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Technical Brief No 2

Productivity Norms

for labour-based construction

International Labour Organisation
ADVISORY SUPPORT, INFORMATION SERVICES, AND TRAINING (ASIST)
Nairobi, Kenya

The Employment-Intensive Programme (EIP) is a sub-programme within the Development Policies Department (POLDEV) of the ILO. Its objective is to promote the use of local resource based technologies in infrastructure works in developing countries and to strengthen their capacity to apply such technologies.

ASIST is a sub-regional programme under the EIP, one of whose objectives is to achieve an improved effectiveness of road construction, rehabilitation and maintenance in Sub-Saharan Africa and thereby promote employment and income generation in the rural and urban areas.

The aim of ASIST Technical Briefs is to spread knowledge about labour-based technology and management amongst policy makers, planners, designers, implementers and trainers.

Productivity Norms

for labour-based construction

First edition

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ASIST technical team in Harare, Zimbabwe,
and Nairobi, Kenya.

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Contents

List of Tables

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Abbreviations

ASIST	Advisory Support, Information Services and Training for labour-based technology
CTP	Construction Technology Paper
DFR	Department of Feeder Roads
ELHU	Excavate, Load, Haul, Unload
KIHABT	Kenya Institute of Highways and Building Technology
KTC	Kisii Training Centre
LCU	Labour Construction Unit
LBDU	Labour-based Development Unit
MART	Management of Appropriate Roadworks Technology
MRP	Minor Road Programme
TRL	Transport Research Laboratory
RARP	Rural Access Road Programme
USD	United States Dollars
WB	World Bank

1 Introduction

All civil engineering projects rely on the productivity of their equipment and workers to achieve good results. Major capital works projects with a high element of equipment can estimate with some accuracy how much and what kind of equipment will be required for the type of work envisaged. Estimating manuals such as the Caterpillar Performance Handbook provide work outputs for most common equipment types (based on the assumption that they are properly utilised), and these figures form the basis of all cost and time estimates. Individual labour productivity, while important to ensure equipment is utilised effectively, will have a minor impact on overall costs and timing.

Labour-based projects however are almost entirely dependent on the productivity of labour. Provided the workers are properly organised and supplied with the correct handtools, they will be able to carry out most of the activities usually done by earthmoving machinery. However, it is essential to have realistic estimates of expected labour productivity in order to plan and carry out labour-based work effectively.

The first action of any planning engineer on a labour-based project should be to determine the quantities and type of work to be carried out. The engineer should then divide this work into activities that can be carried out by individuals or groups of workers, and then, by applying work norms, determine the required labour force and the duration of the project. Choosing the correct work norm is the most critical part of this process.

As a very simple example, one kilometre of drainage ditch to be excavated for a pipeline could be considered as only one activity, *i.e.* excavation. If it is known that the average amount of material to be excavated is $2m^3$ in volume per metre length of ditch, and the productivity norm of the workers is set at $3m^3$ per day, then the project could be completed in one day with 667 workers. At the other extreme, it would take about three years with one worker. A more typical set-up would be a group of 48 workers deployed over 14 days.

The critical figure is the productivity norm. Workers are commonly set tasks in labour-based works that equal these norms. If the task is underestimated by 30 per cent, *i.e.* $2m^3$ a day for excavation rather than $3m^3$ in the example above, the direct cost of the project will increase by 30 per cent. Conversely, if the tasks are overestimated, then much of the workforce will not be able to meet its targets and there will be considerable disruption and discontent on site.

Estimating the correct productivity is probably the most important decision for the engineer. If the physical quantities are wrongly estimated this can be corrected on re-measurement. If the number of people recruited are insufficient this can also be easily rectified; but altering the norms significantly at a later stage involves convincing workers to do more work for the same money, which can be very difficult, and not conducive to success in a labour dependent project.

Fortunately, there has been a lot of work done on determining realistic work norms for different activities in different situations. It should therefore be possible for a planning engineer to draw upon that experience at the start of any project, with the confidence that it is the correct order of magnitude and that it can be fine-tuned as work progresses. Unfortunately, much of this data is difficult to find, and often relates to very particular circumstances, with unique project assumptions. It can therefore be quite misleading to simply apply such norms without a full appreciation of the project and project organisation from where the data came.

ASIST has been involved in project design and monitoring of labour-based programmes for a decade, and has access to project reports and data from projects all over the world. It has therefore been decided to look at all currently available data and make a synthesis of prevailing productivity norms to allow the project planner to have a better handle on what is most appropriate for his or her use.

Even this synthesis will have its limitations, and it is important to appreciate that these are productivities that can be expected under ideal circumstances. That is, the workforce is well organised and supervised, understands the work it is supposed to do, and has the correct handtools in good condition. Poor tools or poor organisation can easily halve the workers' output. It is also assumed that the worker is healthy, properly paid, working normal hours, and has good access to food and water.

The issues of worker conditions and labour management are not covered in this guideline as it is assumed that they will be properly applied. However, the reader is referred to the ILO publication Employment-Intensive Infrastructure Programmes: Labour policies and practices[1], which covers this subject comprehensively.

This Brief is targeted at professional staff, either engineers or technicians, who have experience of road construction and maintenance activities and some exposure to the concepts and application of labour-based technology. It does not aim to be a primer in engineering techniques or labour-based technology. The reader is referred to the ASIST Source Book[2] for publications covering those areas.

The Brief is divided into three sections. The first section deals with definitions, in which the various activities relating to construction are clearly defined. The activities are primarily drawn from rural road construction but can be

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[1] Tajgman, David, and de Veen, Jan. *Employment-Intensive Infrastructure Programmes: Labour policies and practices.* ILO, Geneva. 1998

[2] *The Labour-based Technology Source Book: A catalogue of key publications.* ILO/ASIST, Nairobi. 1998

applied to many other labour-based activities such as the provision of water supply, irrigation, drainage or soil conservation work. The definition of worker operations such as day-work, task-work and piecework are also explained.

The second section summarises the productivity norms that have been reported from many projects in Africa and Asia. These norms are related directly to the various activities defined in the previous section. A range of rates is shown, to demonstrate the sort of variation that can be expected under different conditions. Recommendations are also given for an average productivity, which would be a realistic and achievable starting point for any new project or programme. Some activities draw upon much more data than others do; but wherever possible, anomalies are pointed out and commented on.

The third section gives guidance on the factors that can affect productivity and how productivity can be improved. It also gives advice on procedures for the setting, measuring and monitoring of activities so that project-specific norms can be refined.

For those who require more detail, the productivity data obtained in this study is given by country and activity in Annex 2. In addition, a short historical summary of productivity in previous centuries is provided in Annex 3. This is intended to give a perspective on what can be achieved by workers when heavy equipment is simply not an option.

This Brief is by its very nature a work in progress, and ASIST will welcome comments on it. Additional data will also be welcomed for inclusion in future editions.

2 Definitions for labour-based construction

2.1 TYPICAL ACTIVITIES

All construction work can be broken down into self-contained activities that can be achieved by an individual or a group of workers if they are equipped with the correct tools. The permutations are many and can of course be specified in the most convenient way for the work in hand. However, to allow meaningful comparison between projects and programmes, some standards have emerged which have been found to have good universal application.

The three most common standards are those developed in the Kenyan Rural Access Road Programme (RARP)[3]; the parameters specified in the original World Bank study into labour-based methods[4]; and the parameters proposed in the ILO workplans manual[5] based on various projects carried out in Francophone multi-sector projects.

Such documents as these, and others quoted in the ASIST Source Book, should be consulted by any project designer requiring detailed solutions for specific circumstances or "pre-cooked" solutions relating to say dams, tree planting, paved roads *etc.*[6]. However, for this exercise we have concentrated on the most common operations utilised in rural road construction. These activities will also constitute the major activities for any labour-based construction project and as such will have the biggest effect on costs and output for most projects. Based on these activities project planners can evolve a realistic set of activity norms tailored to their needs.

Activities are often combined into one global activity. A good example of this is the operation of taking material from a borrow pit to form a nearby embankment. In large projects in Asia this would commonly be described as one activity: excavate, load, haul, unload (ELHU). However, in Africa this would be set as three discreet tasks, excavating to a stockpile (E), loading into a wheel barrow (L), and hauling to the embankment (H) for unloading (U). For these guidelines, all activities will be taken as the simplest constituent part.

The principal activities for this exercise are defined below. As part of the definition, a description is provided of the sort of work to which the activity applies; the tools used; the way

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[3] de Veen. *The Rural Access Roads Programme: Appropriate technology in Kenya*. ILO, Geneva. 1993

[4] *The Study of Labour and Capital Substitution in Civil Engineering Construction*, as summarised in Coukis et al: *Labor-based construction programmes: A practical guide for planning and management*. The World Bank. 1983

[5] *Standardised procedures for the presentation of work plans*. ILO, Geneva. September 1990

[6] for example, *Labour enhanced construction for bituminous surfacings: Methods and procedures*. Southern African Bitumen and Tar Association. March 1993

the activity is measured; and the various parameters that can be used to subdivide the activity even further.

Even handtools can be defined differently in different parts of the world. For this technical brief, all handtools are as specified in the Guide to Tools and Equipment for Labour-based Road Construction[7].

2.1.1 Site clearing

This activity covers the removal of all obstacles before serious excavation commences. In road related activities it is often referred to as “clearing the road reserve” or “bush clearing”. However, the activity certainly embraces more obstacles than just bush. As a general definition it includes the removal of boulders, buildings, trees, shrubs, grasses, crops; and of topsoil containing any vegetable matter which renders the material unsuitable for fill.

The amount of vegetative cover can differ considerably, from semi-arid areas where the clearing work is negligible, to tropical rain forests where chainsaws and plant pullers may (unfortunately) be necessary to remove extensive tree roots. Redundant buildings are not common features on any rural project, although they may be in urban upgrading programmes.

For this exercise it has been necessary to make a subjective judgement on the data received. Bush clearing has been defined as light, medium or dense; to which has been added tree stump removal (where individual trunks exceed 20cm in diameter), referred to in Table 1 as de-stumping, and topsoil removal[8].

For general reference, definitions based on the type of tool necessary to clear the bush can be used to identify bush density (see Table 1 below). All clearing is measured in square metres except for substantial trees and boulders, which will require individual tasks to be set.

Table 1: Bush clearing characteristics

Bush type	Suitable tools
Light bush	Bushknife, brush-hook
Medium bush	Scythe, axe, bowsaw
Dense bush	Axe, chainsaw, plant puller[9]

[7] *Guide to tools and equipment for labour-based road construction*. ILO, Geneva. 1982
[8] Sometimes referred to as “grubbing”, although in maintenance operations this typically only means removing plant roots.
[9] Any device for pulling directly from the ground by animals, tractors or hand operated winches, using pulling aids such as tree hooks, mallet levers and sheave blocks.

2.1.2 Excavation

This is the most common labour-based activity and can be applied to many items in a construction programme.

Excavation is required:

- to produce a level road formation platform in virgin terrain
- to obtain material to raise or widen a road
- for the primary activity in producing road side drains, even if the side drain work may be broken down into first digging a trench and then sloping the sides
- in quarries to obtain gravel for surfacing
- to form the embankments of irrigation canals
- to obtain material for small earth dams.

Even the activity of breaking up rock boulders is strictly speaking excavation.

This activity can usually be carried out by hoe or shovel, but as the material hardens, a mattock, pickaxe or even a heavy crowbar[10] will be needed. For fractured rock, chisels and hammers can be utilised, but for very hard rock, drilling and blasting will be necessary[11]. For soft material, the worker will only require one handtool such as a hoe or shovel, but for harder materials each worker will need to be equipped with two tools, typically a pick to loosen the material, and a shovel to remove it.

The method of disposal of the excavated material needs to be well defined in how the activity is specified. Many projects expect the excavator (the person who does the excavating) to load material into a headbasket, wheelbarrow or trailer as part of the operation. In other cases the excavator is expected to "throw" the material out of the road reserve, or into the centre of the road, to contribute towards the camber formation. A study of the literature and country data received from various projects confirms that this extra operation does not seem to add significantly to the effort required. Thus the excavation parameter for this study is defined as including loading or throwing, providing this does not include a lift[12] of more than one metre, or a throw of more than four metres.

The most important parameter for excavation is the hardness of the material. This can alter the expected productivity by a factor of four or greater. Materials are typically described as

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[10] This item refers to an 11kg crowbar at least 1.8 metres long, with chisel and pointed ends, used as an impact tool.

[11] Fire and water can be very effective but can be an environmentally damaging operation as rocky terrain often occurs in areas with sparse vegetation and a fragile environment.

[12] "Lift" is a well described parameter in the literature referring to the height through which material must be moved to be loaded or disposed of. *Labor-based construction programmes: A practical guide for planning and management*, page 284, Table F-3 and Figure F-3 detail the effects of increased lift on productivity.

soft, medium, hard, very hard or rock and these terms are used in the comparison of different project data. The World Bank in their definitive study[13] produced a comprehensive definition based on soil type and tool penetration. This is set out in Table 2 below in a simplified form as a useful way for projects to assess their individual situation. As with the site clearing definition, the most practical description is the required handtool, but the soil descriptions are commonly accepted terms for soil scientists.

All excavation is measured in cubic metres of *in situ* material.

Table 2: Soil excavation characteristics

Activity definition	**Soil description**		**Suitable tools**
	Cohesive	*Non-cohesive*	
Soft	Soft	Very loose	Easily excavated with a shovel or hoe
Medium	Firm	Loose	Can be dug with a shovel
Hard	Stiff	Compact	Mattock, pick or other swung tool required
Very hard	Very stiff or hard	Dense or very dense	Crowbar required in addition to pick
Rock		Rock	Sledge hammer and chisels required

2.1.3 Hauling

Hauling is cost-effective when carried out manually only for distances of up to 150 metres. For greater distances, equipment becomes necessary. Typically, headloading is the most effective method up to 50 metres, at which point wheelbarrows are more suitable. However, it should be noted that headloading is not common in Africa as a construction operation, whereas in some parts of Asia, headloading is utilised for considerable haul distances (sometimes up to a distance of 100 metres).

Productivity is very dependent on the condition of the haul route and the height through which the material must be moved, often referred to as the "lift". Similarly, where wheelbarrows are used, the condition and design of the wheelbarrow is critical[14]. Chinese wheelbarrows[15] have a much higher capacity and put much less strain on the worker, although they do require some skill to balance. They

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[13] *Op. Cit.* page 282, Table F-1

[14] ASIST has recently published a Technical Brief which gives design and manufacturing details for a simple but robust wheelbarrow suitable for use in labour-based construction works. See the Reference section for details.

[15] A Chinese wheelbarrow consists of a rectangular tray, with sloping sides, mounted on a large-diameter wheel positioned centrally under the tray. For further details, see *Guide to tools and equipment*, pages 7.26 and 7.27.

are not commonly available in Africa, but for projects with a considerable amount of wheelbarrow haulage they may be worth the investment.

Equipment haulage is typically carried out by a tractor/trailer combination for distances up to five kilometres, with trucks being used thereafter. However, this is a rough guideline and needs to be tested for individual circumstances. Lesotho uses only trucks, whereas Kenya uses tractors and trailers for quite long hauls, simply because that is what they have readily available.

The design of trailers is important and details of a suitable type are to be found in ASIST Technical Brief No. 1[16]. Most commercially available trailers are not sufficiently robust and are too high for easy loading. Experience has shown that the ideal capacity is $3m^3$. Similarly, trucks should not be too large or they will be difficult to load and manoeuvre on a labour-based site. Tipping trucks with a capacity of 5 to $7m^3$ have proved ideal.

Equipment haulage productivity data was not acquired from projects by this study, but typical haulage information is included in this note for completeness (see Table 13).

Table 3 presents the haulage range and capacity for typical equipment used on labour-based projects. All haulage is measured in loose cubic metres of material for a specified haulage range.

Table 3: Haulage equipment characteristics

Haulage equipment	Recommended hauling range (m)	Capacity
Headbasket	4 – 50	$0.02m^3$
Western wheelbarrow	25 – 150	$0.08m^3$
Chinese wheelbarrow	50 – 400	$0.16m^3$
Animal cart	100 – 500	$0.7m^3$ [17]
Tractor and trailer	250 – 5000	3 – $3.5m^3$
Tipper truck	2000 upwards [18]	5 – $6m^3$

2.1.4 Loading, unloading and spreading

As noted in the previous sections, these activities are often combined with others as a single activity. Loading is often part of the excavation activity where no double handling of the material is involved, and lifts are less than one metre. Similarly loading, unloading and spreading is often included

[16] Hamper, J & Mason, D et al. *Designs and specifications for a standard trailer and hitch.* Technical Brief No 1. Third (revised) edition. ILO/ASIST, Nairobi. 1997

[17] For two oxen or donkeys hauling.

[18] The distance at which tipper trucks become more economic is very dependent upon site conditions and the availability of equipment. This should be researched carefully before committing expensive procurement or long term hire arrangements.

with the haulage activity when material is being obtained for a gravel road surface from a stockpile. However, it is important to have data on the separate activities so that a project can evolve its own norms.

Loading refers to loading from a pre-excavated stockpile, and can be applied to any material. However, it must be remembered that if material is left to stand for a considerable period and subjected to wetting and drying, it will need to be re-loosened, which constitutes a new excavation task. Loading heights of more than one metre are very difficult by manual methods, and loading bays should be fashioned to avoid this problem. Loading is measured in loose cubic metres of material.

Unloading is probably unique to labour-based activities in civil engineering. It does not refer to wheelbarrows or headbaskets, but to emptying non-tipping trailers or trucks. Because of many problems experienced with small hydraulically operated tipping trailers, many projects have found it preferable to develop specially shaped rigid trailers which can be relatively easily emptied by hand. The figures given relate mainly to $3m^3$ trailers with or without special side doors. However, they are equally applicable to flat trucks or larger trailers if they are properly designed. Unloading is measured in loose cubic metres of material.

Spreading refers to the general activity of converting loosely dumped soil or gravel into a smooth and even road surface. It includes moving material by shovel, hoe, rake, and the use of levelling devices such as the camber board and string lines. Productivities are similar for formation work, where the material is usually won from side drains; and gravelling, where the material is delivered by trailer or truck. No distinction is therefore made in this note between these operations. Spreading can be measured in loose cubic metres or square metres of material for a given thickness.

Table 4 lists the typical handtools used for these activities.

Table 4: Tools for loading, unloading and spreading

Activity	Suitable tools
Loading	Short or long handled shovel
Unloading	Short or long handled shovel
Spreading	Shovel, hoe, rake, sledgehammers[19], camber board, string lines

2.1.5 Compaction

It is not generally recommended to use manual methods for compaction of road pavements. Most research and experience shows that it is not possible to achieve enough impact to make any significant difference to the density of the

[19] For breaking down oversize material.

pavement material. Compaction should be carried out either by towed or self-propelled equipment; or in some circumstances the pavement can be left for traffic to compact[20].

Manual compaction can be used for backfill to drainage structures or in maintenance operations (such as filling of potholes), using hand rammers. Pavements are best compacted with 1.25 tonne pedestrian operated vibrating rollers or towed dead weight rollers with a weight of one to two tonnes. Productivity rates are given for both labour and equipment operations. Manual compaction is specified in cubic metres of compacted material, and equipment compaction in square metres.

When specifying compaction equipment it is important to know the daily output required. Most labour-based projects produce a maximum of 500 to 1000 square metres of formation or gravel pavement a day, and the equipment should be matched to that output. Typical heavy construction compaction equipment will have much higher outputs than this and will therefore be largely under-utilised. Conversely, small-scale equipment can prove to be very unreliable if worked eight hours a day, day in day out. It is not designed for this. Standby equipment should thus be available, at least with a sufficient capacity to keep utilisation rates down to four hours per day.

Table 5 specifies the typical tools and equipment used for compaction on labour-based projects.

Table 5: Tools and equipment for compaction

Activity	Tool/equipment	Typical unit weight
Manual compaction	Rammer	7.5kg
Equipment compaction	Pedestrian operated vibrating roller	1.25 tonne
Equipment compaction	Towed dead weight roller	1.0 – 2.0 tonne [21]
Equipment compaction	Towed vibrating roller	600kg

2.1.6 Culvert laying

Culvert laying is the most common drainage operation that can be specified as a single activity. More complex activities such as erecting retaining walls, providing concrete drifts, or installing small bridges are best split down into their component parts.

[20] *ASIST Bulletin No 3*, August 1994, gives an overview of research on compaction alternatives.

[21] A one tonne roller cannot produce adequate results with all soils, and may need to compact in 75mm rather than 150mm layers. A two tonne roller is more reliable but too heavy for animal haulage.

Types of culvert can vary dramatically from country to country and project to project. For this exercise we are assuming that precast concrete pipes or galvanised steel pipe sections (such as Armco) are already available on site and that the operation consists of excavation, providing bedding material, laying and backfilling the pipe segments, and providing upstream and downstream headwalls.

A typical set of tools for a culvert laying team is set out in Table 6 below.

Table 6: Tools for culvert laying

Typical tools required for culvert laying team[22]	Pick and shovel for each worker, plus 5 crowbars, 5 wheelbarrows, 5 sledgehammers, 5 hand rammers, boning rods, heavy rope.

2.2 WORK METHODS

In all the literature on labour-based construction there is much reference to daywork, taskwork and piecework. These are very straightforward concepts, but unfortunately they are sometimes defined in different ways by different projects. This can give rise to considerable confusion when comparing data from different places.

Daywork means simply that a worker is paid a fixed rate for being present on a site for a full working day, which is usually eight hours of work[23]. The amount of work produced depends entirely on the supervisor's ability to encourage the worker, and the worker's own motivation and sense of responsibility. In many circumstances this can lead to very low productivity, especially with permanent staff who have no particular incentive to work hard. They know they will be paid (generally very poorly) whether they work or not.

Piecework is a method of setting work, usually preferred by the private sector. The worker is allocated an amount of work for an agreed rate of pay. The work they do is measured and the more they do the more they are paid. This approach can give very high productivities, but it can also result in exploitation, especially when the rate for the work is too low. Casual workers are seldom in a good position to negotiate favourable rates. The most dangerous situation is when workers have to put in very long hours to achieve even a subsistence rate of pay.

Taskwork evolved on projects where the workers were subject to government regulations, which meant they could not be paid more than the prevailing government wage for a day's work. Some other incentive had to be provided. Setting

[22] All concrete and mortar can be effectively mixed by hand. However, where high quality concrete is important, manually powered mixers are available. Contact ASIST for details.

[23] In line with the relevant International Labour Standards. See Tajgman & de Veen, *Op. Cit.*, for a full explanation of labour standards in relation to labour-based works.

a realistic task, or amount of work to be completed for the day, meant that workers could work as hard as they wanted and then go home to do other things. Tasks are generally set to be achievable in 70 per cent of the working day (a working day being assumed as a period of eight hours), but are often completed in 50 per cent of the working day (*i.e.* in four hours). This approach has proved very successful in practice, often doubling the amount of work achieved in a day; and by inference doubling the productivity of the individual worker, as well as halving the costs.

A variation of the individual task is the ***group task***, where work is set for groups of people rather than for individuals. This is done where the nature of the work requires the cooperation of a team, such as excavating and loading material into trucks or trailers. There is no basic difference in the concept, and task quantities are usually a simple multiple of the individual tasks making up the group.

The most common mistake is to confuse taskwork with piecework, by setting more than one task in a day. If a project is in the situation where it can pay a variable rate to the worker according to output, then this should be considered as piecework. There is no problem with setting work norms based around the recommended daily task, and then paying for more work on a *pro rata* basis. However, the project must then be set up to accurately measure the amount of work completed, with the agreement of the worker. In this case the procedure should be clearly recognised and termed as piecework. It is recommended that if piecework is adopted there should be a clearly recognised minimum daily wage that should be paid if for some justifiable reason the worker's output is low (*i.e.* the task was too hard). It should never be necessary to work more than eight hours in a day to achieve a basic daily wage.

3 Productivity norms

To produce this Brief, a questionnaire was circulated to all active labour-based projects in the Sub-Saharan Africa region to obtain data on their current norms. In addition, a number of documents were consulted to obtain data from completed projects and projects in other regions. These sources of additional information are included in Annex 1.

The data was synthesised to obtain a best fit with the agreed parameters and is summarised in Annex 2. The process was quite problematic since projects do not use the same definitions for activities, particularly with respect to the difficulty of working in various soil conditions. However, average productivities have been determined for a number of countries and are set out below.

From this data, a median[24] value for each activity has been calculated. To give this value a context, we have included the equivalent standard figure from the Kenyan Rural Access Road Programme. This programme was originally one of the most researched programmes in the region, and gives a very good idea of what can be achieved with tight supervision and a well motivated work force.

When using productivity norms it is important to appreciate that, although they can be the basis for setting tasks, the amount actually achieved is often less than the task set. This can be confirmed by post work measurement. Sickness, bad weather, and unexpected obstacles all contribute to reducing output. Five countries, namely Botswana, Ghana, Kenya, Lesotho and Zimbabwe, have recently conducted site trials, measuring actual output achieved over time, and these have also been synthesised to provide an idea of the contingency that needs to be built into any estimating exercise.

3.1 SITE CLEARING

The figures in Table 7 are compared with site trials and with the original RARP data below (Table 8). The median figures for bush clearing and grubbing are very low compared to the original RARP figures and the measured output from the various trials. In view of this and the relative simplicity of the activity, somewhat higher than the median figures are recommended as a starting point. The information on de-stumping is not sufficient to make any recommendations. Most projects seem to rely on the experience of the foremen to set appropriate tasks for this activity.

[24] The median value has been used rather than the mean value, as the amount of data was limited and the median better excludes extreme or anomalous data. The mean is the sum of a number of values divided by their number. The median is the middle value of a series of values.

Table 7: Site clearing norms – country data

Country	Average productivity by type of cover m² per worker day *Dense bush*	*Medium bush*	*Light bush*	*Grubbing*	*De-stumping*
Botswana	—	750	750	150	—
Cambodia	30	60	100	15	0.75
Ghana	—	—	375	375	—
Indonesia	130	175	—	37.5	1
Kenya	50	150	300	100	—
Lesotho	50	100	250	65	—
Tanzania	50	100	250	150	3.5
Zimbabwe	200	—	300	250	—
WB Study	—	—	150	15	—
Median	**50**	**125**	**275**	**100**	**1**

Table 8: Site clearing norms – recommended values

	Average productivity by type of cover m² per worker day *Dense bush*	*Medium bush*	*Light bush*	*Grubbing*	*De-stumping*
Country median	50	125	275	100	1
Site trials	105	209	311	209	—
RARP	320	480	640	I75	—
Recommended value	**100**	**200**	**350**	**175**	**By experience**

3.2 EXCAVATION

The highest productivity norms for excavation were in China with productivity rates up to 9 and 7m³ per day respectively for soils classified as of soft or medium workability. However, China is very well organised in this sort of activity, and its workers are accustomed to work levels which may not be acceptable in other regions of the world.

Zimbabwe's productivity norms were up to 6m³ per day and consistently higher than other countries in all activities. Materials in Zimbabwe are not noticeably easier than other central and east African counties. It is interesting to note that the data are from a relatively new project under close supervision and monitoring. Having said that, workers were achieving their tasks in 70 to 80 per cent of the normal day, so these levels should be generally achievable.

Some of the rock excavation figures are high and may reflect a lack of data in this area for manual methods, apart from Lesotho and Nepal.

Table 9: Excavation norms – country data

Country	Average productivity by soil classification m³ per worker day				
	Soft	*Medium*	*Hard*	*Very hard*	*Rock*
Botswana	4.15	3.8	2.5	1.9	—
Cambodia	2.75	2	1.25	0.75	—
China	9	7.0	3	2	—
Ghana	3.75	3.75	3.75	3.75	—
Indonesia	—	—	2.5	—	—
Kenya	5	3.5	2.25	1.75	0.75
Lesotho	4.5	3.5	2.75	1	0.5
Nepal	—	3.3	2.5	—	0.61
Tanzania	5.5	4.5	4	2.5	—
Zimbabwe	5.5	5.5	4	3.5	2
WB Study	6.7	2.1	3	2	1.7
Median	**5.00**	**3.50**	**2.75**	**2.00**	**0.75**

The median results can be compared with the results from recent trials and the original productivity norms from the RARP. It is noticeable that the data from the various trials for soft, medium and hard soils is very scattered, with improbably high figures for very hard soil. This probably reflects a lack of attention to site conditions among site supervisors. In general, the norms being set by projects do not differ significantly from those originally developed in Kenya.

Table 10: Excavation norms – recommended values

	Average productivity by soil classification m³ per worker day				
	Soft	*Medium*	*Hard*	*Very hard*	*Rock*
Country median	5.00	3.50	2.75	2.00	0.75
Site trials	3.6	3.2	3.45	2.2	0.8
RARP	5.5	4	3	2	—
Recommended value	**5.0**	**3.5**	**3.0**	**2.0**	**0.8**

3.3 HAULAGE

Productivity rates for wheelbarrow haulage appear to have declined considerably since the inception of the RARP programme. Some road projects no longer use this approach as they consider it ineffective, relying on adjacent materials for all fill requirements. However, many other infrastructure projects, particularly soil and water conservation projects and urban projects, will make much more use of this activity.

Table 11: Wheelbarrow haulage norms – country data

Country	**Wheelbarrow[25] haulage norms by haul distance m³ per worker day**					
	0-20m	*20-40m*	*40-60m*	*60-80m*	*80-100m*	*100-150m*
Botswana	8.4	7	6.7	5.6	5.2	4.7
Kenya	10.5	10.5	8	6.5	5.5	4.5
Lesotho	8	6	5	4.5	4	—
Tanzania	11	11	8.25	6.25	5.25	5
Zimbabwe	5	5	5	5	5	4
Median	**8.4**	**7**	**6.7**	**5.6**	**5.2**	**4.6**

It has therefore been decided to keep the recommended norms at the higher end of the range. These figures are achievable but require the operation to be well set up, particularly with regard to the condition of the haulage route. World Bank data[26] has demonstrated that a poor haul route can halve productivity.

Table 12: Wheelbarrow haulage norms – recommended values

	Wheelbarrow haulage norms by haul distance m³ per worker day					
	0-20m	*20-40m*	*40-60m*	*60-80m*	*80-100m*	*100-150m*
Country median	8.4	7.0	6.7	5.6	5.2	4.6
Site trials	5.3	4.8	4.6	4.3	4.2	4.1
RARP	13.5	10.5	8.5	6.5	5.5	—
Recommended value	**8.5**	**7.0**	**6.5**	**5.5**	**5.0**	**4.5**

Equipment haulage productivity depends to a large extent on the efficiency of the loading teams. However, haulage route condition and type of haulage equipment also play a large part, as well as the organisation of the loading and unloading areas.

[25] This refers to a typical western wheelbarrow in good condition. Chinese wheelbarrows could achieve significantly higher rates.
[26] Coukis et al 1983. *Op. Cit.*

To aid the designer, a table has been provided giving the number of trips that can be expected from either a small tipping truck, or from a tractor-plus-two-trailers combination, in a day. Quantities have not been included here since this will depend on the capacity of the truck (typically 5m^3 of loose material) or the trailer (typically 3m^3 of loose material).

Table 13: Typical haulage rates for manually loaded equipment

Haul route condition	Good					Average					Poor				
Haul distance (km)	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
Trips per day per truck[27]	22	19	16	11	8	18	15	12	8	6	16	12	10	7	5
Trips per day per tractor/trailer combination[28]	20	12	8	6	4	18	11	6	5	4	16	9	4	4	3

3.4 LOADING, UNLOADING AND SPREADING

The median norms do not differ markedly from those set by the original RARP programme, although the trials show slightly lower productivities being achieved for loading and spreading. If hydraulic tipping trailers or trucks are used, then the manual unloading activity is not required.

Table 14: Loading, unloading and spreading norms – country data

Country	Average productivity rates m³		
	Loading	*Unloading*	*Spreading*
Botswana	12	—	14
Cambodia	8	15.5	5.25
Ghana	6.7	10	—
Kenya	10	9	13.5
Lesotho	5	—	14.25
Tanzania	11	—	15
Zimbabwe	8.5	—	9
World Bank	—	—	11
Median	**8.5**	**10**	**13.5**

[27] Modified from the *LCU Technical Manual*, Ministry of Works, Kingdom of Lesotho, May 1996.
[28] Modified from the *MRP Technical Manual*, Ministry of Public Works, Republic of Kenya, January 1992.

Table 15: Loading, unloading and spreading norms – recommended values

	Average productivity rates m³ per worker day		
	Loading	*Unloading*	*Spreading*[29]
Country median	8.5	10	13.5
Site Trials	6.5	11	12
RARP	8.5	—	13.5
Recommended value	**8.5**	**10**	**13.5**

3.5 COMPACTION

No significant additional data was obtained from the trials on manual or equipment compaction. In addition, a RARP comparison cannot be made as they did not use tasks for compaction but largely relied on traffic consolidation of the pavement. Hence, for this study, the median results below are the recommended values. These values are in line with the expected values from the literature.

Table 16: Compaction norms – country data and recommended values

Country	Manual compaction	Equipment compaction
	m³ per worker day	*m² per roller day*
Cambodia	10	—
China	3.2	—
Kenya	7.5	700
Lesotho	15	700
Tanzania	9	700
Median	*9.0*	*700*
Recommended value	**9.0**	**700**

As noted in the section on compaction above, manual compaction is only recommended for backfilling or other minor operations. It is not effective for consolidating pavements. In addition, the machine figures should be changed if different types of equipment are used. Heavier items of vibratory equipment will need fewer passes, and the reader is referred to Table F8 of the World Bank Labour-based Construction Programs Guide or TRL guidelines for typical construction equipment output. Conversely, lighter towed and non-vibratory items may need more passes or

[29] Spreading activities are often specified in square metres, particularly if the activity is spreading material excavated from side ditches to form a camber. If this measure is preferred, simply divide the norm by the average thickness. Thus a typical average thickness of 0.15 metres gives a spreading norm of 90m² per worker day.

thinner layers of material between passes, and these must be tested against the individual equipment item. Existing performance data for such equipment is not very reliable since there have been very few published examples of rigorous scientific testing[30]. Most light equipment has consisted of locally fabricated one-off devices, used in circumstances where soils testing facilities where not available.

3.6 CULVERT LAYING

The RARP did not have a linear metre rate for culvert laying or a specific rate for concrete and masonry work, but a few recent trials have been carried out on these norms in Kenya, Lesotho and Zimbabwe, showing significantly lower rates being achieved for concrete and masonry work. However, based on other reading, it is recommended to keep these rates near to the specified norms.

Table 17: Culvert laying norms – country data

Country	**Activity**		
	Culvert installation m per worker day	*Concrete m^3 per worker day*	*Masonry m^3 per worker day*
Cambodia	—	1.25	1.25
China	1.2	—	—
Kenya	0.3	1	1.5
Lesotho	1.1	1.75	1.35
Zimbabwe	0.8	0.8	0.75
Median	**0.9**	**1.13**	**1.3**

Table 18: Culvert laying norms – recommended values

Country	**Activity**		
	Culvert installation m per worker day	*Concrete m^3 per worker day*	*Masonry m^3 per worker day*
Country median	0.9	1.13	1.3
Site trials	0.95	0.6	0.6
Recommended value	**0.9**	**1.0**	**1.0**

3.7 AN EXAMPLE OF COMBINED ACTIVITIES

Using the above activity norms, the engineer can combine activities to span an overall operation and derive suitable combinations of workers and equipment. A typical example of a gravelling operation is given below. This is based on the use of 60hp tractors in two-trailer-to-one-tractor

[30] *ASIST Bulletin No 3*, August 1994, gives an overview of research on light compaction equipment.

combinations on an average quality of haul route and with workers functioning on the task rate system, excavating in hard material.

The example is actually from the Kenyan MRP Technical Manual, which has a number of useful tables for estimating equipment and labour requirements based on over twenty years of experience.

Table 19: Typical equipment /labour combinations for gravelling

Haul distance	Loads per day	Total volume	Excavation	Loading	Un-loading	Spreading
Km	*unit*	*Loose m^3*	*Workers per tractor*	*Workers per tractor*	*Workers per tractor*	*Workers per tractor*
0 to 2	18	54	18	7	6	4
2 to 4	11	33	11	4	4	2
4 to 6	7	21	7	3	2	2
6 to 8	5	15	5	2	2	1
8 to 10	4	12	4	2	1	1

3.8 SUMMARIES

The set of tables below summarises the recommended values for the various activities.

Table 20: Summary of recommended values

SITE CLEARING

	Average productivity by type of cover m^2 per worker day				
	Dense bush	*Medium bush*	*Light bush*	*Grubbing*	*De-stumping*
Recommended value	**100**	**200**	**350**	**175**	**By experience**

EXCAVATION

	Average productivity by soil classification m^3 per worker day				
	Soft	*Medium*	*Hard*	*Very hard*	*Rock*
Recommended value	**5.0**	**3.5**	**3.0**	**2.0**	**0.8**

WHEELBARROW HAULAGE

	Wheelbarrow haulage norms by haul distance m^3 per worker day					
	0-20m	*20-40m*	*40-60m*	*60-80m*	*80-100m*	*100-150m*

Recommended value	**8.5**	**7.0**	**6.5**	**5.5**	**5.0**	**4.5**

LOADING, UNLOADING AND SPREADING

	Average productivity rates m³ per worker day		
	Loading	*Unloading*	*Spreading*
Recommended value	**8.5**	**10**	**13.5**

COMPACTION

	Manual compaction	**Equipment compaction**
	m^3 per worker day	*m^2 per roller day*
Recommended value	**9.0**	**700**

CULVERT LAYING

	Culvert installation	**Concrete**	**Masonry**
	m per worker day	*m^3 per worker day*	*m^3 per worker day*
Recommended value	**0.9**	**1.0**	**1.0**

TYPICAL HAULAGE RATES FOR MANUALLY LOADED EQUIPMENT

Haul route condition	**Good**					**Average**					**Poor**				
Haul distance (km)	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
Trips per day per truck	22	19	16	11	8	18	15	12	8	6	16	12	10	7	5
Trips per day per tractor/trailer combination	20	12	8	6	4	18	11	6	5	4	16	9	4	4	3

TYPICAL EQUIPMENT / LABOUR COMBINATIONS FOR GRAVELLING

Haul distance	**Loads per day**	**Total volume**	**Excavation**	**Loading**	**Un-loading**	**Spreading**
Km	*unit*	*Loose m^3*	*Workers per tractor*	*Workers per tractor*	*Workers per tractor*	*Workers per tractor*
0 to 2	18	54	18	7	6	4
2 to 4	11	33	11	4	4	2
4 to 6	7	21	7	3	2	2
6 to 8	5	15	5	2	2	1
8 to 10	4	12	4	2	1	1

4 Factors affecting productivity

The preceding sections have set out the average amount of work that can be expected from an average worker in reasonable health, based on observed data from many projects and countries. However, this average figure can be affected by many factors, which are fortunately mostly under the control of the programme management. The most important are:

- Motivation and experience of the workforce
- Organisation of the work
- Type and condition of tools and equipment provided to the worker
- Continual monitoring of performance.

These factors are discussed in the following sections.

4.1 MOTIVATION AND EXPERIENCE OF THE WORKFORCE

The World Bank in their seminal study[31] produced various tables attempting to summarise the observed differences in productivity between projects and programmes taking into account the familiarity of the country with labour-based methods (*i.e.* organisation and worker experience) and the method of payment of the workers (*i.e.* motivation).

The example below uses excavation of medium hardness soil as the baseline (*i.e.* with a norm of 3.5m³ per worker day).

Table 21: Observations on worker output[32]

Payment method	**Countries' experience with labour-based technology**	
	New approach m³ per day	*Long tradition m³ per day*
Daily paid	0.88 to 2.62	1.75 to 5.25
Taskwork	1.75 to 5.25	3.5 to 8.75
Piecework	3.5 to 10.5	7.0 to 14.0

The most striking feature is the difference by a factor of 16 between inexperienced and presumably poorly paid day workers, and experienced piece workers. In mitigation it has to be said that new workers often find this type of work quite difficult for the first two weeks, although they quickly develop the required muscles. Thus task workers should quickly move to the median figure of 3.5m³. Daily paid workers seldom have the motivation to improve, and the

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[31] Coukis et al, 1983. *Op. Cit.*
[32] This table is taken directly from the World Bank Study, Coukis et al, 1983. *Op. Cit.*, page 180, Table 7-7.

author has observed productivities increase by a factor of four, simply by introducing taskwork methods to an experienced daily paid labour gang. Conversely, piece workers tend to work very long hours indeed if the money is available. Twelve to 14 hours were not uncommonly observed occurrences on sub-contracts in the Indian sub-continent.

Although piecework demonstrably gives the highest output, it does have its own problems as discussed in section 2.2. On a well-organised and controlled construction site with easily measurable quantities, there are real advantages for all involved, particularly if the workforce is living in a construction camp away from home, with the sole motivation being maximum earnings in a minimum time. However, in the more typical rural works, drawing on local labour with other home-based interests (particularly subsistence agriculture and family care), taskwork has proved a much more viable option.

However, for taskwork to function correctly it is essential to establish the correct daily wage. If the wage is much lower than the prevailing cash wage for similar work in the area then there is a danger that an insufficient number of workers will be attracted, and the attendance of those that do come will be unreliable. If there is very high unemployment, or more commonly if there are few alternative chances of getting waged employment (as opposed to payment in kind), it has been found that, although workers will be recruited, they will lack motivation and be resentful of normal task rates.

Responsible management must avoid the situation where below-poverty-line-payments are being accepted by desperate people. Conversely it is important that wages are not so high as to distort the local economy. Labour-based projects seldom create permanent employment, and if workers are tempted away from existing full time employment in essential agricultural or service areas, then the local economy may suffer.

It is usual practice to carry out a thorough labour market analysis in any new area where labour-based programmes are being started. This should establish the basic acceptable wage, and most importantly the inflation index whereby annual increments can be determined[33].

One problem facing the site manager is that, because a workforce does improve with experience, there is the temptation to carry the workforce forward for the duration of the project. The normal practice is to recruit workers adjacent to the works and let workers go as the work progresses. This has the benefit of spreading earnings and skill acquisition through the served community. On the other hand, keeping on workers can result in the establishment of

[33] There have been several documented cases where, although thoroughly researched wage levels have been established at the start of a pilot project, wage levels have then been kept at that level for many years in countries experiencing high inflation. In all cases the problem has been the lack of an accepted mechanism for wage adjustment.

labour camps and the disruption to rural settlements through the influx of a relatively large number of cash rich migrants. On balance it is recommended that the unskilled labour force is discouraged from following the project, and camps and transport should not be provided unless there is insufficient population in the area. On the other hand, individuals with special skills can be taken on as supervisors, artisans, or future maintenance workers.

If a community has sufficient vested interest in the works being carried out because of their direct benefit, then it is possible that worker motivation will be much higher. However, it is difficult to programme for this, and any such productivity boost should best be considered as a bonus rather than as a factor to be built into the expected task rates. Conversely, if a workforce is in very poor physical condition because of malnutrition, it is inappropriate to expect normal output. Any project operating in conditions of famine or extreme poverty should alter its norms accordingly.

4.2 ORGANISATION OF THE WORK

This factor relies entirely on the training and experience of the site supervisory staff, and its importance cannot be underestimated. The labour force will in fact quickly learn what is expected of them and in our general experience will then work well and skilfully. However, the initial direction can only be given by the supervisors.

Having said that, it has to be recognised that labour-based technology is very supervisor intensive, and without the continued presence of trained supervision, outputs will drop substantially. Table 13 sets out the variation in haulage times for material depending on the quality of the haulage route. This is not entirely a measure of the roughness of the route, but of the set-up of the quarry and the site unloading operation. These factors are largely dependent on the organisation of the work. Similarly, the quality of work will also decline if the level of supervision is reduced.

Training materials have been developed by a number of projects which give detailed specifications for all activities, how to organise the work, worker balance between the various critical activities *etc*. These training materials can only be effectively applied in conjunction with a training site, and this process of supervisor training is a prerequisite for any large-scale operation. A listing of suitable published training materials can be obtained from ASIST. Training courses covering the management of labour-based roadworks are also provided by the Kisii Training Centre[34] in Kenya.

[34] Contact the Principal of KIHABT, PO Box 57511, Nairobi, Kenya (Fax +254-2-534890) for the latest course details.

4.3 TOOLS AND EQUIPMENT SPECIFICATION AND MAINTENANCE

Unfortunately, there is no precise data on the exact magnitude of the effect on productivity of having poor quality tools. Recent studies[35] indicate that blunt or worn excavating tools can reduce worker output by up to 25 per cent. Badly made or poorly fitted handles also have a significant negative effect, but this was not measured quantitatively. However, the actual effects of these factors on outputs in a project are disguised by the taskwork system. Standard norms are established with good quality tools at the start of a project. As tool quality decreases, the workers have to compensate by putting in longer hours to achieve their daily task. This is not fair on the workforce, nor is it realistic for long-term project effectiveness. The overall effect for the project is a gradual lowering of morale and a decline in standards as the tasks become harder.

The bottom line is that if a tool handle is broken or the point of a pick is fractured then the worker using it cannot produce the required amount of work for the day in the time available. The worker is effectively on down time, as with any item of broken powered equipment. As a general rule, poor tools can reduce individual worker output in the long run by a least a half.

Tool management must achieve two things to ensure maximum productivity. Firstly a handtool of the correct strength for the rigours of construction work must be specified and procured so that it does not easily break or bend on the job. Secondly a system of routine maintenance and tool replacement must be in place on any site to ensure that workers always have good tools.

The specification of tools is covered in a number of publications, the definitive work being the ILO Guide to Tools and Equipment[36]. As this guide shows, agricultural tools are not appropriate for many roadwork activities, and it may be necessary to get local manufactures to change their specifications. This can be an expensive option for a small tool run so it is often necessary to import from abroad. An alternative is to encourage small-scale specialist production using scrap metals from cars or other industrial uses. For cast items it is relatively easy for a manufacturer to change the composition of the metal, but retooling for a new shape is much more expensive.

Maintenance of tools will require an on-site workshop which can replace handles, sharpen edges of cutting tools, and re-forge picks, chisels and crowbars. The alternative is that

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[35] IT Transport Ltd. *Effects of worn handtools on worker productivity in labour-based roadworks.* MART Working Paper No 9. Institute of Development Engineering, Loughborough. 1997. Paul Larcher. *MART questionnaire on tools and equipment.* Proceedings of the 6th Regional Seminar for Labour-based Practitioners. CTP 157. ILO, Geneva. 1998

[36] *Guide to tools and equipment for labour-based construction.* ILO, Geneva. 1981

tools are regularly replaced on-site and sent for remedial maintenance to a central depot. The worse situation is where tool maintenance is left to the discretion of individual users. This can lead to the fitting of "bush" handles, poorly secured axe and pick heads, and other horrors that can easily result in severe accidents as well as poor output.

4.4 MONITORING NORMS

Once norms are established, it is normal practice to build these into the daily site reporting procedures and to rely on the supervisor to set and check the tasks daily. It has to be appreciated however that, over time, supervisors can become blasé about making detailed measurements, and often fail to check the finished quantity against the assigned task. The pegged distances are invariably achieved, but the physical quantities thereby assumed by the supervisor may not equal the theoretical norm. It is therefore essential that more senior management staff periodically check these productivity settings. This means physically checking the site measurements, not just the data sheets.

In addition, it is often the practice of managers to take the reported daily tasks set for the various activities, and to assume that these represent the actual output of the project. This habit has grown with force account operations where payment is not linked to production, but to worker muster rolls. In fact, quantities are seldom equal to the sum of the set productivities. Site obstacles, diversion of workers to other activities, sickness, broken tools, wrong task setting, all contribute to a false total.

It is not being suggested that all finished work should be re-measured. This would probably put too great a burden on the typically small supervision team of a labour-based project. At the end of the day, what is required is a usable piece of infrastructure at a cost-effective price. It is therefore suggested that work progress should be tracked in terms of certain key outputs. In the case of roads this is usually kilometres of formation completed, kilometres of gravel placed, and linear metres of culverts placed. As long as these figures are accurately recorded on site together with the number of worker days expended to achieve this, a good measure of site progress and cost will be obtained.

Some typical inputs from various projects are listed in Table 22. These are based on recent evaluations and are calculated from total worker inputs to complete specified roads. As such they capture all activities including those not specified or set as tasks.

Monthly reporting of such totals from site give management an excellent tool for monitoring progress and problems. Each project and programme should establish its average input for key operations as a first priority, and check this against site returns every month.

Table 22: Average worker input for completed operations

Project	Operation	Input
	Construction of	*worker days/km*
Botswana[37]	Earth road	1981
Botswana[37]	Gravel topping only	2157
Ghana DFR[38]	Gravel lowland road	1580
Kenya MRP[39]	Earth lowland road	1442
Kenya MRP[39]	Gravel topping only	1819
Kenya MRP[39]	Regravelling	1209
Laos LAO/90/MO1/FRG[40]	Gravel lowland road	2203
Lesotho LCU[41]	Gravel lowland road	2645
Lesotho LCU[41]	Gravel mountain road	4400
Zimbabwe LBDU[41]	Gravel lowland road	3260

[37] See Brudefors, Ulf; Keam, Dave; Strøm, Ørnulf. *LG-117 labour intensive public works labour-based road programme. Review of technical status.* Ministry of Local Government, Lands and Housing, Botswana. 1995

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ANNEX 2: Country productivity data

Note: There are many gaps in the tables below. However, it is hoped that the publication and dissemination of this Brief will stimulate readers to contribute to filling in the gaps. If you have relevant data, please send it to one of the ASIST offices (see the back cover for addresses).

COUNTRY DATA FOR SITE CLEARING ACTIVITIES

Production targets	**Bush clearing**						**Other clearing**					
	Dense		**Medium**		**Light**		**Grubbing**		**De-stumping**		**Boulder removal**	
	m²	*m²*	*m²*	*m²*	*m²*	*m²*	*m²*	*m²*	*No*	*No*	*No*	*No*
Country	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Botswana				750		750		150				
Cambodia	20	40	40	80	80	120	10	20	1	1		
China												
Ghana					350	400	350	400			5	15
India		130	150	200			30	45		1		
Kenya		50		150		300	0	200		Exp		Exp
Lesotho		50		100		250	30	100		1		Ds
Mozambique												
Tanzania		50		100		250		150	2	5	Ds	Ds
Thailand												
Zimbabwe		200				300	200	300			1	10
World Bank						150		15				
Minimum	20	40	40	80	80	120	0	15	1	1	1	10
Maximum	20	200	150	750	350	750	350	400	2	5	5	15
Average	20	87	95	230	215	315	103	153	1	2	3	13
Median	20	50	95	125	215	275	30	150	1	1	3	13
Number of records	1	6	2	6	2	8	6	9	2	4	2	2

Actual output	**Unit**	**Botswana**		**Ghana**		**Kenya**		**Lesotho**		**Mozambique**		**Zimbabwe**	
Clearing		*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Dense Bush	m2		17.4		33.9		11.3						
Medium Bush	m2		29.2		53.8		27.5						45
Light Bush	m2		35		64.9		52.5						65
Grubbing <20 cm	m2				27.5		31.3						75
De-stumping > 20 cm	No												
Boulder removal	No												

Ds = Depends upon the size; Exp = By experience

COUNTRY DATA FOR EXCAVATION ACTIVITIES

Production targets for excavation in cubic metres per task

	Soft		*Medium*		*Hard*		*Very hard*		*Rock*	
Country	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Botswana	3.8	4.5	3.1	4.5	2.5	2.5	1.9	1.9		
Cambodia	2.5	3.0	1.5	2.5	1.0	1.5	0.5	1.0		
China		9.0		7.0		3.0		2.0		
Ghana	3.0	4.5	3.0	4.5	3.0	4.5	3.0	4.5		
Indonesia			1.7	3.5		2.5				
Kenya	4.0	6.0	2.0	5.0	1.5	3.0	1.5	2.0	0.5	1.0
Lesotho	4.0	5.0	3.0	4.0	2.5	3.0	0.5	1.5	0.5	1.5
Mozambique										
Tanzania	5.0	6.0	4.0	5.0	3.5	4.5	2.0	3.0		
Thailand										
Zimbabwe	5.0	6.0	5.0	6.0	3.0	5.0	3.0	4.0	1.0	3.0
World Bank		6.7		4.2		3.0		2.0		1.7
Minimum	2.5	3.0	1.5	2.5	1.0	1.5	0.5	1.0	0.5	1.0
Maximum	5.0	9.0	5.0	7.0	3.5	5.0	3.0	4.5	1.0	3.0
Average	3.9	5.6	2.9	4.6	2.4	3.3	1.8	2.4	0.7	1.8
Median	4.0	6.0	3.0	4.5	2.5	3.0	1.9	2.0	0.5	1.6
Number of records	7	9	8	10	7	10	7	9	3	4

Actual output of excavation in cubic metres per task

	Soft		*Medium*		*Hard*		*Very hard*		*Rock*	
Country	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Botswana	5.2	3.6	5.2	3.2	5.2	2.9				
Cambodia	6.0		6.0		6.0		6.0		6.0	
China	10.0		10.0		10.0		10.0			
Ghana	5.0	4.1	5.0	4.1	5.0	4.1	5.1	4.2		
Indonesia										
Kenya	4.0	3.0	5.0	2.5	5.0	2.0	1.5	1.3	5.0	0.9
Lesotho		3.3		2.9				1.4		0.7
Mozambique										
Tanzania										
Thailand										
Zimbabwe	5.0	5.0	5.0	4.5	5.0	4.0	5.0	3.0		
World Bank										
Minimum	4.0	3.0	5.0	2.5	5.0	2.0	1.5	1.3	5.0	0.7
Maximum	10.0	5.0	10.0	4.5	10.0	4.1	10.0	4.2	6.0	0.9
Average	5.9	3.8	6.0	3.4	6.0	3.3	5.5	2.5	5.5	0.8
Median	5.1	3.6	5.1	3.2	5.1	3.5	5.1	2.2	5.5	0.8
Number of records	6	5	6	5	6	4	5	4	2	2

COUNTRY DATA FOR HAULAGE ACTIVITIES

Production targets for hauling in cubic metres per task

	0-20 m		*20-40 m*		*40-60 m*		*60-80 m*		*80-100 m*		*100-150 m*	
Country	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Botswana		8.4		7.0		6.7		5.6		5.2		4.7
Cambodia												
China												
Ghana												
Indonesia												
Kenya		10.5		10.5		8.0		6.5		5.5		4.5
Lesotho		8.0		6.0		5.0		4.5		4.0		-
Mozambique												
Tanzania	10.0	12.0	10.0	12.0	7.5	9.0	6.0	6.5	5.0	5.5		5.0
Thailand												
Zimbabwe		5.0		5.0		5.0		5.0		5.0		4.0
World Bank												
Minimum	10.0	5.0	10.0	5.0	7.5	5.0	6.0	4.5	5.0	4.0	0.0	4.0
Maximum	10.0	12.0	10.0	12.0	7.5	9.0	6.0	6.5	5.0	5.5	0.0	5.0
Average	10.0	8.8	10.0	8.1	7.5	6.7	6.0	5.6	5.0	5.0	0.0	4.6
Median	10.0	8.4	10.0	7.0	7.5	6.7	6.0	5.6	5.0	5.2	0.0	4.6
Number of records	1	5	1	5	1	5	1	5	1	5	0	4

Actual output of excavation in cubic metres per task

	0-20 m		*20-40 m*		*40-60 m*		*60-80 m*		*80-100 m*		*100-150 m*	
Country	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Botswana	5.0	6.0	5.0	5.0	5.0	4.5	5.0	4.0	5.0	3.8	5.0	3.3
Cambodia												
China												
Ghana	5.9	4.6	5.9	4.6	5.9	4.6	5.9	4.6	5.9	4.6	5.9	4.6
Indonesia												
Kenya												
Lesotho		3.5		3.5		3.5		3.5		3.5		3.5
Mozambique												
Tanzania												
Thailand												
Zimbabwe	5.0	9.0	5.0	9.0	5.0	8.0	5.0	7.0	6.0	6.0	6.0	5.0
World Bank												
Minimum	5.0	3.5	5.0	3.5	5.0	3.5	5.0	3.5	5.0	3.5	5.0	3.3
Maximum	5.9	9.0	5.9	9.0	5.9	8.0	5.9	7.0	6.0	6.0	6.0	5.0
Average	5.3	5.8	5.3	5.5	5.3	5.2	5.3	4.8	5.6	4.5	5.6	4.1
Median	5.0	5.3	5.0	4.8	5.0	4.6	5.0	4.3	5.9	4.2	5.9	4.1
Number of records	3	4	3	4	3	4	3	4	3	4	3	4

COUNTRY DATA FOR LOADING, UNLOADING AND SPREADING ACTIVITIES

Production targets		**Botswana**		**Cambodia**		**China**		**Ghana**		**Indonesia**		**Kenya**	
Load, unload, spread	*Unit*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Loading soil	m3		12	8	12							8	10
Loading gravel	m3			5	7				6.7			8	10
Unloading soil	m3			15	20							8	10
Unloading gravel	m3			12	15				10			8	10
Spreading soil	m3		10	5	7.5							12	15
Spreading soil	m2								50		60		
Spreading gravel	m3		18	3.5	5							12	15
Spreading gravel	m2							50	75	35	50		

Production targets		**Lesotho**		**Mozambique**		**Tanzania**		**Thailand**		**Zimbabwe**		**World Bank**	
Load, unload, spread	*Unit*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Loading soil	m3					12	15						
Loading gravel	m3		5			7	10			8	9		
Unloading soil	m3												
Unloading gravel	m3												
Spreading soil	m3	14	16			15	18			7	10		11
Spreading soil	m2		90			60	90						
Spreading gravel	m3	12	15				12				10		
Spreading gravel	m2		60				60						

Actual output		**Botswana**		**Cambodia**		**China**		**Ghana**		**Indonesia**		**Kenya**	
Load, unload, spread	*Unit*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Loading soil	m3			6								6	9
Loading gravel	m3			6				6.25	6.5			6	9
Unloading soil	m3			6									9
Unloading gravel	m3			6					12.7			6	9
Spreading soil	m3			6									
Spreading soil	m2							5.4	91			6	13
Spreading gravel	m3			6								6	13
Spreading gravel	m2							5.8	86				

Actual output		**Lesotho**		**Mozambique**		**Tanzania**		**Thailand**		**Zimbabwe**		**World Bank**	
Load, unload, spread	*Unit*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Loading soil	m3									5	6		
Loading gravel	m3									5	6		
Unloading soil	m3									5	11		
Unloading gravel	m3									5	11		
Spreading soil	m3									5	11		
Spreading soil	m2												
Spreading gravel	m3									5	11		
Spreading gravel	m2												

COUNTRY DATA FOR COMPACTION ACTIVITIES

Production targets	Handrammer					
	Formation m³		*Structures* m³		Slopes m³	
Country	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Botswana						
Cambodia	10.0	12.5			7.5	10.0
China		5.7		2.5		1.5
Ghana						
Indonesia						
Kenya			6.0	9.0	6.0	9.0
Lesotho						
Mozambique						
Tanzania	8.0	10.0				
Thailand						
Zimbabwe						
World Bank						
Minimum	8.0	5.7	6.0	2.5	6.0	1.5
Maximum	10.0	12.5	6.0	9.0	7.5	10.0
Average	9.0	9.4	6.0	5.8	6.8	6.8
Median	9.0	10.0	6.0	5.8	6.8	9.0
Number of records	2	3	1	2	2	3

Production targets	Mechanical											
	Formation m³		*Structures* m³		Slopes m³		*Structures* m²		Slopes m²		*Structures* m²	
Country	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Botswana												
Cambodia	75.0	100.0			10.0	13.5						
China		16.7										
Ghana												
Indonesia												
Kenya												
Lesotho	100.0	150.0						700.0				
Mozambique												
Tanzania		140.0						700.0				
Thailand												
Zimbabwe		250.0										
World Bank	170.0	280.0										
Minimum	75.0	16.7			10.0	13.5	0.0	700.0				
Maximum	170.0	280.0			10.0	13.5	0.0	700.0				
Average	115.0	156.1			10.0	13.5	0.0	700.0				
Median	100.0	145.0			10.0	13.5	0.0	700.0				
Number of records	3	6			1	1	0	2				

COUNTRY DATA FOR CULVERT LAYING ACTIVITIES

Production targets		**Botswana**		**Cambodia**		**China**		**Ghana**		**Indonesia**		**Kenya**	
Compaction	*Unit*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Culvert laying													
600 mm	m			6	12		1.4						0.33
900 mm	m						0.9						0.33
Concrete work	m3			1	1.5	0.1	0.2						1
Stone masonry	m3			1	1.5								1.5

Production targets		**Lesotho**		**Mozambique**		**Tanzania**		**Thailand**		**Zimbabwe**		**World Bank**	
Compaction	*Unit*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Culvert laying													
600 mm	m	1	1.1				0.36			0.5	0.9		
900 mm	m												
Concrete work	m3	1.5	2							0.6	1		
Stone masonry	m3	1.2	1.5							0.5	1		

Actual output		**Botswana**		**Cambodia**		**China**		**Ghana**		**Indonesia**		**Kenya**	
Compaction	*Unit*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Culvert laying													
600 mm	m			7								5	
900 mm	m												
Concrete work	m3			7								6	0.28
Stone masonry	m3			7								6	0.3

Actual output		**Lesotho**		**Mozambique**		**Tanzania**		**Thailand**		**Zimbabwe**		**World Bank**	
Compaction	*Unit*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*	*Hr/task*	*Max*
Culvert laying													
600 mm	m	7	1								0.9		
900 mm	m	7	0.8										
Concrete work	m3	7	0.5								1		
Stone masonry	m3	7	0.5								1		

ANNEX 3: Labour productivities in construction works — a historical perspective

By Gary Taylor, I. T. Transport, UK

There is, of course, nothing new about the use of labour-based methods for major engineering projects. The great building feats of all centuries prior to the present one were largely carried out by hand labour. It is therefore interesting to compare current labour-based projects with those of earlier periods, particularly in respect of labour productivities for common operations. However, it is quite difficult to obtain statistics about labour productivities for engineering projects carried out more than one hundred years ago.

One of the reasons for this is that many projects were carried out by forced or bonded labour and output per day was not something closely monitored. For example, we know from historians that the Great Pyramid of Egypt was built in about 2500 BC with either 300,000 men, according to Diodorus Siculus, or 100,000 men, according to Herodotus, in about twenty years. The size of the pyramid is 230 metres square and 147 metres high, and it has been estimated that it is constructed from 2,300,000 blocks of limestone of between 2.5 to 15 tonnes each. The labour expended in the building of the pyramid has been calculated (by Lecount[42]) as the equivalent of lifting 136 million cubic metres of stone one metre high. This suggests an "average" productivity of between 0.1 and 0.3 cubic metres of stone lifted one metre per manday — not such a useful statistic, and one hedged around by various uncertainties over the exact content and continuity of the work!

The Great Wall of China is another example of a massive engineering undertaking carried out by labour-intensive methods. The 2,250 kilometre long wall was built around 200 BC and is estimated to have occupied 500,000 workers. The wall is eight metres high and six metres wide and its total volume is about 100 million cubic metres. If the wall took, say, 20 years to build, the average labour productivity would be around 0.2 cubic metres of stone lifted one metre per manday. That is probably of the same order of productivity as for the Great Pyramid, but again it is difficult to bring this to units which we can compare with productivities on current day labour-based projects.

The building of the canals in Europe and America from the late eighteenth century onwards was the beginning of an era of large-scale public works construction by labour-intensive methods. Initially the typical system of labour recruitment was for the companies which were formed to construct and operate the works to hire labour directly. Their main

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[42] History of the Railway Connecting London and Birmingham, Lecount, 1839.

interest was to engage labour on terms which, as far as possible, bound the labourers to their employment for the period required for the works. They paid labour on a "days worked" basis and relied on overseers to achieve high productivity through diligent supervision and the enforcement of long working hours. Consequently, it is again difficult to obtain comparative labour productivity data.

Gradually there was a shift to the use of contractors, and in the great railway-building era of the mid-nineteenth century, several large and successful civil engineering contractors emerged. This was accompanied by a move on the part of contractors to the use of incentives to motivate high productivity from their labour forces. These incentives varied, but the most widespread and successful was the use of "piece work" — payment being based on output.

In 1864 it was reported that, in the building of the Suez Canal "the greater part of the excavation is by piece work, for which excellent results are obtained..."[43]. This contrasted with a difficult period before 1864 when forced labour had been used for the early part of the construction work.

The use of piecework brought much greater attention to the daily output of labour, and some extraordinary feats are reported. In the building of the Blackstone Canal in North America, sand was removed by ox-drawn carts: six labourers loaded 50 carts per hour[44]. Assuming each cart held at least 0.25 cubic metres, this equates to a productivity of 2.1 cubic metres per hour per man, or 16.5 cubic metres per man per eight-hour day.

In another unusual feat of labour, three Irishmen on the Erie Canal dug 228 cubic metres in five and a half days of work. This equates to 14 cubic metres per man per day. This is reported to have been about three times the normal average, which must then have been approximately 4 to 5 cubic metres per manday. By further comparison, slaves working on the Santee Canal some time earlier, in the 1790s, were expected to move about two cubic metres per day.

Thomas Brassey was one of the most successful of the British railway contractors of the nineteenth century. At certain periods in his career, he and his partners were giving employment to 80,000 people[45]. One of his agents gives precise information on the average amount of labour done by the English "navvies", the name given to the labourers engaged on the hardest physical work of railway building. He said that a full day's work consisted of fourteen sets[46]. A "set" is a number of wagons — in fact a train. There were two men to a wagon. Therefore each man excavated and filled the equivalent of seven wagons per day. Each wagon contained just over two cubic metres. Therefore each man loaded over 14 cubic metres per day, and the height of lift was about 1.8

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[43] Sue: De Lessep's Canal, John Pudney, 1968 (p.109)
[44] Common Labour; Workers and the Digging of North American Canals 1780-1860, Peter Way, 1993 (p.137)
[45] Life and Labours of Mr Brassey, Arthur Helps, 1872 (p.160)
[46] Ibid. (p.77)

metres. Furthermore, navvies sometimes contrived to get through sixteen sets — that is 16.5 cubic metres per man per day.

Quoting estimates from the early nineteenth century, McDermott said that “in a summer's day a labourer can excavate in ordinary and favourable soils five cart loads, or about 5 cubic yards (4.6 cubic metres) of earth”[47]. In a contemporary comparison between men and machines for railway building, the same author estimated that 100 men would be required to excavate 600 cubic yards (550 cubic metres per day). This equates to a productivity of 5.5 cubic metres per manday[48].

Evidence by Mackay, one of Brassey's staff, on average wages and costs of labour in railway contracting from 1843 to 1869 reveals that the average productivity for labour in earthworks in this period was between 5.5 and 6.5 cubic metres per manday[49].

It is difficult to get closer than these estimates of labour productivities with the evidence that is readily available. However, the figures most regularly quoted for nineteenth century engineering works are of the order of 5 to 6 cubic metres a day for excavation work.

It is important to remember the background to these productivities. Contractors such as Brassey subcontracted most of the manual work to labour-only subcontractors[50]. The labourers, or “navvies”, moved with the work, living in shanty camps. Their wages were high in comparative terms — about two to three times higher than those of agricultural labourers. They ate well (and drank heavily!). Therefore, although the work was heavy in the typically wet and clayey soils of much of England, the men were strong and well accustomed to the work. Also, because they were not working close to their homes, they worked long hours — ten to twelve hours per day being fairly typical.

And so to the dawn of the 21st century. For most developing countries labour-based technology for infrastructure works is still the most sensible and viable option. In Europe, where the average daily wage for unskilled labour is around USD100 per day, the use of equipment-based methods is clearly appropriate. In developing countries, on the other hand, with much lower labour costs and high levels of unemployment, labour-based technology still retains an important claim as the technology of first choice.

However, even with comparatively low labour costs, efficiency in labour-based methods is fundamental to its continued use in developing countries. This Technical Brief is an important contribution towards maintaining and improving productivity on labour-based sites in all developing countries.

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47 Life and Work of Joseph Firbank, Frederick McDermott, 1887 (p.25)
48 Ibid. (P89)
49 Work and Wages by Thomas Brassey, 1872 - quoted in The Railway Navvies by Terry Coleman, 1968 (p.67).
50 Life and Labours...” Op cit (p.45)