some of the Chief Engineers who have tried these recommendations maintain that productivity certainly increased in different projects from 15 to 20 per cent. With better field organisation, training of supervisors and site organisation, I think the productivity will increase still more.
There are a few points on which I want to focus the attention of this forum. One is improved tools, implements and wheelbarrows. The design needs improvement. We are not the only users of these hand tools; there are other departments all over India and I suggest the setting up of some sort of a Committee in the Ministry which can lay down the specifications, get these tools manufactured, put them on trials and make final recommendations. We have found that at our own level when we formulate certain specifications and ask for quotations, the rates differ very much, for example, say one wheelbarrow from Rs. 350 to Rs. 800. Unless the tools are available for implementation in an economical manner, the economics of projects will be vastly different. That is why some of the Chief Engineers have not been able to readily use the improved design of wheelbarrow.

The second point which the authors have very forcefully emphasised is the incentive scheme for increased productivity of labour. We have two types of labour—one is the departmental labour permanently employed, and second is the daily wage labour which we employ in projects for varying periods. The incentives for both types of labour will differ. For departmental labour, the incentives may have to be considered on an initial facility like compensatory allowances, improved ration scale and additional increments for good work. We find over the years our labour force which is permanent is on poor rations though working in high altitude areas. As far as the daily employed labour is concerned, rations on subsidised rates, medical facilities plus clothing, shoes and shelter etc. should be provided so that they are more satisfied with the Government for purposes of working than with any other private agency. I feel, incentive scheme is a very good suggestion and we should introduce it early but its implementation must start in concrete terms so that one can approach the Government based on this study. These recommendations are to be implemented either in phases or in parts applicable to both types of labour.

Next point I want to comment upon is about the technical feasibility of manual-intensive or labour-intensive methods. There are a number of jobs which are technically feasible to be done by labour-intensive methods but cannot be entrusted to labour because of technical requirements, specifications of the large quantum of work involved—for example it may be formation cutting on several sectors of the road, it may be compaction
of road bases on several stretches of the road or mass concreting work in bridge foundations. Even if you arrive at the break-even wage for these jobs, you may not like to do it by manual-intensive methods for the purposes of specifications and quality of work required.

The Authors have also given the idea of intermediate technology and economic feasibility. To my mind, the improved implements will provide intermediate technology for better productivity. At present apart from tools we have married labour force with the machines to achieve an optimum economic output. I do not think it would be right to divorce the machines completely and arrive at manual-intensive methods even if they are economically feasible.

On output of machines, I would mention that we have machines working from 4,000 ft altitude to 14,000 ft altitude and the working period differs from 90 days to 200 days a year. Their output should not be related to the output given in the pamphlets. It may be very different and may be quite small. Apart from this, the quality of machine, the repair cover and other facilities may be a very relevant factor as regards their output. The output should be related to actuals and may be based on the different project areas.

Lot of emphasis has been laid by the experts on break-even wages. The productivity will increase if supervision and site organisation are improved but it is doubtful if productivity will increase by paying higher wages only. On this also, we cannot say how much it will increase. At one point the authors have suggested that we can afford to pay Rs. 20 per day and increase the productivity three times. This I feel is a debatable point and we may not be able to achieve this ratio.

Another point raised is the diversion of agricultural labour to projects during peak harvest season by paying higher wages. It is very difficult to implement this on the ground because you cannot change the labour wages periodically and every season. Once you start paying higher wages, they will not come down to accept low wages after two months. Also if you adopt this policy then you will be distracting the agricultural labour from food production which may not be in National interest.
Another method which has been suggested for greater productivity is incentives and getting the work done on piece-work basis. As regards piece-work system, it is very difficult to implement this on the ground in a Government department. If it is based on the production of the individual or gang, it will differ from mile to mile and lot of records and measurements will have to be kept. We will have to evolve some sort of concrete recommendation how this piece-work system by Government agency can be organised without fault and without the inherent problem of increasing lot of staff, lot of measurements, lot of checks on corruption. This recommendation should include particular type of work which can be given on piece-work basis for increased productivity such as breaking up of stone, collection of sand and masonry work, etc.

Next is health and hygiene. Generally the nutrition is on the low side and it would be good if recommendations are also made in this behalf for implementation in two parts, i.e., for the Government permanent labour and the daily employed labour.

Shri S. N. Sinha

At the outset, I must compliment the Bank on the excellent study which has been more or less completed in a very efficient manner and these two Papers have been published and presented today. I have been personally interested in this matter for quite sometime. I have also seen some of the earlier publications. I did have the opportunity to go through some of the very large amount of connected technical literature published since then. But I may be permitted to say that my interest has been more than personal. When this study was originally initiated, I had the opportunity to be associated with it in my position then as DG(RD) and after quite some discussions, the work was started and has progressed in business-like and efficient manner. At the outset, I would like to say that any comment in detail on these two Papers is not possible. It has, necessarily, to be superficial to a large extent because the Papers published are based on a very large amount of technical work and technical publications which very few of us had the opportunity to study.

While presenting this Paper, Dr. Harral had mentioned specially one important factor in respect of the labour-intensive
factor. This is about the delay in completion of road project and the consequent loss to the country as a whole. The term 'delayed completion' of the project, they had taken pains to emphasise and illustrate as to what it really means. But I cannot agree with him wholly. Even I would venture to disagree that such delays in project completion have been mainly or largely due to our system, in this country, of using labour-intensive system of working. We have been working on a system of Five-Year Plans, so conceived and detailed in a system of planning where roads have never been in the core sector or in fact given the importance they deserve rightly. Another factor, apart from that of roads not being in the core sector, is that road plan has always been the first casualty where there are constraints on funds for any reason. The requirements for funds for roads have been large and there has been a clamour from every section with the result that whatever is available is virtually split up badly and doled out to a large number of schemes. The completion of any project in time has never been the criteria. Everybody has, thought of satisfying the maximum number of persons— not many— without caring whether there is any return in the shape of even sectorwise completed projects. This aspect of doling out money to a large number of projects had resulted in delayed completion of almost all projects and labour-intensive methods have got practically nothing to do with it. Even if the methods of construction in this system of planning are not labour-intensive, and we were using highly mechanised methods, the results would, perhaps, be no different. The recent scaling down of allocations for the National Highway projects, for what a lot of equipment has been purchased and ordered for is a glaring example. It would clearly support this view and would indicate that the delay could not be due to using labour-intensive methods as the National Highway projects have been generally comparatively more mechanised. Reasons for delayed completion are somewhat else. The fact, that the delay in completion results in a very serious handicap and generally serious loss to the country, has never been realised. It is, however, to be admitted that labour-intensive projects are by their very nature, such that the impact of uncertainty of funds reduces losses due to delayed completion. In the case of mechanised equipments, this should have added to the disadvantage. Therefore, the reason, which has been emphasised that there have been delays in project and these delays have been attributed to labour-intensive schemes only are not based on facts as these exist in India.
The second issue is about the availability of labour. Statements have been made at more than one place about the dearth of labour in the so-called labour-intensive areas. In these areas, it is said that there is abundant labour available but still there have been occasions, and very many of them, when there is dearth in the supply of labour. I would not have narrated my personal experience but I feel I should do so to illustrate what is possible with proper organisation and the method of managing the labour. It has been actually possible to organise work on a stretch of about hundred miles of a road, by over 50,000 labourers a day completing the 35,000 crore cu. ft. of earthwork in the road in a period of one season between November and April end. It is not that it is not now possible. I would state again if one has proper authority and organisation and management techniques, labour-intensive projects with minimum of equipments could be completed in time. That was done several years ago. It could still be done better in the years to come. I would suggest that better recruitment techniques, better amenities, better facilities for them and better management methods need be given effect to. And the suggestions made in the Paper are very valuable indeed in this respect. I wanted to add further that utilising labour departmentally should normally be authorised.

I have not mentioned what has been happening in the Border Roads Organisation as such. I shall come to that just a little later. I had headed the Committee for Economy in Expenditure on the Construction of Border Roads and the Committee had made some suggestions intensifying use of labour on the basis of which the Government could effect very substantial savings. The system of incentive and of working through petty contractors has also yielded quite satisfactory results besides timely completion. The incentive is an addition to the basic rates in which completion periods at various stages are so specified that say 50 per cent work is done in 50 per cent time and 25 per cent work in 30 per cent time or something like that. I think some 75 per cent of the work had been completed even before the stipulated period of one season, say, as 3 to 4 months, by giving a basic rate and a ten per cent incentive. In effect this system of incentive increased the penalty to 25 per cent (if the contract specified 10 per cent penalty). Thus for non-completion of works hardly 5 to 10 per cent contractors could choose to lag behind. Even these could be removed at the very first instance where they are found lagging behind and the engineer is aware of the work and new
contractors brought in. This incentive or the disincetive idea would also not result in a very large management force. The managerial force has however to be different. There is to be a training, there has to be proper management-oriented staff but the problem of manning labour in such large number in this system may not be there. I should try to elaborate on this but I will refrain from going further. About piece work system, I may add that it is possible that by resorting to this type of contract labour to a certain extent besides departmental labour will reduce intensity of mechanised work and thus cut down costs quite substantially. This was basically and specifically worked out by me.

This being the case, I would rather advise a system for advocating of piece work contract with departmental labour properly organised. Minimum equipment however have to be used.

As regards the output of the machines, I have to say something. It has been mentioned in the Paper of Shri Green, for instance, that the output of a bulldozer as a whole can be as high as 1,000 cu. metres per day. It may be theoretically possible, it may be possible to some extent in a country where specific proficiency has been achieved in the use of equipments but I believe this kind of output may not be possible for quite some time in developing countries or in countries which have to adopt this type of machine-intensive work in the beginning. We had the output of the bulldozers used in the Border Roads Organisation in India. We have also studied (and in fact I am heading a Committee on Mechanised Roads Construction) and we are studying the output of the bulldozers in our works itself and it is found to be rather quite low. There is every reason that this should be improved but the break-even wage with a very high output for the machines and a low output for mechanised labour will to some extent, I may submit, distort the perspective effectively. I, therefore, feel that here is every reason to adopt to break even wages which I calculated for the ECAFE on certain projects in 1972–73. These are higher. Although there is a sort of similarity, it is not the same and after two–three years when the prices of equipments go high and the efficiency of labour goes up, the break-even wages will again shift.

One further point which I would like to emphasise is the use of intermediate technology. It has to be accepted that we can improve our labour-intensive methods by the use of intermediate
technology. Intermediate technology should not shift from the labour-intensive to the machine but it should go up from the machine-intensive to the labour-intensive in developing countries. However, there is every reason to suggest for adopting the changes which have been worked out in the Paper after discussions and modification. The suggestions are very valuable in this respect and much can be achieved.

Prof. S. R. Mehra

The two Papers under discussion, which are based on detailed expert studies, have brought out clearly, that for a considerable time to come, labour-intensive projects will remain, not only financially viable, but also of great help in meeting the unemployment problem, in India.

Fortunately in this country, there is no dearth of proved techniques, specifically suited to labour-intensive methods of execution, thanks to prolonged indigenous research, followed by full-scale execution under normal conditions, according to specifications laid down by the IRC etc., after careful examination of the behaviour of proving projects over the years, by competent expert committees. To quote one very important example, the use of "processed" local soil as a material of construction, for permanent engineering works, not only in roads but also in rural housing and in lining of small irrigation water channels, etc., etc., has abundantly shown very good promise.

To encourage large scale use of such proven labour-intensive techniques in developmental works, the Central Government, being convinced of the high potential of these techniques, in combating unemployment as well as high cost of construction, have instituted "risk funds", to protect the engineers-in-charge, against the small risk of failure inherent in rapid utilisation of new techniques, even after they have been competently declared usable in normal engineering practice.

In spite of all this, a certain amount of hesitation still exists among the engineers responsible for execution of projects. This hesitation arises from the fact, that the expert supervision of engineering works today, in the field, leaves a lot to be desired.
The overseer is normally supposed to provide such supervision. But neither by training, nor as a result of technical ambition, is he capable of delivering the goods. It is not his fault at all. He is trained neither as an engineer (which he is always aspiring to become), nor as a supervisor or "Foreman" (which by virtue of his very training he considers *infra dig* anyhow).

It is a matter for serious consideration, as to whether a specialist class of dedicated engineering foreman, should not be created, whose ambition, should be not to become half-baked engineers, but to become top level experts, in supervising actual execution of engineering works in the field.

To make this essential service attractive enough, it should be made more lucrative than the profession of an overseer, by linking emoluments with the number of years of "approved" specialized experience, rather than with "grades" dependent on availability of vacancies. This will create a national pool of specialists for expert supervision of different types of engineering works on site—a tangible national wealth.

Before long, it will be found that the profession of a "foreman", has come to be considered more prestigious than that of an overseer, besides being more lucrative. That will be the time to consider whether the overseer class should be gradually wound up, and the training resources released as a result thereof, utilized towards developing the profession of foreman.

Prof. C. G. Swaminathan

Way back in the early twenties, it was a very common practice, especially in the districts during famines, to go in for road construction programmes as one of the main famine relief operation. Even Shri Jagus in his Vice-Presidential Address has mentioned that for a given outlay, a road construction project can employ 10,000 people as against 7,000 or 5,000 for other civil engineering projects of similar outlay. So, all of us do appreciate that labour-intensive methods definitely have social benefits. But the extent to which we can derive economic benefits, has been highlighted by the Authors. Here again, the question as I see it, is: "Given three technologies namely labour-intensive, equipment-intensive and the intermediate technology which technology
should we use, when and why and under what conditions of work? This is the question, answer for which we would like to know from the Author. No doubt Mr. Green in his Paper has given on page 38 certain parameters based on productivity. But I feel that these parameters are not adequate. Also, they should be grouped in a different form. Further, additional parameters will have to be included such as the nature or type of activity like the nature of surfacing in a road construction for example. Secondly, the magnitude of the work should find an important place. If it is excavation, amount of excavation, if it is crushing, quantity to be crushed, in the case of road work is it 100 miles or 150 miles or a series of small jobs. Two other factors which I do not find a mention in this Paper are: (a) the quality of work and the degree of quality—what should be the quality of work if I have to do the job completely manually or completely using equipment or by machines; (b) the social benefit which is accrued. This is again a very important parameter as far as India is concerned, especially as at the present juncture we engineers are being asked to get involved in social uplift and social development, by affording employment potential. These are only some of the factors based on which one has to judge and find out as to which method, out of the three technologies one should choose in a given situation. With the limited experience that we have and with the limited study we have conducted, we find that in developing countries an intermediate technology using a harmonious blend of men and machines with a perfect co-ordination between the two, perhaps may be the answer for most of our jobs. Many of us in Delhi, especially those interested in intermediate technology, do come, across a 100 tonne paver finisher, being fed by mix made at the road-side and by a team of 30–40 labourers using shovels with the result that by the time the hopper is full, the mix is cold, or if the mix is hot, the paver can only move a few feet forward.

Surely, this is not an appropriate intermediate technology. Because of this many feel that as far as asphaltic concrete work is concerned, it is not amenable for adoption of labour intensive techniques. But it is not always so. Here, I would like to give an example. On a job which was done ten years ago and immediately after the Chinese operations, an airfield, had to be upgraded by laying a $2\frac{1}{4}$" asphaltic concrete. The tenders were called for and the lowest had gone to a contractor who did not have any machinery for hot mix work. Nor was any paver or hot mix
plant available immediately. But the work had to be completed in two months. It so happened that the team visited our Institute and during my discussion with them, my view was that it was impossible to do the work without two hot mix plants of 40-tonne capacity and a paver finisher. However, as it was an Emergency time and as the job had to be done at a top priority basis we worked out a plan, according to which we put into operation 14 small 5-tonne capacity hot mix plants. We sent out a team of 6 or 8 people to the site to do the quality control and we did come across, as expected, a large variation in the quality of the mixes provided by the different plants. With suitable modifications at the site, we were able to narrow down the range. Again a completely manual laying procedure had to be adopted. We laid two lengths of 2½” angle iron strips along the runway at a distance of 10 feet apart and the hot mix was spread between these two strips to the required height manually and rolled. One should remember that this was an airfield mix satisfying the limits of high stability, low void content and what not. We had to implement these specifications by manual methods. We made suitable modifications in the design as well. This has reference to page 25 of Mr. Harral’s Paper where he states that while choosing the technology one may have to change the design or the norms. We went for a high percentage of the sand fraction in the mix so that it would be possible to lay the mix between the two angle iron strips, allowing an easy facility of uniform spreading and at the same time affording a good compaction. After the job was done, it was found that only the riding surface was not up to the mark and we had to face a lot of trouble to get a riding surface as per the norms laid for a machine laid surface. This again highlights the need for a change in the quality requirements, when the work is to be done by manual means. Another work where manual methods are adopted successfully in India is mastic. In a country like Germany which is highly advanced one finds a huge hot mix plant to make the mastic asphalt and specially made tractors and trucks having revolving hoppers to carry the mastic asphalt to the site where a special paver lays the same. But we in India, do this work by intermediate means. If both Mr. Harral and Mr. Green get the opportunity, they could visit some of the works where the mixing is being done with small machines but laying is completely manual. By giving these examples my intention is to stress that as far as developing countries are concerned, I am sure a technology that is in between and which uses both men and machine can be highly efficient. For that, there must be a harmonious blend of men and machine
and a perfect co-ordination of the two. A good amount of planning before and during execution is a must. After all, it is a hybrid technology. What is wrong with a hybrid technology. Even God in his infinite wisdom has given us the most versatile and a sturdy mode of transportation in the hills i.e., hybrid animal namely the mule.

Shri G. R. Laharwal

It has been stated that base wage rates of U.S. $ 1.00 to U.S. $1.80 per day combined with an effective incentive system represents the upper limit (in 1976 prices) at which labour intensive methods can be economically attractive.

I hope this observation has been made on the basis of specific minimum output of an average labourer. This needs to be clarified. In our country, a large section of our labour population comprises women labourers whose output may not be equal to that of the male labourers. It needs to be clarified if this factor has been considered in the studies.

A normal daily wage system is not economically efficient in labour-intensive works particularly in the absence of a very tight supervisory control. When a labourer is assured of a fixed daily wage without subjecting it to a certain minimum output of work, the labourer gets inclined not to work to his optimum capacity. In the state of Jammu and Kashmir, we have tried the system of giving piece works directly to labourers through their headman called a mate at some reasonable rates consistent with the nature of the work and the site conditions. This method has worked quite efficiently and has been found to be fairly economical particularly in ordinary earthwork of roads.

The system besides ensuring quick execution of the job, eliminates the middle man's profit as in normal contract system.

However, the labour intensive system has some limitations so far as construction works in far flung areas in rocky strata are concerned. It has been observed that in such cases, the execution of work without adequate machinery is not only uneconomical but entails unimaginable delay in completion of the job.

Similarly for snow-clearance from roads, we have mainly to depend on machines for the quick execution of the job, more so
because of the reluctance of the labour to come out for the work in adverse weather conditions.

In respect of incentive wage system, I feel that the contactors who engage permanent mobile groups of labourers for deployment of different jobs should suitably share their profit with the labour in the form of bonus. This system is understood to have been adopted by a contractor in our State who has organised a labour-intensive system of executing works and his performance has so far been quite satisfactory and the labour-employer relations fairly good.

The report suggests maintenance of health and nutrition standards of the labour. This takes care of the immediate problem of the labour so far as the execution of a particular job is concerned. These are the considerations which, I believe have to be kept in view in respect of working animals on the work like mules as well—perhaps more in the interest of the employer. The requirements of human labour are more than health and nutrition only and we should be conscious of these in the interest of the future generations over and above the immediate interests of the labourers.

The permanent mobile labour engaged by contractors move to the work sites along with their families. Thus their children are not in a position to receive education. Some system should be devised for imparting sufficient basic education to the children of the mobile permanent labourers engaged by contractors.

Shri N. S. L. Rao

I had been working in Nepal for a little over three years, where six countries including India as well as several U.N. Agencies are helping to construct roads which Nepal needs badly. Some countries have taken on the job of building roads themselves whereas others are paying for the cost of roads being built by the Government of Nepal. U.N. Agencies have been helping Nepal in conducting feasibility surveys for roads. The road construction techniques being used by these countries vary and so do the systems of planning, organisation, inventory control and use of men and machines. Some countries use capital-intensive methods, others labour-intensive methods and some a judicious combination of both. The Central P.W.D. has been adopting a judicious combination of both the techniques in the
road construction programmes being financed by the Government of India. This has given me an opportunity to study in depth relative merits of construction of roads by various techniques.

Before capital intensive methods are resorted to on a large scale, one has to ensure that there will be continuity of work for the machines purchased. Unless machines are used for full periods of their rated service lives, capital intensive methods may prove to be costly. Planning should be such that the equipment purchased could be used effectively and economically and transferred from one project to another, the time interval being the shortest possible. I have come across an instance where at the end of a project, equipment worth nearly Rs 20 million became surplus and the same is rusting for more than five years without any use whatsoever. Job requirements differ from project to project. It may not be possible always to utilise equipment in ideally economical combinations. One has to utilise the equipment in combinations which are not normally economical. One of our contractors had used extensively a rare combination of a dragline, dozer and two petrol driven dump trucks on a guide-bund work in a river—this is because of the equipment he had with him. Appraisal of relative economics of methods of construction should take these factors into account.

Timely procurement of spare parts and effective control to ensure low levels of inventory is more easily said than done. Import of spare parts even with an easy foreign exchange position sometimes becomes nerve racking, when idle periods of useful items of equipment become unduly long particularly in good working season. Running and maintenance of heavy earth-moving equipment needs competent mechanics and operators, which is a very rare commodity to come by, particularly in developing countries. Efficiency of a machine is as good or bad as the performance and capacity of the operator behind. It is essential to have a band of trained, competent, efficient and sincere workers if capital-intensive methods are to become economical.

Each method has its own advantages and disadvantages—one has to choose one of the methods depending upon variety of circumstances.

Even though the real economic benefits of a highway accrue after its completion, the secondary benefits of employment during
construction are also substantial and if benefits of development are to go largely to the people living in the locality, labour-intensive methods score over capital-intensive methods. However, if adequate labour is not available to complete the project within the scheduled period, there is no other alternative except to supplement the labour with machines. Speed of construction is an essential criterion particularly in developing countries which are racing against time to build a better life for their people and the same will dictate a judicious combination of labour-intensive and capital intensive techniques. This is exactly what we are doing on our road construction programmes in Nepal. Our requirements of labour for the project in hand are about 15,000 to 18,000 labourers per day, whereas the availability of labour including those who come across the border rarely exceeds 8,000 to 10,000 labourers. As such, we have no other alternative except to combine both the techniques but while doing so we use the two techniques in those operations where each has definite advantages over the other.

I do not agree fully with one of the main conclusions of Sarvashri Sud, Harral & Coukis that labour-intensive methods can produce the same quality of product as capital-intensive methods—this is true in some of the major tasks of civil construction but in some of the activities like premix bituminous carpets, machine laid surface is definitely superior as measured by surface roughness. I also do not agree fully that hand crushing of coarse aggregates cannot economically achieve gradation standards comparable to those achieved by mechanical crushers. In the coarse aggregate of sizes from 90mm to 40mm, our experience has been that breaking by hand is much more economical than by crushers and required gradings are achieved, but in the case of smaller sizes of coarse aggregates, we had to resort to use of granulators on a large scale. Compaction by self-propelled and tractor or animal towed rollers can never be as satisfactory as that achieved by fully mechanised road rollers. Mechanised road rollers are available in most of the developing countries and they are simple to operate. It is for the project authorities themselves to procure these road rollers and issue them to contractors for use on work. If compaction is not to the required degree even if pavement thickness is substantially increased, it is not possible to obtain a satisfactory riding surface which can take substantial quantum of traffic.

Even in Nepal with a labour abundant economy, flow of labour to our construction sites is very inadequate. The position
becomes worse during seasons of agricultural activity. Our experience has been that local labour particularly in Terai area of Nepal are liable to be drawn away from the road work when they are called upon in agricultural seasons like sowing or harvesting more out of personal preferences or under commitments to local landlords as per traditional practices than merely out of better earning opportunities. To meet this problem, we had been adjusting our construction programmes to suit the convenience of the agricultural labourers—we had been changing the hours of working so that the agricultural labour can attend to agricultural operations in the morning and work on our construction projects in the afternoon. This practice has given the local labour not only financial benefits but also a sense of active participation without jeopardising in any way their agricultural interests.

Incentives in kind like supplying badly needed consumer articles to labour living in remote areas has been found to have a profound effect in improving efficiency of local labour. We have been able to persuade Nepalese contractors to take up works by resorting to deliberate incentives like exemptions from enlistment regulations, requirement of previous experience, lenient application of contract obligations and waival of penalties in deserving cases.

We have adopted with substantial success piece-work system providing different rates for each task under varying conditions. The field formations have been given powers to award works on piece-work basis within certain percentages above or below approved schedules of rates which are constantly kept up-to-date. It is true that this procedure throw a heavy burden on the supervisory staff but it is worth the trouble. Some expressed a feeling that large projects cannot be executed on piece-work basis but we have successfully executed large projects and we are still executing them in Nepal largely on piece-work basis.

In their Paper, M/s. Green & Brown have mentioned that contractor typically adds 70 per cent to his direct costs including tools, to allow for overheads such as supervision, finance and profit. This figure of 70 per cent is too much on the high side. Contractors who add such a high percentage of overheads are not normally likely to get work on comparative tender basis.

My own personal feeling is that we should not try to make a dogma of labour intensive technique even where employment
maximisation is socially desirable. Instead we should adopt a harmonious blend of both the labour-intensive and capital-intensive techniques carefully tailored to meet the requirement of each project.

Shri R. G. Gokhale

Apart from economic growth, social justice or removal of unemployment and poverty is a very important consideration for us in the developing countries. In our Five-Year Plan outlays, civil construction contributes as much as 50 per cent of the total allocation, and as such, adoption of appropriate construction technologies which will meet our twin national goals of economic growth and social justice, assumes great importance. This useful study made by the World Bank about labour-intensive technologies in civil construction appears to be confined only to road and irrigation projects. As building construction forms about half of the total Plan outlays in civil construction, it would be useful if such studies are extended also to labour-intensive technologies in building construction.

Though it has been admitted in the World Bank study that labour-intensive methods are technically feasible, it has also been said that labour-intensive methods are inefficient and economically inferior to capital intensive methods. This view seems to be based on comparing field observations of actual works being carried out by labour-intensive methods with theoretical costs of capital-intensive methods based on theoretical outputs of machines. It would be necessary to closely examine as to what would be the actual output of mechanised methods in conditions prevailing in developing countries as it may not be as high as in developed countries.

Further, in comparing costs it would not be enough to compare only the monetary costs but social costs and social benefits should also be assessed and accounted for in the comparison. The social cost of unemployment created by use of machines will have to be added to the monetary cost of capital-intensive works. Or, in other words, social benefits through creation of more employment would have to be deducted from the monetary costs of labour-intensive works.

It has also been mentioned in the World Bank study that adequate organization and management would be a critical
consideration in adopting labour-intensive construction. In the conditions obtaining in developing countries rather than those in advanced countries, perhaps this consideration may be more critical in adoption of high degree of mechanisation.

The non-availability of adequate labour during construction season due to migration of labour to their farms during cultivation season, which affects the progress of work, has been mentioned as one of the considerations in favour of adopting more capital-intensive technology. Before coming to such a conclusion it would be necessary to set off the advantage in earlier completion of the project against the social disadvantage of creating unemployment through use of machines for faster completion of work. Moreover, this gap between the completion time through manual methods and mechanical methods can also be considerably narrowed down by properly programming labour-intensive work. There is also one more aspect in this connection. One of the reasons, why the construction labour tends to be migratory and employs itself on agriculture during cultivation seasons, is because the construction process is many time discontinuous due to climatic conditions and also due to other technical reasons and does not assure continuous employment to the workers. In case we can bring about some changes in our methods of work so as to ensure continuous employment to construction labour, it could go a long way to reduce this migratory tendency of labour and we may be able to get more professional construction labour. I would quote only one instance to illustrate this. At present our brick burning methods in open kilns are such that burning operations have to be suspended during monsoon months thus throwing the brick-making labour out of employment who tend to become migratory and would like to employ themselves on agriculture during cultivation season. If some improvements could be introduced in brick-making methods by using covered kilns, the brick-burning process can be made continuous all round the year. This will ensure continuous employment to the labour which will tend to become less migratory. The brick-making industry also will stand to gain by getting more professional labour with increased productivity. Though the initial capital cost of the kiln may be somewhat higher, it would be worthwhile doing so because it is likely to reduce the production cost of bricks, by reducing consumption of coal and will also produce better quality of bricks.
It has also been stated in the Paper that scope of developing new intermediate technologies are limited. I would not wholly subscribe to this view. If intermediate technology means partial mechanisation of operations, I consider that the possibilities of improving operations through the right type of partial mechanisation seem to be really enormous and it is only a question of using one's ingenuity and selecting the right type and amount of mechanisation to be introduced in our present methods of work.

The final comment that I would like to make is about the term "Intermediate Technology" which has been used in this Paper. I would suggest that "Appropriate Technology" would be a better term, because intermediate technology may not necessarily always be the appropriate technology.

Shri K. V. R. Krishna Murty

In both the papers, break-even analysis has been used extensively to facilitate decision as to when the labour-intensive methods would become competitive with machine-intensive methods, provided both manpower and equipment resources are available and standards in terms of quality and speed permit the usage of these alternative methods in civil construction. Supposing the current wage rate of labour exceeds the break-even wage, determined through these detailed analysis, will it be prudent to dispense with labour-intensive methods? This is most important as both the papers deal with labour abundant and capital scarce economies. To my mind, in countries with wide inequalities in income levels and where the gainful employment poses formidable problems, the decision on the labour-intensive methods have to be taken from socio-economic standpoint. In this context, break-even analysis has limited practical utility. I may hasten to add, however, that such an analysis should be attempted in ensuring control of costs on individual projects but in the general context of formidable problems facing less-developed-countries (with labour abundant and capital scarce economies), the break-even analysis has to be used with utmost caution and the overall gains of adopting only labour-intensive methods needs no further emphasis under such circumstances.

Secondly, in order to maintain the labour-intensive methods to be competitive, it is very essential that the site organisation is absolutely competent. There is inertia to undertake civil construction departmentally presumably for reasons that depart-
mental system is not geared to undertake works in remote areas competently and also because the organisational problems are far too many. We are not possibly paying due attention to resources management which is most essentially needed when works are undertaken departmentally. In this direction, the site organisation is most important in order to ensure that there are no imbalances in the works system. There has to be thorough appreciation of the tasks to be done, detailed knowledge of jobs attempted and output expectancies in ensuring resources balancing as well. This is where most economies are made or lost although the budget restrictions in themselves could ensure economy on the basis of priorities and goals at the higher level of works management.

Thirdly, it is heartening to note that there is concern at the 37th Session of Indian Roads Congress on productivity of labour. In respect of labour, the output cannot automatically be ensured unless the working environments improve and the labour is provided with food and shelter as the inputs. As far as the labour is concerned, the problem for them is how to keep the body and soul together. It is necessary that wages and amenities in terms of food, shelter and the environments are looked into concurrently when attempts are made to improve productivity. It is just not enough to consider that given the daily wages of Rs. 6 or so to the labour per day the productivity will automatically be taken care of. The wage has to be need based so that the workmen give their best to the civil construction they serve.

In the end, I may mention that unless the well-being of the labour is properly thought of, the impact of productivity movement may not be felt.

Shri M. R. Malya

The importance of large-scale utilisation of human labour in all activities, in developing countries rich in manpower, cannot be questioned. However, economic consideration should be given with an overall view of country's long term economic interests versus consideration of a specific project. For instance, a quickly completed project whether it is an irrigation project or power project or a highway construction project can perhaps provide more employment from an earlier date on a perennial basis than that offered by the construction project for a short
duration of time. It is also an established fact that more than other projects, highway construction provides greater opportunity for labour employment.

Secondly, it has already been pointed out that as in every civil engineering construction, in highway construction also there are certain tasks or operations which have got to be executed by mechanical equipment to ensure minimum standards of quality required.

Thirdly, it would appear prudent to provide opportunities for semi-skilled and unskilled labour to acquire new skills of operating and maintaining mechanical equipment.

Thus it would perhaps be best to accept the fact that while in our country, where there is abundance of manpower, should make maximum use of it in civil engineering construction, it would be wise to utilise mechanised equipment where quality and speed demand it.

Shri T. S. Vedagiri

I have two points to make: the first concerns the comparative economics of labour-intensive and equipment intensive method. There are a few imponderable items one of which is the foreign exchange requirement for spare parts and the other is social and economic benefits. These can properly be accounted for by adopting the method of shadow costing. This will make the comparison very realistic.

The second point I would like to make is on equipment utilisation. In the developing countries, the equipment utilisation is much less due to larger downtime caused by non-availability of spares and trained personnel for operation. With this the labour-intensive methods are bound to have greater application. The management effect required for labour intensive methods may be more but not of a type which is difficult to attain, whereas in equipment intensive methods the management has to be highly technical-oriented which is difficult to obtain at all construction sites.

I think incentives for labour should be brought in. If proper work study is done and a suitably-geared system of incentives is adopted, labour productivity can definitely be improved.
The problem of migratory labour will not be that difficult if planning is done in advance and necessary residential and health facilities are provided at site for the labour. There is however, one point which emanates from political quarters mainly with reference to the employment of local labour whether they are efficient or otherwise. This will militate very much against the adoption of labour-intensive techniques.

The intermediate technology as advocated in Paper is also worth consideration. Application of work-study techniques on the construction sites can go a long way in improving the methods of work and improvising the tools and tackles that are best suited for the job with a view to improving productivity.

Industrial engineering (i.e. work study) techniques have been adopted with great success in almost all industries. Unfortunately, this has not taken any root in construction industry. It is high time that construction engineers acquaint themselves with the modern management concepts and apply them on other works whether labour-intensive or equipment-intensive.

On the whole it is felt that there is a great scope for improving labour-intensive techniques and make them viable in the present state of economy.

Shri R. T. Atre

It is necessary to collect data about the out-turn of different categories of labour carrying out various types of work under different geographical and climatic conditions so as to realistically prepare some norms for the out-turn expected from labour involved in road construction. These data would be very much useful for preparation of the rate analysis for the various items involved in road construction. Rate analysis forms the very basis of the District Schedule of Rates and as such it needs to reflect correct facts.

In India today, the need of the hour is employment-especially for unskilled rural labour. It could, therefore, be very necessary to adopt manual methods of construction in the given situation of time which is likely to continue in the near future. Considering this need of the hour, the Maharashtra State has launched upon an ambitious scheme known as the 'Employment Guarantee
Scheme where the Government gives guarantee to a conglomerate of 50 willing workers to find out a suitable work for them. Under this Employment Guarantee Scheme it is possible to take up road works in hilly areas, provided these roads are included in the 1961-81 Road Development Plan.

In order to encourage labour-intensive jobs in road construction works, it is very necessary to change the specifications for such items. For example, earth work in case of rural roads can be specified with less compaction as compared to earth work on State and National Highways. The gradation required in case of over-size metal and size-metal could also be specified differently for manual operation and separately for crusher-broken metal. It has also been experienced that it is possible to obtain hand-broken chips for light asphaltic treatments such as 20 mm premixed asphalt carpet, 2 coat-surface dressing etc. However, it is necessary to adopt different specifications for hand-broken chips than the existing ones which may perhaps ultimately lead to economy.

There is no doubt that we need to increase efforts aimed at increased productivity of labour. Following steps could be taken in this direction:

(a) Encourage labour co-operative societies.
(b) Encourage piece-work system by way of granting initial advances.
(c) Encourage assigning of work on task basis instead of daily rated basis.
(d) Increased medical facilities.
(e) Hutting facilities at work-sites be furnished to the labour.
(f) Improvised tools being provided to the labour and regular maintenance thereof, etc.

There are certain obvious works where labour-intensive methods would not be appropriate and where use of equipment is a must, such as hot-mixed, hot-laid Bituminous Macadam and Asphalitic Concrete work. In case of other works it may not be proper to compare just the items but it may be appropriate to compare the requirement as per design in case of labour-intensive methods and equipment-intensive methods (e.g. laying of 150 mm size metal machine crushed and laid could perhaps be considered equivalent to 225 mm hand-broken and hand-laid metal from performance point of view and the relative costs could be worked out for comparison).
It would not be appropriate to depend upon the out-turn data made available by the manufacturers of various items of machinery. It would be necessary to collect real data about the actual out-turn of the various items of machinery on different works which are spread out in the interior areas considering the following works:

(a) Sickness rate
(b) Available repair facilities
(c) Non-availability of matching equipment

Shri C. Rama Rao

Light refreshments and tea served to the labour on the work spot, at proper time and prompt medical attention to them for small illnesses, have resulted in much more out-turn of work by the labourers.

For obtaining maximum out-turn from machines: (i) at least 2 operators for each machine are needed to cut down idle time; (ii) incentives to operational staff have resulted in substantial out-turn; (iii) regular servicing and lubrication at the site by mobile servicing equipment has resulted in minimum breakdowns and minimum replacements.

It has been observed that feeder roads serving a number of villages are better done with good output by local labour. They generally take interest in the work and complete the work before the target date.

State Highways, M.D.R.'s in the hills are economically done by a combination of mechanical equipment and manual labour, where the height of hill cutting is more than 5 metres, it is economically done by manual labour.

Shri R. K. Banerjee

We in Border Roads work mainly departmentally and seldom use contractors or petty contractors. The area of work is far flung and ranges from the foot hills of the Himalayas to very high altitudes. Through experience we have laid down norms for the various types of work at various altitudes, including remote areas and cold areas. I am not saying that we have come to the
ultimate output by labour. The studies are in progress and the norms are being changed from time to time. In 1971-72, we had a Cost Benefit Committee. During the deliberations of the Committee, a rigorous study was made by the department itself and department fed data to the Committee as to what should be the constitution of the various units and what should be the output by each and this was based on the utilisation of the labour force and the machines which are handled by us. Even after 1972, this study is on and the things are being improved. Since we employ labour departmentally and do not work on contract, we do find it difficult to create labour intensive methods in creating more output from labour. The only way is to see that the labour is not idle, it is utilised properly and is given proper tools to give better output. Under the rules of the Government, we cannot just give each labourer some additional money for the output which he has given.

In the course of the discussions, it was stressed that we can get and improve lot of output through the labour by giving incentives to petty contractors or large contractors. I am yet to see that when we give encouragement to the petty contractor or the contractor, if that money really goes to the labour. I think the Paper is for incentives to the labourer and not to the middle man. So, we are yet to formulate a device where we can really give the benefits to each individual if he is giving a better output to the Government. And I think that this problem is being faced by not only Border Roads but all the departments in India. To give benefit to each individual we cannot create a system of measurement and payment and all the same which will be subject to audit of the Government and give the necessary benefit to the labour.

As regards the improvement of site management, it is a constant study that has been made in our department. I can say we have brought a happy combination of the machines and men and today in all we have achieved efficiency to the tune of about 75-80 per cent and still a study is on as to how best it can be further improved. The main factor which is coming in the way is how best to utilise the equipment. Men-management has not been a problem at all because we are not facing unions, lock-outs, etc. But as regards the machines, we find quite a few problems. Our own engine manufacturers are permitted to change the models of equipments every now and then. A big manufacturer like Bedford has changed their engine three times during the last five
years. There is need of standardisation. In the last six to seven years, a Government organisation has effected three changes in their tractor design i.e., D6, D8, D88A12. No doubt, D88A12 is one of the best which has come out but what is happening for D88A12 and D88A6 for which we are not getting spares. The money which has been invested on this capital equipment is not being fully utilised. Thus the project cost goes up. Since we have not been able to utilise the equipment, we are paying higher charges without getting the necessary return. Then we have got some of the equipments from foreign countries. In the foreign countries, we find the problem that they are very eager to sell their equipment but they are not prepared to give spares for the equipment. By the time within a year or two when we go in for spares, they come out and say the equipment is obsolete in that country and no spares are available. So, these are the problems which we face when we try to economise our work and bring the work to close proximity to our estimates or otherwise.

I will again come to the point of equipment. The heavy equipment which was being used in India are mostly in the river valley projects like Bhakra, the Damodar, Hirakud and other places. There it was working in certain spheres in a localised way, the equipment working within a radius of 5 to 10 kilometres can be much better looked after, can be much better serviced and that will definitely give better output. In Border Roads for a 100 kilometre road, we have inducted an equipment at the beginning of the stage, at the beginning of the road, at the middle of the road, at the end of the road by dismantling them, by taking them through the nullahs or the rivers or the bank. However, the problem of maintenance of this equipment is far more difficult. So the output of the machines belonging to the Border Road equipment cannot be compared to that of a river valley project or dam project.

Shri G. V. Subba Rao

I had been associated with this study from the beginning for over two years and it is only about three—four months back that I went back to the Border Roads Organisation. It was a problem for me and for many of my colleagues to find out from the revenue records as to how much of our population works on civil constructions. As a first step if we want to plan our labour properly, we should see and find out in which area, in what parts
of the country, how much distant away to a project the labour potential is available. I hope from our observation we should start now taking the statistics from the Government's side on this aspect which will help our planners to execute projects in a planned labour-oriented system.

The second point I would like to bring in is by increasing the efficiency of labour, whether it is working under department or on a contract, the labour is benefited in one way or the other. But this benefit is not seen by the labour who are employed by the contractor. Shri Banerjee has brought out what is the guarantee that the labour gets the benefit. Well, it is a very difficult problem unless at every level this is sorted out and probably the contractors' rates are dragged on by overall competition. What I can see is that if the labour is employed by the contractor and gives a thought to these improved methods, it is likely that today the labourer who is spending about 10 hours to earn Rs 12 may be spending about 8 hours and go happily with his family getting the total income as he wants to get it. This is not the case for the departmental labour but the contractors' labour are definitely oriented for the money.

The third point I would like to bring in is that we have got mates for the labour. They perform a duty which is just in collection of labour and nothing beyond that. If these people are trained in a systematic way, we can get better output from the labour. In the remote areas the mates are definitely acquiring some training which in turn helps towards the higher output of the labour. Howsoever, the Junior Engineer or the Assistant Engineer may try to tell or induce the labour, the effect of mate on the labour is more.

One more point I would like to bring in is the study of various tools and equipments we need. These cannot be obtained from the local market because our local market is also at the same level of development. They should be guided. Probably the purpose or the viewpoint of the executives is not known to the commercial agencies who are in the local areas. Unless a proper liaison is developed between the two forgetting the formalities, the tools we want cannot be produced in the market.

Shri R. L. Nanda

The Authors have discussed merits and demerits of mechanisation and manual operation in vogue in developing countries.
In developed countries, no doubt, mechanical devices for the construction of roads such as Single Pass stabilizers have proved to be economical because labour cost in those countries is very high. Such is not the case in developing countries, particularly in India, where labour is available at cheaper rates and in addition opportunities have to be created for their employment as a social responsibility.

Mixed technology using men and machines was adopted by CRRI for the construction of experimental soil stabilised roads, in various parts of the country. In this method, preparation of subgrade, excavation of the soil from the borrow pits and its spreading was done manually whereas pulverisation of highly clayey soil, such as black cotton soil, was done using simple agricultural machines like disc harrow and offset harrow. Mixing of sand-clay and lime-soil was done by rotavator. Water was added by tanks and compaction was done by road rollers. The field performance of these experimental stretches is quite satisfactory.

The second point is concerning the problem of non-availability of labour during peak agricultural season. In this respect, mention may be made that during the technical appraisal conducted by CRRI of roads constructed under "Crash Scheme for Rural Employment," it was noted that labour mobilisation was possible without any interruption even in the harvesting season, except in a few States. Thus, this problem is also not a very serious one even in an agricultural country like India.

Shri E. C. Chandrasekharan

Utilisation of natural soil, as it is, forms a major, if not the most important item of work in road construction in developing countries like India. This is done in the formation of embankments for roads. For embankments of small heights, say a metre, it may be quite adequate to adopt manual labour for doing the earth work. The compaction may be done by a self propelled roller and not by hand rollers. Thus these light earth works can be done by labour-intensive methods. In case of heavy earth work as for approaches to over-bridges, high fills on low lying areas, etc., mechanised construction using bulldozers, scrapers, dumpers, graders, etc. may be warranted to achieve economy, quality and speed. Thus machine-intensive methods would be
desirable where manual labour may not be effective and may be time consuming.

Next comes the utilisation of natural soils in combination, or soil with external additives, in the construction of stabilised sub-base or base for economical road construction. The question arises as to how far and how effective can the employment of manual labour be in this type of road construction. The developing countries cannot afford to replace the manual labour entirely by mechanisation, though the latter may produce better results. An optimum combination of the mechanical labour and manual labour is the real need for the developing countries, so that an adequate employment is ensured to the labour, especially the agricultural labour during the off seasons. A combination of the two, with the mechanical component being restricted to the use of tractors with a series of attachments as trailer, water tank, rotovator, disc harrow, disc plough, and rollers of various kinds may be a proper approach to the problem. The question of adopting "Single-Pass Stabilisers" and the equipments of that type, may not arise unless it is for an emergent operation, where social cost or financial considerations may not be the primary factors.

In making use of equipments like tractors and attachments, it is obvious that the extent of supervision will have to be more extensive. This means that the number of quality control tests would have to be increased. This will not offer a problem as this also provides employment opportunities for technically qualified people at various levels.

In the construction of the other components of road pavements like water bound macadam, bituminous base courses, wearing surfaces of various types etc., except in asphaltic concrete there is a considerable scope for using manual labour. The manufacture of stone metal involves use of considerable manual labour, though in special situations especially near cities, where manual labour is equally or more costly, the use of compressors and stone crushers may be necessary. Spreading of the stone metal and other operations for water bound macadam are still done by manual labour, except of course, the compaction by rolling.

Development of techniques for uniform spreading of stone aggregates and controlled spraying of bitumen by simple techniques, (not involving high mechanisation adopting aggregate
Spreader and bitumen distributors) may enable adoption of surface dressing even in remotest parts of the country with an ample scope for employment of manual labour.

In so far as the construction of high type pavements like asphaltic concrete is concerned, it is obvious that the hot mix plants and pavers etc. must be used. Even here, experience shows that the hot mix plant may not be really highly sophisticated or "automated" as in developed countries. This may be of a relatively simpler design and of modest capacities, capable of being maintained, repaired and operated without much difficulty by utilising local talents and skilled labour with some initial training.

For a better and extensive adoption of the "intermediate technology", a good system of training the staff at various levels including at the labourers' levels is very much needed so that special attention may be paid for obtaining the best quality by controlling the construction works at every stage.

Shri V. A. Khaire

Decision on the type of technology adopted on the basis of economy considerations can be termed as an internal choice as it is internal to the technology itself. We are constantly making such choice in every project or even as a generality. For example, while the British preferred structures based on steel, European practice often preferred RCC structures and labour-prone techniques. On the Jawahar tunnel project for the construction of a 2½ km long highway tunnel in the Himalayas, the German firm of contractors adopted the 'Kunz' method. In this method, the work was done manually, in stages and in bits and all the steel arch supports for the excavation and concreting were used over and over again. This was in sharp contrast to the American practice of embedding all temporary steel supports in the permanent lining.

Depending upon the prevailing conditions in an individual project, there can also be a forced choice of technology. In far away mountain terrain, we may be forced to take recourse to heavy equipment or labour-intensive work, depending upon the relative availability of equipment and labour and the possibility or otherwise of bringing them to site. In a forced choice, relative
economy gets second place because the only alternative to extra expenditure may be non-completion or abandonment of the project itself.

The adoption of labour-intensive techniques on the 'SPR Project in Nepal' can be cited as an example of a partly forced choice.

The third, namely, the conscious choice of technology for the generality of projects in a country draws upon such experience in a variety of projects so far as the technological part is concerned. The decision in the conscious choice of technology has, however, to be based on considerations other than technical also. Economy alone or technical sophistication alone do not govern or rather should not govern such conscious choice. At sufficiently high cost, developing countries have learnt during the past 30 years, that quick injection of the high technology does not necessarily give strength or stability to a nation's economy. Considerations like the need for full employment and equitable distribution of the Gross National Product have also to be brought in while making this conscious choice. These considerations demand a synthesis of the modern technology with and as applied to and by the large human force. It implies the concern primarily for man and only secondarily for monetary economies or technical sophistication. Such conscious choice lead us, therefore, to a technology, "Intermediate" only through the eyes of the West while it is the technology which the developing countries can properly apply.

The first imperative for the success of the conscious choice of intermediate technology is to define the area of its application on the macro-economic national level. Intermediate technology can be made applicable to most Civil Engineering work, barring those situations where there is risk to life e.g., under-water work, or when machines are a must e.g., pumps. Without such a decision, purposive application of the technology is not achieved and facile comparisons with applications of high technology are attempted, giving diverse conclusions, mostly based on personal preferences.

Naturally then, intermediate technology shall have to be applied not only to the labour component of projects but also to the materials. In our country, the approach to this aspect has been halting and ad hoc. Local materials are often advocated
but seldom perfected. Temporary shortages of cement give a fillip to the advocacy of lime. There has, however, been little effort towards production of lime scientifically on the basis of existing manual techniques, in the public organisations. Not only this, lime is forgotten away as soon as cement supplies are abundant. Our research has not been much directed to manual methods of brick making or lime production. For the housing works in Delhi in the Delhi Development Authority, we put up four lime kilns to the design of the Khadi and Village Industries Commission's Research Wing. We could employ a few innovations for such simple things as the access to the top of the kiln so as to be comfortable and efficiency-prone for the manual labour. The production itself was achieved through petty running contracts awarded to the labour gangs. Improvements in technique were sought to be made by control of temperature with the sophisticated thermometers made in the country. The capital cost for this venture was less than 5 per cent of a project for the manufacture of dehydrated lime on factory-scale. Besides, the kilns could be put into operation within four months of the conception of the project while the factory project has taken almost many years. It is thus not impossible nor impracticable to apply this conscious choice to materials also.

The application of intermediate technology is often associated with work in difficult areas. This need to be so. The approach which was adopted on the SPR Project referred to earlier was also applied with complete success in the capital town of Delhi. Building, development, and re-settlement works worth millions of rupees were executed in Delhi by the same system of petty contracts with departmental supplies of materials, decisions on contracts being decentralised and works being split up in manageable bits. As a matter of fact, the metropolitan areas offer fertile ground for application of intermediate technology. They contain large volumes of migratory labour from rural areas. Adherence to tradition bars the majority of them from taking to non-hereditary occupations in their home towns. Such inhibitions are absent in their new environment. Therefore, there is increased possibility of having fresh entrants to many occupations and also of organising them for improved and newer techniques.

At the field-level of labour-intensive work, the organisation of work as well as work-agencies calls for rational remodelling. Works have to be split up into labour oriented trades and items.
The materials and tools and plant have to be supplied as much as possible, by the Department. The role of the labour-agency has to be limited to labour inputs. This can be achieved by giving the so-called 'petty' contracts on work orders for works other than direct employment of labour. (Work orders are simple contracts without Earnest Money or Security Deposit and are terminable without notice.)

Shri M. B. Jayawant

There cannot be a dispute over the suggestions made by the Authors that the present methods of construction using manual labour need considerable improvement. I do not agree with their final objective and also the conclusions drawn from the studies in India. The ultimate objective of any construction project is to provide amenities to the users in shortest possible time with expected qualities. The financial cost is a relative factor to be related to the necessity of urgency and the required quality of the finished work. There are many other important social considerations, which take priority. Intensive manual methods can provide daily wages to a large number of manual workers for a few days. As compared to this, a quality job completed well on time can provide the entire community the benefits that it is expected to derive from the project earlier. Roads for example are not required just for having a road. The purpose can be to open up the country for transport of goods, agricultural or industrial, provide social services like education and medical facilities, through road transport into villages, enable the farmers to market their goods at profitable prices through efficient road transport and such other innumerable benefits. In India, we are racing with time to develop our vast interior country to the minimum standard. In such situation, use of manual labour for any project should be considered only if absolutely unavoidable and not as a desirable objective. Suggestion of the Authors to provide manual labour with equipment of intermediate technology and to stop there will mean complete stagnation. We should not expect our men to carry head loads, break stones and continue with such other manual labour for generations together. It is essential to provide them with proper machines and train them to use these machines. The machinery manufacturers should be encouraged to make machines suitable for Indian conditions. Engineers from advanced countries can think only in terms of highly sophisticated, complicated machines. We have examples of many European countries that have developed and are still
using machines which can give quick results at comparable cost with desired qualities in the finished product. The industrial development of the country should be the primary objective rather than providing daily wages for some. Turning the grinding wheels by manual labour can provide jobs for thousands. Do we suggest that should be done instead of using diesel engine or electric motor? At present we satisfy ourselves with the results obtained from the manual method of construction mainly because the so called mechanised methods adopted in India are not properly developed and controlled. The Authors have put the same facts in reverse way stating that the end results are not satisfactory because manual labour is not properly organised.

In both the Papers, the Authors have justified that only excavation work can be economically carried out by manual labour. Apart from this activity, for all other activities, their views are more towards mechanisation but they have suggested an intermediate method without considering several other advantages that can be derived from mechanised methods. They have dealt at length with cost only. This factor, as many of you will agree, is not the overriding factor. By presenting this Paper, the Authors have rightly drawn our attention to the out-dated equipment used by our manual labour. The suggestion to use wheel barrows for earth work cannot be practicable at all sites. However, use of proper wheel barrows for other operations such as transporting asphalt mixes should be looked into. Use of trolleys and ropeways is mostly adopted at bigger size projects and contractors having proper standing always carry such equipment on large-scale project.

When constructions are mechanised, the size of each job will be large enough instead of the present method of breaking the job in small works. Large works will enable the contractor to provide all the necessary social benefits to their workers. Food, shelter and clothing can be provided when the total project with each contractor is sizeable.

There are many such aspects that leads us to the conclusion that manual and labour intensive methods are to be tolerated when unavoidable but not encouraged.

**Shri S. C. Jain**

I had worked in association with M/s. Scott-Wilson Kirkpatrick and Partners, England, as the Senior member from Madhya
Discussion on

Pradesh, P.W.D. I shall review the performance of small equipments the firm had introduced and demonstrated on NH-12, and a few suggestions and comments on the demonstrations.

The venue of study was NH-12 near village Deori approximately 150 km from Bhopal.

The following two equipments were designed and demonstrated by the firm for haulage of earth.

(1) The hand operated rail cart.
(2) The scooter tyred wheelbarrow.

I shall first discuss the few points on rail cart.

The operation of rail cart: A cart was designed, which was sliding on the light-rail track. One end of the track was in the earth-borrowing area and the other on the formation of road.

The system of operation of the rail cart was as follows: The two loaders were loading the excavated earth into the bamboo baskets which were to be placed on the cart. A cart was carrying 8 to 12 numbers of basket at a time. The two numbers of pullers were pulling it by the rope on a pulley at the road end. Two numbers of unloaders were unloading the baskets by the side of the track, and thus a cycle of task was completed.

In my view, it was not a successful demonstration and appropriate intervention for substituting the traditional haulage of earth by head load. It is because as compared to the output by traditional method of earth haulage by head load, the output of the rail cart was less for same soil conditions and same parameters.

The labourers had not accepted it with full heart and their preference was still for traditional methods. The main reason was the type of activity assigned to them. In the complete cycle of operation i.e., excavation, loading, hauling and unloading, toughest work is of pullers (Haulers). The women labourers who were in quite large number were not prepared to pull the cart as this particular activity is not to their liking. In addition I should make clear that almost in whole Madhya Pradesh the women do not excavate the earth.
As it is a complete task of these four activities, output had to be measured in the accumulated form of output produced by all labourers engaged on a rail-cart. So also the input. Hence it is expected that all labourers should work in a synchronised manner, and if a labourer of idle nature comes in such a group of labourers, the complete cycle of work gets disturbed and delayed.

It had been concluded by the author on page 54 article 5.3.4 that greater the haul distance, larger the advantage. It is an accepted fact. But in the road construction generally 80 per cent of roads have got earth borrow-areas within 50 to 100 metre of lead from the formation of road and it is observed that the haulage of earth by head pans is economical and feasible upto 100 metres lead.

In case of haulage of earth by rail-cart, the unloaded material was collected in the form of big heaps by the side of rail track which requires another handling of material that is spreading of earth thus collected, whereas by the head pans the material can be thrown in the required region of the road with the approximate required thickness of earth-work.

Throughout the period of demonstration of rail-cart, the total time available for work in a day was 8 hours. The setting of the track in a proper gradient was requiring nearly 30 to 46 minutes for a single borrow-area i.e., 6 to 8 per cent of the total time in a day. This setting of track at one place only covers at the most 10 metre of the road length (5 metre either side of the track) beyond 5.0 m, each side it was difficult to unload the basket as it may require another manual haulage. Hence for more than 10 metre of road length track has to be shifted again, which may require same setting time again. Thus in the demonstration setting up of the track was involving too much time. Moreover setting of track at proper gradient for minimising pulling effort was a job of highly skilled labourers.

In cases of earth-work on high embankment, rail-cart is not at all feasible.

The other types of carts were also designed. A cross wooden bar was put as a handle on the tray and the pullers were running by the side of tracks. It was difficult or rather 'impossible way
of operation as the supports placed under the track and dip of the roadside drain were obstructing the operation.

The tray was designed as tipping to either side and the excavated material was placed on it. It was unloading the material only upto 2 m distance either side, hence shifting of track may be required more times.

**Wheel barrows**; In study on NH-12, the wheelbarrows with scooter tyres and named as ‘G’ type were demonstrated. My comments on its function and output achieved are as follows:

They had given better results than the results by rail cart, even then they could not beat the headpans output.

Greater difficulty in case of man operated wheelbarrows was experienced when crossing the road-side drains.

It has been noticed that only the tall labourers can handle the wheelbarrow efficiently.

The third aspect is the use of the rail-cart and wheelbarrows at murrum quarry to load a truck or a trailer.

It has given better results where they are to be rolled down in a truck or a trailer from a higher level to a lower level, as in this case less effort is required for pulling down the equipment.

Fourthly we come to the use of bamboo chute (gravity chute) or transportation of stones from quarries.

In study on NH-12, in Madanpur stone quarry a bamboo chute of 70 m length was erected. An empty bitumen drum was used as a container to take up the boulders to 70 m length downwards. It was sliding on bamboos by gravity and was getting self unloaded into a trailer standing at the end of the chute, the empty drum was pulled back on a ropeway.

I have the following comments to make on this process:

The method of pulling back the drums was a very difficult job. The puller felt fatigued even after pulling a drum.

The falling of boulders with the greater speed into the trailer caused considerable damage to the trailer. This aspect had been overlooked.
The chute erection for a particular feeding quarry is only economical when a large quantity of stones is required to be handled. This is because the erection cost of chute is itself very high. The erection of a chute, setting of proper curves for free sliding down of drums, etc., is a highly skilled job and beyond the scope of ordinary labourer.

During the study I had noticed some really feasible and helpful points in organisation of work to improve productivity which are as follows:

**Gang composition:** In demonstration carried out at R. K. Puram service roads, Delhi, the task was spreading 40 mm size metal for consolidation. The work was done on task work basis. There were 8 gangs of labourers put for the work, each gang was composed of two labourers. It was noticed that the the gang composition of either a husband and wife, or his relatives, the output was amazingly high. I fully agree with the Author on page 46 para 5.1.1., that poor gang balance is a frequent cause of low productivity.

**Use of two or more trailers for a tractor in transportation of material to the road side:** Reference, page 59, para 5.6.3. In my view, it shall definitely minimise the waiting time of the trailers and tractor too. This could, however, be improved if we do not send the unloaders in the trailer with the material to the unloading point. This work of unloading can be taken up with the labourers working at that site on other tasks. This suggestion of course, is applicable only in case of departmental works or contract works where contractor is doing other works also. Thus the unloaders going in the trailers can be put on other activities.

**Avoidance of second handling:** Transportation of murrum by tractor and trailer was observed on NH-12. The murrum for base-course was directly unloaded on the road itself and measurements were taken by section after proper spreading. This helped to minimise the loss of material.

**Lt. Col. Avtar Singh**

I would like to go along with Prof. Swaminathan in asking a few pertinent questions before deciding upon our
approach to the execution of the tasks. I will not repeat it, but will only add to it.

Firstly, the environmental and climatic conditions of the area where we are going to work. Secondly, the logistical problem which will be created if you are to induct a large human force into the area where the force is not already available. Then there is the question of essentiality of a particular equipment, like you cannot do any rock cutting without the help of pneumatic compressors whatever else you may like. Finally, there is something called speed of construction or the speed of development which needs to be taken into account.

It is demanded of us in this country, not only to keep pace with the socio-economic progress but help accelerate and, boost it. Can we afford to ignore that? Are we wanting to bridge this ever widening gap between the developing countries and developed countries or do we want to further widen this gap? If we were to adopt only this man-intensive methods, surely we cannot keep pace of progress which we want to achieve, and will be only lagging further. To stress my point, building industry is a typical example. This industry as it is today is completely man-intensive but why do we want to change it to mechanisation? It is for the simple reason that we are not able to cope with the housing requirements of large urban areas today by the conventional methods. We are going in for the prefabrication to help speed the tempo. This particular aspect has to be borne in mind before we decide on our approach.

We are very grateful to the Authors of the Paper for drawing attention to two very important aspects which so far, frankly speaking, have been completely ignored. One is the output of man wherever the man-intensive methods were used or can be used. The output of a man is basically man plus his tools he uses plus the motion he is required to make in performing the task. Frankly speaking, we engineers—when I say engineers I mean civil engineers—do not apply our mind to these two other essential elements, *i.e.*, the tools we use and the motions we make in the techniques and processes of construction. To that extent, the authors, observations that the work study techniques and the improved tools will improve output, is really very welcome.
Another point is regarding the organisation, the organisational changes required, the procedures and our outlook towards the work. Wherever man-intensive methods are to be used, training of the lower level supervisory staff becomes very important. It is far easier to achieve proper quality by use of machines than manually, in which case a very close and constant supervision is needed. As Prof. Mehra has already pointed out, we have on the ground today poor superintendents and bad engineers. Certainly something needs to be done in this vital field of training.

There was a point raised regarding incentive to the labour and mobilisation of labour. There can be no better incentive than paying him based on his output. In my own experience, this has always proved to be the best method although most of the departmental procedures do not allow it. The biggest advantage in this approach is that not only productivity gets linked with wages but also that the whole family can work thereby contributing to the family income. Such areas of labour-intensive works are:

(a) Stone quarrying and collection
(b) Stone breaking
(c) Loading vehicles
(d) Spreading WBM metal etc.

A method which proved very helpful in inhospitable areas for getting labour was paying them ration or other things in kind at controlled rates or concessional rates rather than paying them cash. The area in which you have migratory labour and the local labour is not easily available, this could be tried. I do not think it would be correct to draw the labour away from the land as has been suggested particularly in the agricultural season. Not only it will have impact on the food production but at the same time the problem of migration of labour from villages towards the urban areas will increase.

I think what we need is to have an integrated approach to the problem because there are two ends of the spectrum man-oriented intensive and machine-intensive. Now, the output of any machine or equipment is a reflection on the technical development infrastructure of a particular country. If you have
necessary logistical backing, if you have the capacity (volume of work) to use the machines, if you have the requisite skilled people available to operate and maintain your machines, there is no doubt that the machines' output will be much higher. Otherwise if you lag in these essential pre-requisites the machine output will be very low. Hence we have to adopt an integrated approach keeping in mind what is best for the particular task in the particular environment.

Yes, we have to make use of manpower available in the country. Hence, there is need to identify areas of work where the time of completion is not a problem, where the quality of work is not so demanding and labour is locally available, those areas we must reserve for man-intensive working but areas where your quality and speed are of paramount importance, you certainly cannot do that. Take the case of road paving in the cities of Madras or Bombay or Delhi, you try man-intensive methods, you land yourself in a soup.

Finally, there was a point raised regarding break-even while working out the economics. This also is applicable up to a certain level only. If you go beyond that by trying to improve the output of the man by all incentives and making his monetary compensation much higher than what is generally available in the country it will have repercussion on the production cost of other industries in the country, and economy of the country as a whole will be affected.

So I would say that what is required is a healthy blend of labour and equipment for optimum results—a job composite approach. Our motto should be balancing of the available, i.e., resources, men and machines for the maximum utilisation, economy and efficiency.

Shri K. Arunachalam

The question whether it should be man or machine is likely to be controversial for some more years to come, the proponents and opponents having their own arguments. On the equipment side, there is no denying of the fact that these lead to better quality of work in several cases which is generally not accounted in terms of money in economic analysis. Significant developments on equipment methods have taken place in other countries, and we cannot afford to be static.
On the other hand, the position with regard to labour and employment is rather disturbing. I would like to counter the arguments of the Authors about problems of labour mobilisation with facts and figures. The 27th round of National Sample Survey in the country showed that the number of unemployed and intermittently employed casual workers in 1972-73 was about 30 million of whom more than 4 million were chronically unemployed. There is a belief in some quarters going by Stiglitz’s theory that in the presence of seasonality or seasonal variations of employment, surplus labour cannot exist, but this was not found tenable by some recent studies. The farm management studies of Ferozepur District, one of the prosperous districts of the country suggested that nearly 20 per cent of the work force was surplus as recently as 1968-70 even after allowing for peak seasonal requirements of labour. For more details, I would refer the authors to an interesting book by Prof. Amartya Sen recently brought out by the ILO.

The problem therefore deserves a very close scrutiny. One approach could be to identify and demarcate work areas and tasks where equipment can produce better quality in definite terms and reserve these for equipment-intensive methods. In the field of road construction, bitumen spraying and grouting, bitumen macadam, asphaltic concrete and the like would fall under this category. A trend in this direction is already visible in the country, particularly for major roads. The other task like earth-work, production of large sized aggregate, etc., which can be done without losing quality could be reserved for labour methods. It will be a great disservice to the nation and the labour force if one brings in a big equipment to do the job and drive out thousands of labourers out of work and livelihood.

I understand that the ESCAP some three years ago had prepared a detailed document on the subject. I would like to know whether the authors are aware of this and if so how the results are comparable. Secondly I would like to point out that some observations on productivities of bulldozers was made in Indonesia during the Phase II study and in India during Phase III-A study. In reaching the conclusions, these data have not been taken into account. I would like to know why this was so, and why the authors had to make assumptions from manufacturers’ manuals, which have since been revised three times over a period of 2 years.
Dr. M. P. Dhir

I believe that factors many more in number and of much larger variety come into play while making the choice about labour-equipment mix. The engineers would not only like to see that the technology adopted in roads construction is most cost-effective but equally, if not more, they would wish to see that the manpower in the country is duly engaged in operations more productive than road construction and that the manual work is not only in keeping with human dignity but also with the exclusion of environmental and other hazards.

The country does face the problem of unemployment and under-employment. This is an important goal-factor identified in the Fifth Five-Year Plan. I believe that we have to seek satisfactory compromises and, surprisingly, the process seems to be fairly self-adjusting. The conclusions projected in the papers seem to be quite acceptable by and large and one is at once impressed by their open-ended character. I wish to comment briefly only on one or two of them. Indications have been given as to the competitiveness of labour-intensive and equipment intensive methods for different wage-levels, etc. I wonder if a host of diverse social factors does not influence the related situations and choices and whether these social and other factors are not operative equally for both labour and machinery. Basing machinery output on appropriate actual data would tend to change the break-even wage more in favour of the labour-intensive methods. In economic terms, the deficiencies in management of lumpy machinery can be much more consequential than those in the management of labour.

I think we should take particular note of the need and scope brought out in the papers for increasing labour productivity through better management incentives, aids, etc. Consciousness about the various possibilities can prove to be of great value in handling works. The papers do not however seem to paint a very hopeful picture for new intermediate technologies. I think the technologies in road construction in India have been undergoing shift in the past and that they would continue to change in future, hopefully at a faster rate. The country as a whole has unique set of conditions and each project may have its own uniqueness in this regard. The labour-machinery mix in a way is a dynamic system. Right now, there is one mix being adopted clearing deep snow at the Zojila pass; there is another for
paving city streets in Bombay; and still another for constructing feeder roads in Andhra Pradesh. The authors have aptly taken note of the various innovations made in the country. Unevenness Indicator, Profilograph, Automatic Unevenness Recorder and the Rotiller—all developed at the Central Road Research Institute—are some other examples. Many more are needed. Many of them are out of context in so far as the developed countries are concerned and solutions must therefore be found by and large indigenously.

Another aspect highlighted in the papers is the need for compatibility of project design and project technology. I believe that this is being kept in view generally but heavy price has to be paid directly or indirectly where this gets ignored. We are also paying attention to the need for differential standards for labour-intensive and equipment-intensive methods. For example, the surface evenness standards being brought out by the Indian Roads Congress are being kept different for machinery-laid and manually-laid construction.

Shri R. Thillainayagam

As regards the technical feasibility of our labour-intensive technology definitely it must be quite possible especially in road and road transport industry to use quite a lot of labour but at the same time when you want to attain quality naturally you will have to go in for capital-intensive technique. Take for instance where you have to lay a high quality airfield pavement naturally the quality of work must be topmost but the same quality may not be necessary for other pavements. Now as regards the type of tools, naturally man himself is a maker of tools. The tools used must be suitable to the working which he is engaged. So, in this connection quite a lot of work has to be done because the tools supplied to the labourer either by the department or by the contractor are not suitable and I think I must congratulate the authors for bringing out these few points.

As regards the economic feasibility, naturally when there is more than one factor, you can substitute one factor by another only to a certain extent but of course the authors have given a figure as regards the wages only upto a certain wage say 1 dollar, 2 dollars, above two dollars whether the capital-intensive technology is feasible or the labour-intensive technology is feasible.
What I personally feel is in the case of wages if it is based on the supply and demand, what they have given is correct but when the labour wages are fixed statutorily, I do not know we can have such a figure.

One other point is the overall cost. When you construct a certain embankment, it is not only the cost of the embankment but the operation cost. Ultimately when you have a very bad surface should also be brought into the comparative cost when you are studying both the capital-intensive and also the labour-intensive industry.

The other point is about the lack of mobilisation. Of course, we have been always talking only about the labour mobilisation but we have not been discussing what happens once you mobilise labour. You get them in abundance and then throw them away or are you going to continuously feed them with work. Especially in the case of road industry, I find that more or less the people who are engaged in breaking stones and similar other jobs whether by department or the contracting industry may feed them with continuous work, it may not be possible for other works.

As regards the seasonal effect of the labour, I would say that it is not applicable to all parts. As a matter of fact you cannot do the agriculture whole day, we have got so much labour for agriculture. So the question of taking away agriculture men arises only in a few areas.

The next is about the supervisory requirements. Usually we have the labour working in a gang, they have a leader and they work with a gang and mostly the contract is only with the supervisory staff of the labour and also the department. Of course, it is quite necessary for the supervisory staff to have some management skill and also the organisational ability.

As regards the wage and incentive system, what I would suggest is the incentive should not be by way of monetary remuneration, it should be in kind. You can give them free food or free tea or free snack, etc.

I agree with the views of some other speakers that the Head of the department or the industry should not only take care of the labour but he should take care of the family of the labourer also
by way of providing free accommodation, food and also education for their children.

Prof. G. M. Andavan

In paras 32 and 33, the Authors have stated that organisation of labour-intensive methods is more difficult than the organisation of capital-intensive methods. It is stated that the site supervisors and graduates of polytechnics and engineering schools where the education tends to be oriented towards design engineering and use of equipments and these supervisors possess no prior experience in working with labour and they rarely, if ever, come up from the labour ranks. The above conclusions appear to be qualitative rather than quantitative.

The studies have concluded that labour-intensive methods are technically feasible and are also comparable to capital-intensive methods with regard to productivity also, when the rates of wages paid to labour are low, say about 1 to 2 American Dollars per day. As such it is clear that the need for capital-intensive methods would arise only when the rates of wages are very high.

However, there may be occasions where the use of machinery would be an advantage for ensuring better quality control or for adhering to a tight time schedule, etc.

Shri A. P. Remedios

We have found that the most efficient method, as well as economical, when using a crusher to crush stones down to 1 in. size the reduction ratio should not exceed more than 3 or 4 to 1, and therefore, we prefer to go for manual breaking of 3 to 4 in. stones and then to put them through a granulator. This is where human labour and machinery get together most efficiently.

Similarly, for sand collection, we are using donkeys to bring the sand to the banks of the river, and then carting by trucks. Very often, the trucks cannot come down to the river bed, and so if you have these two combinations then maximum economy can be obtained.

There is also the question of health hazard in the use of crushers. Unfortunately, all over the country the primitive
system of ‘trommels’, what is called the rotating screens are being used. It is most out-dated, as the first screen gate choked up with everything that comes from the crushers. It is also a health hazard for a person who goes under the screen to collect the material. We should switch to the multilayer VIBRATORY SCREENS (with the larger mesh screen uppermost). These fabricated locally hardly costs about Rs 6,000.

Regarding asphalted roads, the percentage density of the bitumen, this is tied up intimately with the grading of coarse aggregate which is also similar to concrete mix design technology. We have also a number of problems with concrete technology, as there are no training facilities in the country, in the technique of making good, cohesive concrete economically. One of the main reasons why concrete mix design cannot be implemented is, because of lack of proper consistent grading of coarse aggregate, and the crushing/screening arrangements are not satisfactory and vary from crusher to crusher. Each stone manufacturer put whatever size of screen he likes and there is no control on them, especially in city areas, where there may be more than fifty crusher sites. Some have short screens, some have long, and the partitions are not long enough or high enough with the result that various sizes get intermixed. Hence the concrete mix comes out variable and we get honeycombed concrete.

The Central Labours Institute or the Central Technical Institutes, do not train construction foreman. All other industries are covered. The civil engineering industry is the biggest industry in any country. Yet, in India, it is the most neglected industry, as far as training facilities are concerned for the practical aspects.

Shri Sudip Kumar De

In my opinion, major civil construction works carried out by equipment-intensive methods, have an edge over labour-intensive methods due to the following reasons:

(i) Though labour-intensive method definitely generates labour employment, the output and quality of work done by labour intensive method cannot be comparable to these by equipment-intensive method as the former is a slow process and it increases the time of completion of the project and thereby its cost.
(ii) The labour available in India is seasonal and hence it is difficult to maintain the constant rate of progress during the harvesting, sowing and monsoon seasons. The authors have also accepted that the rate of wage increases three times than the normal rates during the harvesting season. Moreover, if the labour is diverted from agriculture activities towards the civil constructional activities by paying higher wages or by more incentive methods such as giving foodgrains, then it will adversely affect the agriculture output which is vital for the economy of this agriculture based country.

As far as our country is concerned we are now in a much better position regarding the availability of civil construction machines. Most of the machines are now being manufactured in India. And hence the dependence for spare parts on other countries has been reduced to the minimum. This has cut down the idling time of machineries sizably. The availability of machines and spare parts recommends the use of equipment-intensive method. This would also give an encouragement to industries in our country.

However, in civil construction, and such major construction for which due to some reasons machine cannot be made available, the labour-intensive method shall have to be adopted.

It is recognised that methods of payments and supervision have a strong bearing on the productivity. Now-a-days in India the wages of labour are controlled by a "Minimum Wage Act". There is always a vast difference between the market rate and minimum wages rate. If the labour are paid on daily wages they do not take initiative, this is mainly because of the fact that they start thinking that even if the output is more they are not going to get more wages.

Secondly, due to vast difference in market rate and minimum wages, the labour potential available is of low productivity.

It is an established fact that output is increased if the mode of payment to the labour is on task basis instead of daily wages. If healthy competition amongst the labour paid on task basis is created, we can further increase the output of work. But there is a limitation to this. After certain stage, manual output cannot
be increased without adversely affecting the quality. For achieving the minimum acceptable standard of quality, it is therefore, necessary to fix a limit on the task that can be done by a labourer depending upon his physical capacity, efficiency, nature of task, etc. To fix the highest limit in task method is necessary because this may adversely affect the labour prices in other sectors of works also. It should also match with the wages of site supervisors.

On most of the civil projects, migrated labour works. The supervisor is generally a local person who has little knowledge regarding their language, food and living habits. In labour-intensive method it requires more supervising ability than the equipment-intensive method. The labour is heterogenous group of persons. It is always better to select the site supervisor from the same group of labour. This helps in better control and organisation. To achieve this, it is necessary to select the supervisor with great care and give him intensive training for the job in hand. This will not only improve the control over migrated labour, but also check the flow of labour during harvesting season back to their native places. It would be desirable that an extra incentive whether in cash or kind be given to the site supervisor, which should be based on output and quality of work done.

With the improved tools the output will increase as also the energy put in will be considerably less. This saving in energy can be utilised for further increased output. However, the labour is not willing to accept a change in the conventional tools being used by them. It will be desirable to give an incentive to labour who use improved tools.

I would like to add a few lines more regarding the results and conclusions drawn after data collection test.

The test conducted by the author, is under certain ideal conditions, having a number of supervisors, which cannot be achieved in real practice. Secondly, due to large variation in boundary condition parameter depending upon each job, place, group of labourers, combination of male and female labourers, individual capacity of each labour, climatic conditions, site condition etc., results and conclusion drawn after certain job observation cannot be applicable truly with the other job.
The test is based on micro analysis in nature and error in output for a job to be compared with this available test result may be of a very high order. This variation is due to the fact that the labour available is a heterogenous group of people throughout the world.

Will it not be a more practical approach if similar tests are conducted for each particular job, having the same boundary condition parameter for which labour-intensive methods are to be applied?

Shri H. C. Malhotra

I have to raise one or two points on this discussion and the first is that on page 65 of the Paper by Sarvashri Green & Brown it has been said that earth work cutting on hill roads by bull-dozer is more costly than labour. My own experience in construction of hill roads is that this is not so. In Himachal Pradesh, we are making use of bull-dozer in formation cutting and we cut the road to the width of 6 ft. in the first instance so that an air-compressor can be taken along the road. With this air-compressor, the reaches containing rocky formations requiring blasting are first widened to full formation width and the soft reaches which can be cut without blasting are left intact. After the hard rock blasting has been completed in a length of one or two kilometres, a bull-dozer is brought and it starts widening the road from one end and having continuous work, it works economically. Our experience has been that road construction in this way with the help of air-compressor and bull-dozer is cheaper than by manual labour or even than the combination of air-compressor and manual labour. I do not know on what data the authors have based their findings, but I feel that it requires looking into again.

Regarding choice between labour-intensive method and complete mechanisation method, my view is that we should not go blindly for any of the two methods. What we need is a proper and judicious combination of men and machines with a view to achieve maximum economy, speed and good quality of work.

In case of labour-intensive method, there has been discussion about giving incentives. Surest way to do work economically
is to get it done on contract basis. But where departmental work is done, we should try to do it on piece work basis.

Some doubts have been expressed that in labour-intensive method, there will be delay in completion of work. I would suggest that where work is allotted on labour rate basis to petty contractors, this in itself is a substitution for piece work. We can give bonus for early completion or completion within the stipulated time. This method has been followed by Irrigation Departments of Punjab and Haryana and they have a definite clause in the work order according to which bonus is given for completion of work earlier than the stipulated time.

Shri P. M. Nadgauda

There are many parts of our country which are chronically subject to scarcity and famine conditions. During such periods, a gigantic labour force is released which is motivated only by the human desire of keeping the body and soul together. Maharashtra has such a period of acute scarcity for about 2 years in 72-73 and 73-74. During this period, a tremendous labour force was engaged on various construction activities. On road works and metal collection works in about 2 years’ work costing over Rs 100 crores was done. Earth work in bank and cutting has been done for miles and miles and huge mountain-like heaps of metal collection has been done. Works which contractors would have taken years to construct were completed in a matter of weeks. The turnover of thousands of labourers was simply amazing. Those who have witnessed this gigantic capacity of the labour force during this period, were only regretful that but for adequate planning and preparation, technical and supervising organisation the energy could have been diverted to achieve maximum useful results and at least 40 to 50 per cent of the energy would not have been frittered away in many cases for works which were not ultimately useful to the society. On the other hand, we know that in the early years of development of China a very large and continuous human labour force was employed round the clock in an organised and controlled manner. The motivation provided was of course the pressures of the political system of that country but the results and progress achieved on construction of roads, dams, and canals were fantastic.

Bearing in mind therefore the tremendous labour force that becomes available during scarcity periods in several parts of our
country, a detailed and in-depth study of organisation and methods for employment of such labour, has to be made and achievements and weakness of Maharashtra should be carefully and systematically analysed for future use. The existing manuals for scarcity works and famine codes etc., do not provide sufficient guidance and organisation of the labour during such periods and realising maximum useful output should be the aim of the study.

Another area of study which I would strongly advocate is the great and unique experiment of Maharashtra known as the "Employment Guarantee Scheme". Under the scheme no able-bodied person, desirous of employment, is denied opportunity to work. A wage of approximately Rs 3 is assured. The wage rate is related to prices of foodgrains and is about 25 per cent less than the normal piece work rate for a labourer's single day's output. The labour is employed only on productive works of minor dams and tanks, canal excavation, contour bunding and trenching etc. Roads are permitted under the scheme only in hilly and inaccessible areas. For every district, almost Rs 2 crores have been annually earmarked for this scheme. No doubt the work carried out under the scheme is far more organised and systematic than scarcity works, yet as the scheme is only in its second year, there is scope for improvement in many areas and great potential for diverting manual labour into useful channels. The scheme is bound to be followed in other states also.

As the Paper indicates that in future the main thrust of the studies would be in implementation, I suggest that Employment Guarantee Scheme should be included in the studies.

Shri J. S. Sodhi

I would ask what is the cost of a work? When we say for comparison purposes that job 'X' with machines has cost 'A' and with man-intensive methods has cost 'B', this does not give complete information.

For any work when we prepare an estimate, we give the name of the work i.e., the situation, time required for completion and the specifications or quality expected of that work. As such, when all the three items are given, whether we do the work with machines or labour, then only the work is completely defined. Accordingly, it is not possible to have a simple comparison of
quantities and the unit costs in both the cases. While comparing works to be done by both methods, it will be necessary to compare all the three items. Giving an instance of time comparison and costs, for a particular-air-conditioning job the quotation was Rs 20,000 if the time required is 15 days, Rs 15,000 if the time is 30 days, and Rs 12,000 if the time is 40 days. So, while comparing costs time element is always relevant to the issue. Similarly, discussing the time and situation factor together. I had been incharge of snow clearance job some time back. Time available for doing the work was about 60 days and the road was to be opened to traffic on a particular date with plus minus a day or two. If otherwise, the opening is delayed, then there would be additional costs by way of air-lift of men, food and stores, besides gross inconvenience to civil population. Since, the time available was only 60 days and we had to move about 1.5 million cubic metres of snow, the quantity to be moved daily was 25,000 cubic metres for which a labour force of about 6,000 per day would be needed. But the deployment of such a large force is not possible. Even if such a large force is found, we do not have the space for it to work. The work is necessarily done largely by machines, supplemented by minimum labour force. In such a situation even the type of machines have to be carefully selected to secure maximum utilisation or output. Similarly, discussing the specifications or the quality control aspects, which have been touched in the Paper also, in bituminous macadam construction to get a smooth acceptable surface mechanical pavers finishers must be used. Even with the maximum precaution taken to do this work with labour, the same quality just cannot be achieved. As such in this case cost comparison of work by machines or labour just cannot be made.

Accordingly a generalisation of the substitution of labour-intensive or machine-intensive methods is a misnomer. We shall have to analyse each particular job and based on quality and time requirements, optimum proportion of different resources of men and machines have to be deployed, to do the work at a minimum cost.

Shri Santok Singh

Construction equipment in this country is still quite expensive. Its maintenance is also equally expensive. If one goes through the detailed costing of construction equipment, one can find that the prices could be practically cut down to half (which
is nearly the international price of the equipment) if Government duties levied by various State Governments are nationalised.

Of course, where speed is a primary concern, employment of equipment is the answer. But costwise, it is our experience that at times employment of labour is cheaper. This is particularly so for earthwork, breaking stone aggregate, etc.

In fact, the best method today would be to combine equipment with labour, thus improving the speed and keeping the huge man-power also fruitfully employed.

I was very glad to learn from our colleague from Maharashtra who told us that last year, they have executed earthwork approximately valued at Rs 1.2 crores in the drought affected areas by labour alone. In fact, I know of something similar.

Way back around 1935–36 when Japan declared war against China, the Chinese realised the imminent loss of their Eastern Sea Board and the need to shift their Capital in the deep south-west to Chungking. They immediately started improving what was practically a mule track connecting Burma. This came to be known as the famous Burma Road. A little more than 1000 miles of this road, mostly in hilly terrain, was built exclusively by labour in about 2½ years. This road had a number of GRANITE rock cuttings of approximately 100 ft. high. I had the occasion of travelling on this road immediately on its opening. Thousands of workers were still working in widening the single lane highway they had just completed. You should see thousands of labourers brushing shoulders with each other and carrying out the gigantic task. One can realise what labour could achieve in an emergency.

Shri Green has been good enough to show a few sketches of equipment which can be usefully employed on our road work and earthen embankments. The revised design of the wheelbarrow is quite interesting. But here again, one cannot make it a general rule. Wheelbarrow can be used by sturdy labourers only. We tried it in our area and found that the labourers would actually fall down along with the loaded wheelbarrow and it had to be discarded in preference to the usual method of transporting the materials.
Shri Green also stated that during their tours in various countries, they had seen that the heating-pan for mixing aggregate with bitumen was found to be superior in Indonesia than what he has found in our country. I wish, he had shown some slides or sketches for our benefit.

Everyone agrees that getting work done on piece work basis is beneficial to all. The labour has the incentive of getting little extra money by doing the work faster and producing more within the same man-hours. But unfortunately, the authorities of the country, do not think the same. They feel that labour is being exploited by making them work on piece work. They think that the best method of employing workers is on daily wages (irrespective of the productivity). The abolition of Contract Labour Act is the first step in this direction.

Increased cost of work due to delay has been rightly brought home during the discussion and attention to it should be invited of the authorities allotting funds. It may be a good idea to prepare the estimates on the basis of completing the work in a particular period and the probable excess cost shown separately year-wise if the work drags on.

Shri S. P. Caprihan

I was a Road Engineer in the past and had constructed a few hundred kilometres of road but now I am an Irrigation Engineer constructing dams and canals. On my work, I have engaged about 20 to 30 thousand labour. I have also used machinery worth about 4 crores of rupees. The above labour and machinery have been used on construction of Tawe Dam and about 2,000 kilometres of canal construction. Based on this experience, I wish to state that I do not agree with the conclusion drawn in paras B and C of the learned authors that labour-intensive methods can only compete with machinery at low wages. This is, in my opinion, not correct. I will illustrate this point with a few figures. On Tawe Canal, we called tenders. We had some contractors who had dozers and scrappers. Other contractors had imported specialised labour from U.P., Rajasthan and Orissa. These two types of contractors were tendering and quoting rates. An analysis of the tenders showed that when the lead is upto 100 metre and the lift is about 2 metre, the contract always goes to the labour contractor. He was quoting a rate of about 30 rupees per 10 cu. m. of earth work and the machinery contractor was
quoting a rate of about 45 rupees per 10 cu. m. of earth work. This shows that there is a definite area where, labour-intensive method is cheaper. In the above works, the wage earned by the imported labour was of about Rs 7 to 10 per day. Certainly this wage for 1973-74 is not low. The difference of rate between Rs 30 per 10 cu. m. and Rs 45 per 10 cu. m. is considerable and apparently upto Rs 10 per day, the labour-intensive method would be cheaper than the machine-intensive method. The author has given valuable suggestions about improving the productivity of labour and if these are adopted, certainly the productivity of the labour will improve and the labour would be able to earn about Rs 15 per day, i.e., they will earn a wage of about 2 dollars and for break-even point with machine rate or cost, probably they may get about 3 dollars. This will show even a higher wage can be competitive with machines in such an area i.e., where small lifts and leads are involved. I accept that labour management is getting difficult with the passage of time for obvious reasons. Ten years earlier machine management was difficult but now it is getting easier because, we are manufacturing spare parts and manufacturing many other items and local workers are getting trained. But, in spite of the increased difficulties in the area of labour and reduced difficulties in the area of machines, I feel that there are two distinct types of marks, i.e., works with small lead and lift where labour will definitely have a better claim than machine. Further, we cannot forget that in our countryside we have considerable under-employed labour and unemployed labour and this fact cannot be lost sight off. I, therefore, feel, even if labour-intensive work is slightly costly, we must use labour-intensive work to make full use of our surplus labour resources. Whatever I have said about canals, I think, it equally applies to the road particularly for the earthwork. There are many other areas like the above and where in our country at least labour intensive methods should continue to be used. I may mention here that where time is the guiding factor, machines will have to be used because the labour-intensive methods take more time. Similarly where climatic conditions do not permit use of large labour force, machines will have to be used.

Shri A. K. Dasgupta

We made studies for employment of equipment and found that output could be increased by giving incentive to operators and the maximum needed output could be achieved without
difficulty. This is particularly so for huge quantity of work with time-bound programme. The ultimate economy can, therefore, be achieved with proper management.

Further study is necessary over a wide area to arrive at a conclusion because the availability of labour and cost of construction vary from place to place. The authors, I wish would have covered the field of building construction in addition to the studies they made. This would have enabled them to offer recommendation connected with this branch of civil engineering.

It has been suggested to draw labour from land but ours is an agricultural oriented country. We cannot think of diversion of labour from agricultural field for any of our civil engineering schemes at the time of harvesting.

In a developing country like ours we have to adopt labour-intensive method in our civil engineering work, although I feel that in these days of mechanisation, we cannot entirely rule out that question of adopting equipment-intensive method. Both the systems have got advantages and disadvantages. Our planning should, therefore, be a compromise between the two for the sake of modernisation, perfection and economy.

Regarding the question of improving the productivity of labour-intensive system, I feel we should exercise more technical control over our work. I was very recently connected with housing schemes where we have got to be very particular for their completion in time and with utmost economy. There we planned posting of technical officials right from Executive Engineers to Sub-Assistant Engineers straight to the site for day-to-day management and quality control. We have dispensed with the services of non-technical staff like work-assistants or work-sarkars, etc. Our Engineer officials, are burdened with non-engineering works which is wasteful of their time. If they can be properly utilised, I feel, we shall be able to improve upon the productivity of labour-intensive system, more so, if the works are done at central place and also through departmental staff.

Shri N. Sen

Regarding relaxation of aggregate gradation and specification of larger sized stone in pavement construction as mentioned in para 44(c) it may be mentioned that the stability of a pavement
layer depends on the shear strength of the layer. The shear strength of granular material depends largely on the grading of the material. A well graded, well compacted material has better interlocking and larger number of contact points and hence higher shear strength. Again, shear strength required for a sub-base layer is lower than that for a base layer. Therefore, the grading standard for a sub-base is more flexible than that of a base. The grading specification approved by various organisations take the requirement of appropriate shear strength into consideration for both base and sub-base. Hence, in my opinion, no relaxation of the approved grading specification is desirable.

The maximum size of stone is again limited by shear strength consideration as introduction of larger size stones will reduce the number of contacts and increase pressure per contact demanding use of stronger aggregate so that crushing does not occur. In consideration of the above fact, the sizes of stones permitted in sub-base could be larger than those in base as level of stress in sub-base is lower than that in base. Here again, deviation from the approved specification is not desirable.

I am conscious of the social obligation of reducing unemployment. Engineers in our country should, therefore, evolve labour-intensive specification which, at the same time, should also ensure quality of work. In this country if the job of crushing stone is organised properly, we shall not find difficulty in getting the specified grading of aggregate. The larger size stones could be manufactured by employing manual labour. For size below 25 mm however, satisfactory product cannot be manufactured through manual labour alone. In such cases, granulators are also to be used. For feeding into granulators, stones are broken to a particular size by employing manual labour. Similar intermediate technologies enabling employment of sizeable number of labour with machine are in use in our country for other items of work also.

Shri T. Sanyal

No definite conclusion as to the suitability of a particular technique for all types of civil construction jobs can perhaps be arrived at in a vast and varied country like ours, having varying degree of efficiency of labour and working conditions apart from other parameters, e.g., availability of labour during working
season, site conditions peculiar to a work, degree of quality of work desired, etc. Quality of work cannot be sacrificed for the sake of socio-economic considerations only. It has been concluded by Shri Sud *et al.* in their Papers that quality obtained out of labour-intensive technique is comparable to that achieved through equipment-oriented one in a wide range of activities (ref. page 4 of the article). Such activities need be specified for road construction and other projects.

I think, before undertaking execution of a project, correct assessment of items of work involved with quantities, is essential so that a definite decision about adoption of a particular technique, —be it labour-intensive or equipment-oriented—in respect of each or a group of items, can be taken beforehand. Results arrived at from observations of a few projects, scattered at different parts of the country, cannot be generalised and applied to all parts of this sub-continent.

Secondly, I would suggest that rural development works on which much stress has been laid of late by the Central Government, should be entirely carried out through labour intensive methods. In major projects where quality is the main criterion, we shall have to have recourse to either of the two methods item-wise as suggested in the preceding paragraph.

**Shri C. M. Mathew**

While performing my duty in the field for executing roads and irrigation construction works, I have come across such mass of poor people, whom I cannot define as labourers, who inspite of their poorest socio-economic condition is not willing to put in the optimum effort by way of putting in labour and earn more wages with an outlook of improving their standard of living or to avoid starvation. The tribals may attend the work for few days and as soon as they receive their payment of wages they cease to attend the work and remain absent from work till they spend all he money and starve for couple of days. So they come for labour without stamina and bring out poor out-turn. Such irregular attendance to the work and poor out-turn make them discharged from the work by the employers. So to improve the socio-economic condition of these poor tribals, their habits are to be got changed and they are to be given incentive of nutritious food at least once on work site.
STUDIES ON LABOUR-SUBSTITUTION IN
HIGHWAY CONSTRUCTION

Shri O. Muthachen

I am afraid that my views are somewhat different from the general trend of opinions expressed by the speakers. I believe that mechanisation is fully necessary in the construction industry particularly in important road construction projects. This will improve quality and speed in execution of works and will create avenues of employment to skilled category of workers.

The arguments advanced in favour of labour intensive methods were:

(a) employment opportunities for unskilled labour and resultant social benefits.

(b) for adoption of equipment-intensive methods there is lack of properly trained operators, spare parts and servicing facilities.

(c) labour intensive methods are more economical when the wage-rate is below the break-even rate of about Rs 10 per day.

My comment on item (a) is that we do not reduce materially employment opportunity by resorting to equipment-intensive technology. On the other hand, we will be creating employment opportunities for skilled workers such as operators, mechanics, drivers, factory workers, etc. The production of raw materials needed for the manufacture of equipments in factories, and operation and servicing of these equipment will certainly need a different type of workers. It is not beyond the competence of Indian Engineers to manufacture such equipment within the country. We should certainly not depend on imported machinery for our needs. Continued dependence on imported machinery will be a hindrance to the initiative of our Engineers and entrepreneurs. Only a few decades ago, we used to import motor cars, trucks and even bicycles and their spare parts. What is the present position. These are manufactured in Indian factories by Indian workers. It is therefore not correct to say that adoption of equipment-intensive methods will reduce employment opportunities in the country.

Regarding item (b) I agree it is necessary to have trained operators, spare parts, and servicing facilities. In the same way as labour force have to be organised to increase labour productivity, the use of equipment-intensive technology will also require managerial skills to organise the work efficiently.
Regarding item (c), the labour rates, for unskilled labour was Rs 3 per day a few years ago; last year it was Rs 7 per day and now is Rs 10 per day and this goes on rising and may soon overtake the break-even rate mentioned in the report. We may soon be caught unawares if we do not now prepare and plan for progressive and increasing use of equipment-intensive technology.

There is severe criticism of our badly constructed roads and delay in execution. Present-day traffic on highways requires stronger and better surfaced roads with better tolerance limits. We have to adopt equipment-intensive methods sooner or later and organise design and manufacture in India of construction equipment such as scrapers, dozers, tractors, trailers, stone crusher, dump trucks hot mix plants, paver finishers, rollers, concreting machinery etc., suited to Indian conditions and sufficient in quality and quantities as may be needed for our projects, and the sooner this is done the better for our country.

I would strongly advocate a more progressive and selective use of equipment-intensive technology on our important road construction projects in order to produce quality work efficiently and economically. No doubt, improvements will be necessary in budgetary procedure and budgetary allocation. Building up and training operational and skilled workers and managerial competence will also be necessary. In each case the engineer will have to assess and decide on the appropriate constructional technology suited to a given project depending on its importance, location, quality and specification requirements, magnitude, time limit for construction, availability of labour and equipment, and of course, relative economics.

Shri P. Jagannatha Rao

It is a common practice with most of the Highway departments to let out on contract, the various items of work that go to make up a pavement system. Often more than one contractor may be involved. By and large, these contractors have limited financial resources, and what is more important, negligible technical expertise. As brought out in the paper, they serve to provide labour, immediate financing of labour and sometimes the material costs. However, to the extent that the contractor supervises the work of the labour, he is involved in the quality of the output, and here is a crucial problem. The engineer is thus
dealing not merely with unskilled and untrained labour, but also with an unskilled and untrained contractor, who has little appreciation and less understanding for the need to use improved techniques emanating from research or from a critical examination of existing practices. If this situation is to be remedied, the departments have either to dispense with small contractors which may not be feasible, or induct into the ranks of contractors graduate engineers, which is being tried in a limited way or train the unskilled contractors in same way of the newer methods. This training should not be an academic one, but a learning-by-doing type.

Shri K. Krishnamurthy

Since it is stated on page 4 that labour-intensive method generally produce the same quality of product as equipment-intensive method, for our country we can still adopt labour-intensive technology thereby simultaneously solving the unemployment problem to some extent and making this technology economically viable. The intermediate technologies adopting employment of animals and animal drawn vehicles are to supplement the haulage of materials which is normally being done by machinery or vehicles. Stress is laid on the world _supplement_ since it is not advocated to resort to only haulage by machinery or vehicles.

As seen from page 68 the maximum daily earnings of a labourer under incentive measures is double that of the daily wages. That is to say the maximum rating is 200 per cent. The rating of 200 per cent is far higher to the maximum humanly possible rating of 150 per cent. So we are driven to the understanding that this high rating of 200 per cent could be due to any of the 3 following reasons: (i) The degree of rating is much liberal. (ii) The normal daily wages and the maximum earnings may not correspond to the same work at the same place. (iii) the sub-standard rating corresponding to say 75 per cent of an inefficient and lethargic labourer is considered as the standard unit of work with a view to give him the minimum daily wages.

So, as stated in para 36 (page 19), a schedule of productivity norms is to be established before venturing to introduce incentive system. To safeguard against overshooting the maximum of 150 per cent rating, performances at normal working and top efficiency of the labourer individually and collectively should be
observed for the condition of daily wages only. Keeping these two performances in view, a judicious norm should be established for the basis of incentive benefits such that the maximum rating of 150 per cent is not exceeded. This will in all probability result in lesser wages than the normal daily wages for a slow or evasive worker. It cannot be helped and if these sub-standard wages are continued to be paid to such worker, it will certainly drive them to gear up to the normal working to earn at least the standard daily wages.

Certain fears regarding budgetary limitations/restrictions import of spare parts involving foreign exchange, non-availability of adequate labour during agricultural season have been expressed causing delay or inoperative costs as low as 30 to 50 per cent of the ideal condition. This can be overcome only by first obtaining the assurance of the minimum budget at the commencement of the year, manufacturing some kind of improvised equivalent spare part to serve the purpose. Scheming out the quantitative analysis needed for achieving the required expenditure and choosing only that kind of plant or equipment whose daily capacity is near about the value of total quantity divided by say 275 working days. Further, instead of depending on the local labour during agricultural season imported labour from urban area can be resorted to.

If due to socio-economic reasons the State/Central Government feel that they have to show some employment potential to the unemployed masses, they must be made to bear the extra cost due to the difference in costs between the labour-intensive and the equipment-intensive technologies.

Shri Christopher R. Willoughby

I just want to make a few very brief points. Firstly, I want to take the opportunity to thank, on behalf of the World Bank, most strongly the Government of India and particularly the Ministry of Shipping and Transport for all the tremendous assistance in this study. As you know, the study is unique. It is internationally supported research which is funded by nine foreign governments as well as the International Bank. But quite clearly the crucial part was taken by the Government of India agencies and departments which have been involved and those individuals, within these agencies, who have been very heavily involved, I am very grateful to them.
Secondly, I am grateful in particular because the results are of such great potential value to so many of our member countries. Some little studies which we have done recently suggest that the techniques about which we have been talking today are relevant to around 70 countries out of 100 that borrow from the World Bank. They suggest that they may be particularly important for around 1,000 million people, one fourth of the world's population. It is very desirable to use techniques of the sort that we have been considering in appropriate circumstances and yet they are not now very much applied or considered in most of those 70 countries.

Let me turn to the third point I wanted to make. You do have in India considerable special expertise and experience in this work. I hope very much that there are some of you who will feel inclined to help others in other countries applying these techniques and I hope the Government of India will facilitate that. I have been pleased to learn that technical advice in this field is already being provided by India to several countries, including Guyana, Libya and Yemen. But there are very many countries which need this kind of advice and assistance. There is a great deal of work to be done. Our main emphasis in the World Bank in this particular area is now to spread and help apply the research results in other countries, as described earlier by Dr. Harral. But we can only do that in co-operation with others.

I wanted to make one more point. The discussion today has been more about the application of the techniques, and possible improvements in them, within India. These are certainly equally important with the effort at dissemination to other countries. I was very interested in one of the remarks made by the President in his opening speech—that rural roads need to be seen as part of integrated multi-sector packages of regional development, that they need to be planned very carefully along with all the developments in other sectors. I would say that that is the approach which characterizes and typifies the actual direct involvement of the World Bank at present in India. It is a fact that there is currently more World Bank financing of roads in India than ever before. But it is all in the framework of agriculture, irrigation and command area development projects. I hope that any of you who have questions, comments, complaints
about the World Bank’s activity in the projects either in connection with the labour-intensive works or other aspects of them, will take the opportunity of the presence of Dr. Harral and myself to pursue them.

Lastly, it remains to me to thank again, on behalf of all of us from World Bank, our very generous Chairman Mr. Marya, who has given such stimulating leadership to these discussions, the Indian Roads Congress who made them possible, and all of you who have contributed sovaluably, so actively to a very fascinating discussion which is of great value for us in the work that we see as being so important, of trying to spread some of these techniques for wider use among other countries.
AUTHORS' REPLIES*

Before giving their replies on the discussion contributions the Authors would like to express their thanks to the Indian Roads Congress for organising such a successful meeting. It is difficult to single out individuals because all the contributors had something useful to say, but particular thanks must go to the distinguished Chairman, Shri J.S. Marya, both for his opening and concluding remarks and for his interest in the World Bank study over several years. We would also like to thank Shri R. P. Sikka for his thoughtful report for highlighting 10 points for discussion.

In his opening remarks Shri Marya pointed out that there are staunch proponents of labour-based methods in civil construction, as well as those who advocate using machines. He asks how should these be balanced, and the question of the appropriate factor mix has been one of the main objectives of the World Bank study, bearing in mind the wide range of conditions under which civil works are carried out.

As one would expect at a meeting of the IRC, the majority of the discussion has been given with road construction in mind, although many of the points can be extended to other types of civil constructions. Two contributors, Shri V. A. Khaire and Shri Dasgupta, have mentioned the need for similar studies in low-cost building materials and in building construction. The authors agree that labour-based methods could be successfully used in these fields, but they were deliberately excluded from the World Bank study because they only represent a small percentage of a typical developing country's budget and because some limits had to be placed on the study to make it manageable.

Technical Feasibility of Labour Based Methods

A number of views were expressed indicating the technical limitations to using labour-based methods, other than on the

* In giving their detailed replies on the discussion, the Authors have not attempted to answer each contributor's remarks in turn, but rather to collect the remarks under subject headings, highlighting some of the salient aspects and answering questions or points of disagreement. There is no special significance in the order chosen for dealing with the subjects, except that it is similar to the one used by Dr. Sud et al. in their Paper.
grounds of cost. These may be broadly grouped under four headings, viz., quality, quantity, type of project and speed of construction.

Prof. C. G. Swaminathan states that the Paper by Shri Green and Brown does not mention quality and this is so, mainly because the Paper was meant to be as general as possible and quality is a project-specific factor. Additionally, Shri N. S. L. Rao disagrees with Dr. Sud et al. that labour-intensive methods can generally produce the same quality of product as equipment-intensive methods. The Authors agree that labour-based methods cannot do a few tasks to the same quality as machines, without incurring exceptional costs; examples of this are compaction of bulk earthworks, long haulage of materials, and bituminous surfacing where a very smooth riding surface is required. However, the real questions to be asked are: (i) can a labour-based technology, aided by a few specific machines, produce a product of equivalent acceptability; and (ii) do we really need the quality which is specified, or are we merely equating needs with what can be done easily by machines. On the first question, Shri R. T. Atre has given a good example of equivalency for road base construction. One example of adopting too high standards of quality is road surface roughness, undoubtedly a paver can give a very smooth road, but is it always necessary? The overall economic assessment of a road should include the initial capital cost, vehicle operating costs and road maintenance costs; our objective should be to minimise the sum of these costs.

Large quantities of work, particularly if the site is of limited size, may not be practicable by labour-based methods; Brig. R. C. Nayar and Shri G. R. Laharwal have mentioned one or two examples. However, generally the problem of large quantities of work can be overcome by deploying more men, provided the labour is available. Hence, the problem of quantities is merely one of labour availability and the physical constraints of the site.

The problems of quality and quantity are linked in a general way to the type of project, and for this reason some projects are more suited to construction by labour-based methods than others. Shri J. S. Marya and Shri Sikka have mentioned this in their remarks. As a broad general rule, it can be said that small dispersed projects such as unpaved rural roads are suited to labour-based methods, whereas large concentrated projects, such as big bridges, are more suited to equipment-intensive construction. Even so, Shri Sikka has pointed out that close examination of
major jobs may show that labour-intensive techniques are applicable for several of the component tasks.

The speed of construction is another factor which needs to be considered. Clearly, if the labour is unavailable and/or the site constraints prevent the deployment of sufficient labour, then the project will take longer to construct. This may mean loss of benefits, but this can be explicitly allowed for in the original cost analysis when alternative technologies are being compared (see also the sections on Delays below).

Delays

One important criticism of labour-based construction methods is the fact that projects done this way get delayed, and hence there is an economic loss. However, two contributors, Shri Sikka and Shri S. N. Sinha, have forcefully pointed out that these delays are not due to labour-methods *per se*, but rather due to budgetary restrictions on the flow of cash to the projects. The Authors agree that most of the delays they have encountered in India have resulted from this cause, but it has to be recognised that if budget cuts have to be made it is usually easier to dismiss men than to face the problem of having large machines standing idle. Thus, indirectly by their nature projects constructed by labour-based methods are more likely to be delayed than those constructed by machines.

Shri Sudip Kumar De clearly feels that labour-based methods are inevitably slower, but this viewpoint is balanced by the example quoted by Shri Santok Singh in which 1000 miles of road were built in 2½ years showing what can be done if the organisation and motivation is right.

Choice of Technology

The question of choosing the appropriate technology generated a large amount of discussion, from which one or two general viewpoints emerged. Firstly, Shri Sikka and others mentioned that the methods chosen must be matched to the conditions thereby highlighting the project and site-specific nature of the choice. Shri Khaire gave an example related to the problem of remote sites; sometimes the difficulties of maintaining labour are too great and sometimes it is impossible to get machines into the area. Secondly, Prof. Swaminathan and Shri N. S. L. Rao both felt
that in mixing men with machines the need was to have a ‘harmonious blend’. These are two viewpoints which cannot be denied, unfortunate the problem is that not all engineers can agree what is the ‘right’ technology for a given set of circumstances. It is hoped that the World Bank study has helped to make this argument more objective (and hence less subjective) than it has been in the past.

On the question of specific technologies, Brig. Nayar of Border Roads has quoted improvements of 15 to 20 per cent by using slightly different technologies for a number of tasks. There seems to be no reason why such improvement cannot be widely achieved if, as mentioned by Shri Gokhale, the engineer uses his ingenuity. Certainly most technologies already exist—the main problem seems to be in recognising the alternatives available and in making the right choice.

Shri A.P. Remedios gives two good examples of specific conditions where particular technologies are appropriate. Shri E.C. Chandrasekharan extols the virtues of small-scale, hot mix plants, reviews the alternative choices for earthworks and points out the versatility of agricultural tractors with a range of attachments. Shri K. Arunachalam points the way in which the development of technologies should move. The Authors agree with all the three contributors.

In the case of wheelbarrow haulage, Shri S.C. Jain has stated that the haulage of earth by headpans is economical and feasible up to 100 m leads (presumably more economical than wheelbarrows). However, experience from a large number of observations has shown conclusively that for relatively flat sites the wheelbarrow is generally more economical than headbaskets for leads in excess of 25 m. Nevertheless, his remarks about the stature of the labourers who can handle the ‘G’ type wheelbarrow is valid. When introducing a new tool or method it is necessary to match it to the available workers and to give sufficient time for the labourers to become accustomed to using it. This learning period is several months.

Prof. Swaminathan has criticised the parameters given in the Paper by Green and Brown. He states that the parameters are not adequate, but fails to say in what way. Certainly there are many parameters which have been recognised but omitted because they only have a small influence on productivity. However, the
success of using the short list of parameters given in the Paper has been demonstrated by the fact that variations in productivity from many sites, both within India and between several countries, can be explained with reasonable accuracy by variations in the parameters.

In reply to Shri Arunachalam, the Authors were aware of the ESCAP document and thank him for reminding them about it.

**Economic Feasibility**

Many contributors spoke on the economic feasibility of labour-based methods and the related topics of cost comparisons and break-even wages. (These latter two subjects will be dealt with in the next section). The viewpoints expressed ranged across the whole spectrum of attitudes towards development economics. On the one hand, Shri M. B. Jayawant and Shri O. Muthachan advocate speedy mechanisation, while Shri Sikka and Shri T. S. Vedagiri suggest using social opportunity costs and shadow pricing which would almost certainly point towards the extensive use of labour rather than machines. The authors do not want to deal in detail with these topics because they have been exhaustively covered in the literature*, however, there are two comments they would like to make:

(1) The question of mechanisation in civil construction is not a simple one. In any country, and particularly in India, there are conflicting demands on capital investment, the question to ask is which sector(s) of the economy should receive priority. Should resources be directed towards automated hot mix plants or towards agricultural tractors? As mentioned in the elegant contribution by Shri Khaire, the hard lesson has been learnt over 30 years that a nation's economy is not always best served by the 'injection of high technology'. More often than not this leads to two economic systems existing side-by-side; the advanced Western-style system and a peasant economy based on subsistence farming. Unfortunately, experience has shown that the two often grow apart rather than together.

(2) On the other hand the use of shadow pricing may well bias the choice of technology towards labour-based methods, but it is mostly a subjective approach and the procedures for its rational application are often complicated and outside the training of engineers.

* For example see Little and Mirrless "Project Appraisal and Planning for Developing Countries" (1974), Published by Heinemann Educational Books, London.
On the whole, the majority of contributors recognised the need for employment creation in India and expressed the viewpoint that labour-based methods must be used, but not at any price.

Shri M. R. Malya and Shri R. Thillainayagam made the point that economic considerations should try to look at the overall cost. The authors agree with this approach, while recognising the difficulties faced by an engineer in doing so.

Finally, Lt. Col. Avtar Singh mentioned the problem of raising wages (by incentives, etc.), to the point where it adversely affects other sectors of the nation's economy. While agreeing that this can be so, the authors do not believe that this is a potential problem in India. The labour supply is vast and, in spite of Shri Malya's view that 'highway construction provides greater opportunity for labour employment', the 'employment potential in civil construction' is very small (in percentage terms) for any country in which the majority of people still work in agriculture.

**Cost Comparisons and the 'Break-even' Wage**

In making cost comparisons we are analysing the micro-economic aspects of choosing between alternative technologies. The analysis can be divided into several steps:

1. Identify the alternative technologies which can carry out a particular task; in the simplest case there may be one labour-based method and one equipment-intensive method.
2. Estimate the labour and equipment productivities which will be apposite for the chosen materials.
3. Calculate the direct costs of the alternative methods by multiplying resource inputs by the appropriate rates.
4. Add the appropriate overheads to obtain the total costs.
5. After doing this analysis for the major tasks, review the overall situation and rationalise where necessary.

The question of labour and equipment productivities and overheads will be dealt with in the next three sections.

The discussion focussed on the two questions, viz., what is the validity of making a cost comparison and what do we mean by a break-even wage in the general sense and for particular cases.
Shri Sinha highlighted one difficulty in making a cost comparison when he questioned the choice of output for men and machines. The authors have generally taken the view that for a given wage rate one technology is more economic than another if both technologies are applied with equal efficiency. Clearly this is rarely so, and if in a particular case experience suggests that labour-based methods are more efficiently executed than the equipment-intensive methods, then this should be allowed for in making the comparison. Dr. M. P. Dhir’s contribution was similar to that of Shri Sinha; he also pointed out that the consequences of bad management of machines may be more critical than bad management of men.

Two contributors, Shri Sudlp Kumar De and Shri J. S. Sodhi, questioned the basis of making sensible cost comparisons. The first mentioned the problems of obtaining comparable data when the number of combinations of parameters is almost infinite. The second pointed out, rightly, that any cost comparison should look at the overall costs, allowing for such things as speed of construction and quality if these will be different for the alternative methods being considered.

On the topic of ‘break-even’ wages, Shri Muthachen has introduced the problem of inflation and suggests that as wages rise so more and more machines should be used. Unfortunately, the Paper by Green and Brown does not make it clear that the break-even wage rates quoted refer to 1976. Clearly, the break-even wage is a function of both wage rates and equipment cost; if wages rise more rapidly than equipment, then there will be a trend towards mechanization, and vice versa.

Two contributors, Shri R. G. Gokhale and Shri K. V. R. Krishna Murthy, feel that the break-even wage calculations should allow for socio-economic factors. In other words, even if labour-based methods are more expensive they might be justified on social grounds. This is broadly the question of shadow pricing dealt with in the section on economic feasibility.

Shri Laharwal has asked for clarification on the range of break-even wages given in the Papers. In answer to his specific query all the calculations have been based on the output and wage rates appertaining to unskilled, casual male workers. The question of women and children workers has been looked at and
it was found in India that the wage rates and output for these categories were similar, *i.e.*, an average woman worker's output is 80 per cent of a man and her wages are about 80 per cent.

One contributor, Shri R. Thillainayagam mentioned the effect of statutory wages on the break-even wage. In reply, the authors feel that the Engineer making a cost comparison must use the rates he will have to pay. If the statutory rate is lower than the market rate he will probably have difficulty in getting the labour he needs, even though the calculations show the labour-based method to be economic. Then, if he can legally do so, he will have estimated how much in excess of the statutory rate he will have to pay to get sufficient labour; this enhanced rate would be the one to use in his final calculations. On the other hand, if the statutory rate is above the market rate he should be assured of a plentiful supply of workers, but in extreme cases of this type it has to be recognised that Governments fixing too high a statutory wage may be, often unknowingly, reducing the employment opportunities.

Shri Jaywant has stated that the authors have justified that only excavation work can be economically carried out by manual labour. This is not so, in fact for wage rates (1976) of less than $1 per day most tasks are more economically done by labour-based methods. As the wage rate rises about $1 so more and more tasks should be mechanised.

Shri H. C. Malhotra's experience of earthworks in hill roads differs from that of Shri Green and Shri Brown—this highlights the site-specific nature of any cost comparison. In fact, the example referred to by Green and Brown showed labour to be more economical only after the labour-based work had been re-organised to improve labour productivity. For excavations in rock the tendency is for machines to be more economical and this may well explain why Shri Malhotra came to a different conclusion to the authors.

One contributor, Shri S. P. Caprihan, stated that he disagreed with the authors' view that labour-based methods cannot compete with machines except at low wage rates. He then went on to give data which agrees very closely with that of the authors, *viz.*, labour-based methods can be economical for wage rates up to $1 to $2 per day. We can only assume that he misunderstood our papers.
Labour Productivity

Only one contributor, Shri Sudip Kumar De, has mentioned, labour productivity, and he has questioned the value of field measurements for two reasons:

1. because the measurements were made under 'ideal conditions' having more supervision than normal;

2. because the variation of parameters is so large it is not possible to draw any general conclusions from field measurements of productivity.

Both these points have validity, unless special care is taken.

On the first point the observers in the World Bank study were usually not part of the supervisory staff and played no part in supervision. Also, the length of observation was considerable, thereby reducing the effect of the observed presence. In addition to detailed daily records, overall weekly and/or monthly outputs were measured and these generally confirmed the validity of the results for normal working conditions.

On the second point, care was taken to measure all the parameters that could possibly affect the work, and after analysis surprisingly good relationships were obtained which showed the effect of a particular parameter on productivity (for example, see Fig. 2 in the Green and Brown Paper). Subsequent use of this approach and data elsewhere in the world has confirmed that it is reasonably valid provided due account is taken of the particular parameters at the site being considered. However, before making widespread use of the data at a new site or in a new country, the authors would strongly recommend the Engineer to make some observations of his own for calibration purpose.

Equipment Productivity

A large number of contributors mentioned the question of equipment productivity and, as pointed out by Shri Sikka and others, there is a danger in distorting a cost comparison if the right equipment productivity is not used.

One major misconception arose concerning the way Shri Green and Shri Brown had presented equipment productivity in their Paper. Shri Sikka, Brig, Nayar, Shri Atre and Shri Arunachalam, all commented on the fact that manufacturers' data had
been used, whereas actual data may be different. In reality, due account was taken of the available (few) field observations but for convenience, simplicity and to conform with early World Bank publications it was decided to present the results as percentages of Caterpillar 'ideal'. However, it must be admitted that although actual data is available and was used it is far from complete and the authors agree with Shri Sikka and Shri Gokhale that further observations of equipment under the type of conditions prevailing in developing countries is necessary.

Shri Sikka questions why bulldozer productivity has changed from 50 per cent Caterpillar 'ideal' in Phase II (1972-73) of the World Bank study, to 25 per cent in 1975 and has now increased again to 31-54 per cent. The explanation is simple:

1. The Phase II value was mainly based on observations at two large dam sites (Beas and Pochampad) and represents more-or-less maximum conditions for India. (Shri Banerjee has, rightly, pointed out that it is much easier to obtain high outputs at concentrated river valley and dam projects).

2. It was realised in 1974-75 that the earlier (Phase II) values of equipment productivity were too high for 'average' conditions and these were reduced to about 40 per cent; unfortunately due to a calculation error this was reported at 25 per cent in Technical Memorandum No. 3.

3. In reviewing our knowledge on equipment productivities for this Congress we decided to express these as a range, i.e., 31-54 per cent, for bulldozers and variously from 29-80 per cent for other equipment. It is true that it is higher than ILO's range and the 'truth' probably lies between the two, viz., sometimes productivities can be as low as 20 per cent and sometimes as high as 54 per cent of Caterpillar 'ideal'.

Availability and utilization factors are additional important determinants of costs by equipment methods. As Table 13 of the Green and Brown Paper makes clear, we have estimated 1,250 hours per year availability for bulldozers and some other equipment and 1,000 hours for other equipment which is either less robust, requiring more maintenance, or more often sidelined waiting between applications. This available time has been assumed to be the same for both Line A and Line B conditions, which may well be wrong, as with weaker organization and management maintenance facilities and operation often are poorer, resulting in more lost time. Although much higher availabilities were actually being achieved at Beas and Pochampad, which were large concentrated projects with extensive
maintenance facilities at site, equipment availabilities are undoubtedly much lower generally, and especially so at smaller scale and more remote sites where maintenance is very difficult, as pointed out by several commentators, including Brig. Nayar and Shri Banerjee. The Authors have looked into this question further since the Congress and have found evidence indicating that this is indeed the case in most developing countries without a well developed system of equipment service facilities. We are indeed grateful to the IRC for the very helpful and knowledgeable discussion on this issue. We point out that this implies that the costs of equipment-intensive operations have been somewhat under-estimated in our Paper and reinforces the principal conclusion that labour-intensive methods can be economically viable under a wide range of circumstances.

Three speakers mentioned interesting points about equipment productivity which are not always appreciated, or at least not given sufficient attention. Shri N. S. L. Rao has pointed out that for efficient and economical use, machines need to have continuity of work over an extended period and if they have to be ‘written off’ over the period of one project unless it is a large one) then the cost of using equipment intensive can be high. As a corollary to this fact, he mentioned that the Engineer planning a job may not always have a free hand in choice of method, and often he is obliged to select a sub-optimal equipment-intensive method because he only has a limited range of machines available to him. Both Shri N. S. L. Rao and Shri Vedagiri mentioned problems of obtaining skilled operators and the availability of spares, while Shri Atre also pointed out that sickness and non-availability of matching equipment can affect the actual outputs under real field conditions.

Overheads

Very little was said by contributors about the percentage values for overheads used by Shri Green and Shri Brown, although these two authors believed this would be a contentious topic. However, Shri N. S. L. Rao felt that the value of 70 per cent for contractor was too high. In reply, the authors defend their value as it was based on discussions with contractors and has subsequently been verified elsewhere. While at first sight 70 per cent seems high, a detailed breakdown of costs for small Indian contractors shows this overhead to be reasonable and, in fact, it
yields a profit to him of about 10 per cent. (Although some people would argue that such a profit is unacceptable, the authors feel that it should be regarded as a justifiable form of top management incentive).

**Tools and Simple Equipment**

Four contributors (Brig Nayar, Shri Subba Rao, Shri Sudip Kumar De and Shri Santok Singh) mentioned the question of tools and simple equipment. All agreed with the authors that good quality tools were beneficial, although both Shri Sudip Kumar De and Shri Santok Singh pointed out difficulties in introducing new tools. Unfortunately, the sad fact remains that more or less world-wide (including India) the quality and maintenance of tools and simple equipment is abysmally poor. If labour-based methods are to compete with equipment it is essential to give the men the tools for the job, and to this end the World Bank with others have now produced a set of draft specifications which should produce tools suitable for most civil construction.

Shri Santok Singh asked about a heating pan mentioned by Shri Green, in fact this was a paraffin (kerosene) pressure heater for heating bitumen drums which was superior to the wood fires often used in India. Unfortunately, no slides or sketches are available, but the authors believe that similar equipment is available in India.

**Employment Potential**

Two contributors, Shri Marya and Shri Sikka, referred to the employment potential of using labour-based methods. However, while it is true that civil construction constitutes an important part of a developing country's budget, and therefore can play a significant (and politically important) part in creating jobs, it is incorrect to assume that it can solve the unemployment problem in India or, for that matter, in any country.

Unemployment and under-employment in India and in those other countries where capital formation is falling behind the growth of population is already a very large and growing problem. Every effort should be made to maximise productive employment in civil construction, but similar measures will have to be taken across all the different sectors; labour intensive civil construction is no panacea.
Availability of Labour

No labour-based technology will be successful if there is insufficient labour available when it is needed, and six contributors specifically commented on this topic.

Shri Sikka pointed out that for piece work earnings of Rs 20 per day there will be no difficulty in obtaining enough men, even at the height of the agricultural season. However, at least two speakers (Brig. Nayar and Shri Sudip Kumar De) mentioned the possible danger to the national economy of enticing manpower into civil construction at the expense of food production. Brig. Nayar also pointed out that it was not possible to pay high wages during the agricultural season and then to reduce them in the off-season. In reply to these points the authors would suggest that for labour-based construction in India the following approach should be adopted:

1. Wages should be set at the level necessary to attract enough men for construction during the non-agricultural season, or at the minimum legal wage, whichever is the larger.

2. If at this wage there is likely to be a reduction in the labour availability during the agricultural season, then this must be explicitly allowed for in the project planning. (Shri Gokhale has pointed out that, in any case, the construction season and agricultural season are often different periods and proper programming of the work can overcome the problem of labour availability.)

3. Where possible, local labour can be given task work which allows the labour to work in their fields for part of the day. If labour is required for certain specific tasks in the agricultural season, then this can be obtained in India by employing landless migratory labour on contract.

Shri N. S. L. Rao gave an example from Nepal of the sort of commonsense measures that can be taken to mitigate the problem of labour availability. However, the authors would stress that each project will be different and the Planning Engineer has to adopt the appropriate measures for his particular project. In this regard a labour market study, as mentioned by Shri Subba Rao, is an essential first step.

Staff and Training

One aspect of the authors' papers referred to the identification, selection and training of supervisory staff for labour-based
construction. Three contributors, Shri Sikka, Shri Sikka, and Shri P. Jagannatha Rao, spoke about this subject. The first two speakers agreed with the authors' belief that task-level supervisors (e.g., overseers and foremen) are very important men in labour-based construction, and Prof. S. R. Mehra's contribution is particularly good in summarising the current Indian position.

All three contributors stress the need for training. Shri Mehra, rightly points out that foremen should not be 'half-baked engineers'. He also says that if the training and experience is properly structured, the 'profession' of foremen should become more prestigious and more lucrative. Shri Jaganatha Rao particularly dealt with the question of small contractors and the need to improve their supervision, either by encouraging them to employ more graduate Engineers or by on-site training in new methods.

**Incentives**

We are glad that several commentators spoke on the issue of incentives. Our study findings emphasize the importance of incentives of various types in promoting greater efficiency at various levels. Shri S. N. Sinha spoke with authority on the role of incentives to contractors in speeding up the progress of works. We would have liked to have an opportunity to discuss with him and others the possibility of incentives to Government staff for the same purpose and for improvements to quality standards of work.

No one contested the proposition that significant incentives to the work force result in substantial increases in labour productivity. However, Brig. R C. Nayar and Shri R. K. Bannerjee have pointed out the difficulties generally faced by Government departments in paying incentives to departmental labour. While Shri G. R. Laharwal, N. S. L. Rao and Lt. Col. Avtar Singh referred to instances in their own experience where incentives were provided with good success apparently on a departmental basis, the more usual method in India is, of course, to use an intermediary i.e., the petty contractor. While Shri R. K. Bannerjee and others have raised the question whether the labour force ultimately shares the benefits of increased incentives to contractors, Shri G. R. Laharwal and others have reported instances where good results of this kind have been achieved through contractors. Our own observation of several contractors operating on a large irrigation works in Uttar Pradesh strongly support the view that benefits
normally get passed to the work force as competition has limited the contractors’ margins to a very modest level. Where labour have been badly treated they often desert the offending contractor who gains an odious reputation and may be forced out of business as a result thereof.

Shri Thillainayagam and N. S. L. Rao, among others, have noted that providing incentives in kind, rather than cash payments, can be very effective. This may be true particularly in more remote areas where the normal sources of supply of wanted consumer items may not be readily increased. We have observed cases outside India where increased cash payments to remote villagers simply increased the local prices of goods so that the merchants rather than the workers captured the major benefit. In remote areas, therefore, the additional burden on the project administration for logistics of consumer items may be inescapable.

Shri Rama Rao was, we believe, the only speaker to cite the greater motivation that local labour may have in constructing works — feeder roads in his example — which are of direct benefit to themselves. This type of incentive has, in fact, been of great importance in several rural public works schemes we have seen in different countries, most notably Mexico and Korea, and it is a fact that should not be lost in planning programmes in this country.

Often the most appropriate incentives scheme for local labour, unlike migratory workers, will be a task work system whereby the labour is paid for a basic day’s work and permitted to return to tend their farms once the daily norm has been completed even if this were only 5 or 6 hours. This is well suited where the local labour is under-employed, but not totally unemployed. A piece-rate system, however, is usually more appropriate to migratory workers without local interests, who will prefer to work as many hours per day as possible.

Project Design

Three contributors mentioned the question of adopting designs for labour-based construction. Dr. Swaminathan explained how on an airfield project he had to modify the pavement design and specification to make it more suitable for labour to construct. Shri Atre pointed out that for rural roads the earthworks can be specified with less compaction, different grading requirements
can be adopted for bases and sub-bases, and hand broken chips can be used for pre-mix asphaltic material on surface dressing. In contrast to this contribution, Shri Sen expressed the view that grading specifications should not be relaxed as this would produce an inferior job. He then explained how it would be possible to meet specification by the judicious mixture of men and machines. The authors agree that one specification is not always the same as another and that in altering specifications it is necessary to allow for this fact. This can be done by using the concept of equivalency; for example, an open graded base may have to be thicker than a well graded base to achieve the same support value. However, this factor works both ways and as often as not the equipment-intensive specification is less satisfactory. One example of this is earthworks in side-long ground where the quantities of excavation by machine can be as much as 20 per cent higher than the quantities by labour-based methods because men can work to closer tolerances. In addition, on one project observed during the World Bank study half the material for the road sub-base was obtained from the excavation in the form of boulders. When bulldozers were used for excavation there was great difficulty in carrying out this selection process and, consequently, there was a substantial increase in the amount of quarrying.

Shri J. S. Marya (Chairman's Concluding Remarks)

In the first instance, I must on your behalf, on my own behalf and on behalf of the Government of India and State Governments offer our sincere thanks to Dr. Harral, Shri Green and Shri Christopher Willoughby and through them the World Bank for sparing funds and efforts in conducting this study in our country which I am sure we all have found to be very interesting, valuable and thought-provoking. It is a very analytical and in-depth study of various aspects of alternative technologies possible. Although many aspects which have been dwelt upon might have been known to us, the study has placed them before us on the basis of scientific analysis from actual job sites and we have a better understanding how the various elements which go into the different technologies really play up in the matter of cost, in the matter of technical implications, in the matter of social aspects and so on. Therefore, I would say that the discussion hereafter today has provided us with a good deal of food for thought as to how we are going to act in the future.

Earlier we had been talking about blend of machines and manual means. Hereafter I suppose there will be more stress on
intermediate technology. I think there has to be some clarification on this. A road construction may involve 10 elements of construction. When we say blend of manual methods and machinery, it really means according to my thinking that for certain elements, machines are necessary, for certain other elements, manual means are necessary and may be for certain elements both. We call that a judicious blend. But the intermediate technology as discussed in the present report really means that in each element of construction, there could be a blend.

For instance, in the case of earthwork there is a possibility that some sub-elements could be tackled only by manual labour, for instance loading, while others could be wholly mechanical for instance compaction. This indeed would be an ideal application of intermediate technology. I am sure in due course the Government will consider the report in detail and the individual departments like Border Roads or the Roads Wing or Central Water Commission would like to place before the Government their views as to the manner in which the concerned authorities in the country should go about in future as to the type of technology to be adopted. I suppose we will opt for a flexible position on the whole. Because so many elements, so many parameters are involved in each job. We have got to go into the technical requirements of a particular job, particular element of construction of a project then the feasibility of the one technology or the other, then there is a most vital aspect i.e., the economic aspect. Then there are the social aspects.

This study revealingly brings out the economics between labour intensiveness, machinery intensiveness and the intermediate technology. At present there is poor productivity of labour, poor conditions of working, inadequate management and very little incentive for workers. We hope that these will be improved and thereby the productivity will go up. It has been brought out that in an element of construction like earthwork the break-even situation could go up from a dollar to even two dollars or more than two dollars under appropriate circumstances. I do not know if in our country today, the minimum wages in various regions plus the other incidental requirements anywhere exceed a dollar. In Border Roads it may be extra because there the work is of arduous nature in difficult environments and lot of facilities are extended to the labour.
Even within the scope of this study it seems that improved management and improved handling of the labour by giving them incentive based wages could bring labour intensive techniques within competitiveness for various elements of construction. So, the procedures and technology we are adopting today, may not be questionable and may work out to be quite an appropriate decision. One thing is clearly brought out in this study, i.e., labour-intensive techniques as also the machine-intensive techniques in our country call for balanced improvement. In case of labour-intensive techniques, the highlighted aspects of mobilisation, management, training of the supervisory staff are very important. While these are receiving some attention in our country in organised sector like river valley projects, high dam projects and Border Roads projects. There seems to be a lot of scope for improvement particularly where other projects are concerned. So we certainly have to set about devoting greater attention in this respect.

As regards machine intensiveness, we must conceive the type of work we want to do by this technology in regard to the highway sector. Mechanisation in some real sense beyond the road roller trucks and other simple machines started from the year 1961-62 when we had the first IDA finance from the World Bank for some of the projects and later when we had to handle some important projects of emergent nature. That was the first time we started getting some sizeable and varying items of machinery and doing bituminous construction in a mechanised way. Further spurt came mainly at the start of the Fourth Plan period. But our experience in regard to the machinery productivity has really not been too happy. Considerable attention requires to be given to the aspect of standardisation of equipment, arranging better and efficient repair facilities, training of operators and mechanics, and above all the training of our managerial staff.

I would like to assure my friends from the World Bank that the study has been very useful. We wish to make good use of it in our country with the co-ordination between the Central Government and the State Governments and all the parties concerned. We wish to sit down and apply our mind as to where we have to give definite attention in improving matters. I am sure I carry in my thinking my colleagues from the Border Roads team who are here although we do not have the CWC representative. But, I am confident that all of us put together, we shall proceed
to make useful application of what has been shown up in the study report and in further suggestions made by the many learned speakers. There will be so many organisations who really would be involved in the whole affair like our Ministry, the State P.W.Ds., the Border Roads Organisation and the Central Water Commission.

Agriculture Ministry would be vitally concerned with the civil engineering factors as also the Labour Ministry since there are so many aspects concerning the labour management and betterment of living conditions for the labour force. Most important of all are the contractors' organisations because in our country quite a percentage of the total activity is being managed through contractors and, therefore, if anything has to be done for labour management, and their health and nutrition, it would have to be with the active co-operation of the contracting industry.

I have a mind to lean on the Indian Roads Congress for bringing out some literature in respect of the study and the discussions which could be immediately circulated to the States, to the contractors' organisations, and others highlighting the important aspects which could be straightaway expected to be assimilated and brought into practice.

Lastly, I would like to bank upon the IRC for arranging some more studies. First of all, I find in the Paper by Dr. Harral and his friends at the end, there are certain suggestions for further research like some research on labour supply, research on adaptation of engineering designs, then research in regard to equipment and may be a few more ideas which may come to our own mind within this country. Such studies are also suggested to be organised by the IRC. Of course, finding funds for such studies would be the job of our Ministry which I hope we should be able to take care of. We may think of utilising our Central Road Fund to some extent. Then, we may have to also associate the Directorate General of Technical Development if there may be some requirement like effecting improvements in the tools to be utilised in the labour-intensive technology. The DGTD would help us and arrange the manufacture of such tools. We are presently confident at the stage of manufacturing all items of highway construction — hot mix plants, pavers, graders and what not — may be they are still of a restricted capacity but we are gradually getting well set. So, manufacture of different new tools like
wheelbarrows should not really pose any problem. Border Roads, ourselves and CWC intend to meet again, take stock of the outcome of the Panel discussion and then acquaint the Government about the study findings as well as our reactions to these and the steps we intended to take further.

Before I conclude, I will again on your behalf like to express my very sincere thanks to the World Bank and their distinguished experts.