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ITC DEVELOPMENT ENGINEERING COURSE

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THIS SERIES OF LECTURES HAS BEEN COMPILED FROM A NUMBER OF MAIN ILO SOURCES:

- **HOWE, J AND H. MULLER** (1998): *UNDERGRADUATE COURSE ON LABOUR-BASED ROAD ENGINEERING: COURSE NOTES.* INTERNATIONAL INSTITUTE FOR INFRASTRUCTURAL, HYDRAULIC AND ENVIRONMENTAL ENGINEERING, THE NETHERLANDS. PREPARED FOR ILO, GENEVA.
- **HOWE, J AND H. MULLER** (1998): *POSTGRADUATE COURSE ON LABOUR-BASED ROAD ENGINEERING: COURSE NOTES.* INTERNATIONAL INSTITUTE FOR INFRASTRUCTURAL, HYDRAULIC AND ENVIRONMENTAL ENGINEERING, THE NETHERLANDS. PREPARED FOR ILO, GENEVA.
- **PETTS, R. C.** (1999): *SMALL SCALE LABOUR-BASED CONTRACTING FOR ROADWORKS*. ITC TRAINING MODULE PREPARED FOR THE ILO UPSTREAM PROJECT, PHNOM PENH.
- **PETTS, R. C.** (1999): *EQUIPMENT COSTING FOR CONTRACTORS.* ITC TRAINING MODULE PREPARED FOR THE ILO UPSTREAM PROJECT, PHNOM PENH.
- **PETTS, R. C.** (2001). *RATIONALE FOR THE COMPILATION OF INTERNATIONAL GUIDELINES ON LOW-COST, LABOUR-BASED, ALTERNATIVE AND SUSTAINABLE ROAD SURFACINGS.* LCS WORKING PAPER NO. 1, INTECH ASSOCIATES, UK.
- **ANDERSSON, C-A, A. BEUSCH AND D. MILES** (1996): *ROAD MAINTENANCE AND REGRAVELLING (ROMAR) USING LABOUR-BASED METHODS – HANDBOOK.* PREPARED FOR ILO. INTERMEDIATE TECHNOLOGY PUBLICATIONS, UK.
- **BENTALL, P, A. BEUSCH AND J. DE VEEN** (1999): *EMPLOYMENT INTENSIVE INFRASTRUCTURE PROGRAMMES: CAPACITY BUILDING FOR CONTRACTING IN THE CONSTRUCTION SECTOR*. ILO, GENEVA.

MUCH OF THIS MATERIAL WAS PREPARED FOR A SPECIAL PURPOSE AND A DIFFERENT AUDIENCE. THEREFORE, MODIFICATIONS HAVE BEEN MADE TO THE MATERIAL TO MATCH THE TEACHING CONDITIONS AT ITC, THE LENGTH OF THE ITC LECTURES AND THE ACADEMIC LEVEL OF THE STUDENTS. WHERE APPROPRIATE, THE MATERIAL HAS BEEN UPDATED TO ACCOUNT FOR RECENT TRENDS IN THE RURAL ROAD CONSTRUCTION SECTOR AND CHANGES IN THE APPLICATION OF LABOUR-BASED TECHNOLOGY. AS FAR AS POSSIBLE, THE EXAMPLES USED AND REFERENCES QUOTED HAVE BEEN DRAWN FROM SOUTHEAST AND EAST ASIA. WHERE CASE STUDY MATERIAL WAS AVAILABLE THAT DIRECTLY REFLECTED CAMBODIAN EXPERIENCES THIS HAS BEEN INTEGRATED INTO THE LECTURES. THE TECHNICAL EDITOR IS RESPONSIBLE FOR ANY ADDITIONS AND OMISSIONS THAT HAVE BEEN MADE TO THE ORIGINAL TEXTS.

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LIST OF ACRONYMS

AAP	District Accessibility Action Plan
ADB	Asian Development Bank
ADT	Average daily traffic
BCR	Benefit-cost ratio
BMN	Basic minimum needs
CRDC	Commune Rural Development Committee
DRDC	District Rural Development Committee
DRDO	District Rural Development Office
EIA	Environmental impact assessment
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical Information System
GPS	Geographical Positioning System
GTZ	German Technical Assistance
GOC	Royal Government of Cambodia
IEIA	Initial environmental impact assessment
IDPs	Internally displaced persons
ILO	International Labour Organisation
IRAP	Integrated Rural Accessibility Planning
IRI	International Roughness Index
IRR	Internal rate of return
LFA	Logical framework analysis
MoE	Ministry of Environment
MOU	Memorandum of Understanding
MRD	Ministry of Rural Development
NGO	Non-Government Organisation
PRA	Participatory Rural Assessment
PRDC	Provincial Rural Development Committee
PRDO	Provincial Rural Development Office
PWD	Provincial Public Works Department
SEDPII	Second Socio-Economic Development Plan
Sida	Swedish International Development Cooperation Agency
UNDP	United Nation's Development Programme
VDC	Village Development Committee

GLOSSARY OF TERMS

ADT (average daily traffic) is the total two-way traffic on a stretch of road averaged over a determined period, such as a week, month or year.

Baseline survey is a survey undertaken before a project starts and represents a "without project" situation. A typical example might be traffic and road conditions before starting repairs.

Basic access is a level of service for roads with low travel speeds and low traffic flows, generally applying to lower/local levels in the road hierarchy.

Carriageway width is the overall road pavement or bridge deck surface on which vehicles travel.

Colmatage is a French term used for describing a form of canal that is cut each year to bring silt-laden floodwaters to low-lying land behind river levees.

Community based works are undertaken by clearly identifiable groups of people (usually with the help of a facilitating agency) for the benefit of the group as a whole, the assets created being owned, managed, used and maintained by the beneficiaries themselves.

Cost-benefit ratio is the ratio between the discounted total costs and the discounted total benefits. If the net present value (NPV) is zero, then the NPV divided by the discounted costs is zero and the cost-benefit ratio is unity (1). If it exceeds unity, the project is profitable.

Design speed is the optimum travel speed for a vehicle related to the type of road, its physical condition and the topography through which it is travelling.

Discount rate is the interest rate at which the banks borrow from a central/national bank.

Discounted cash flows are values represented in "current" costs, allowing the economist to add and subtract the stream of costs and benefits as though they all occurred in the same year.

Economics is the study of the use of scarce resources to satisfy unlimited human wants.

Economic analysis is a form of analysis used in economics that looks at the worth of a project from the viewpoint of the whole economy – the general public interest or public good. These costs are adjusted to account for any distortions, such as subsidies, taxes and transfer payments.

Environmental impact assessment (EIA) is a process for predicting and evaluating the impact that a development activity could have on the natural and human environment - undertaken before the activity starts, to avoid adverse and costly changes resulting from human action.

EIA study or ***statement*** is an in-depth analysis and prediction of impacts, presentation and ranking of alternative plans, development of management/mitigation measures and presentation of proposals for monitoring and evaluation.

Employment-intensive is a generic expression to describe strategies, programmes, projects, activities and assets that will promote direct or indirect, short-term or long-term employment generation at the highest possible level.

Equipment-based technology is the opposite of "labour-based" in that most work is done by labour-replacing equipment, supported by a small labour force – generally effective where labour is not readily available or labour costs exceed around US$ 5 per day.

Evaluation is a process to determine the physical, environmental, social and economic impact and effectiveness of a project in order to use the lessons learned to design new projects.

Financial analysis is a form of analysis used in economics that looks at the viability or commercial worth of a project from the viewpoint of a private investor.

Full access is a level of service for roads with high travel speeds and low roughness, generally applying to higher levels in the road hierarchy.

Gender is the social roles and responsibilities of women and men (as opposed to “sex”, which is the biological difference between men and women).

Gender awareness or sensitivity is the need to be aware of the differences between women and men’s role in society.

Gender division of labour are the work roles, responsibilities and activities assigned to women and men based on gender.

Gender bias is the tendency to make decisions or take actions based on gender stereotypes.

Gender gap is the difference in the equality of access to jobs, rights and other services between men and women.

Geodetic is a term used in surveying to describe land surveys based on the geometry of the land.

Geographical information system is a mapping and planning tool, which expedites the workflow and replaces many manual operations with computerised tasks. With a GIS its power lies in its ability to manipulate complex databases and not just to produce maps.

Geographical positioning system is a hand-held electronic device that determines the co-ordinates of any location using a triangulation system from signals received from three satellite positions.

Internal rate of return (IRR) is the discount rate at which the base year value of costs and benefits are equal (i.e. net present value = 0). If the IRR is higher than the planning discount rate (usually 12%) then the project is viable.

Investment costs or ***capital costs*** are all the initial costs required to fund an investment, including land, buildings, equipment, professional fees and bank charges.

IRAP (integrated rural accessibility planning) is a local-level participatory planning tool for analysing the differences in access communities have to basic facilities.

IRI (international roughness index) is a method for estimating the condition of a road pavement based on measuring and calibrating its roughness, quantified in terms of metres per kilometre.

Job is usually defined as an effective employment of 200 full day’s work per annum, paid at the market rate and not less than the minimum wage.

Labour-based technology describes technology in which labour, supported by light or medium-sized equipment, is used as a cost-effective method (when compared with equipment-based methods) of providing or maintaining infrastructure to a specified standard.

Labour constant is a term used in cost estimating to describe the normal amount of time that a particular construction activity will take to achieve a set output, such as the amount of earthworks excavation that can be achieved per hour.

Labour-intensive works are those works of government or externally funded programmes that focus mainly on short-term employment creation and income distribution and in general do not emphasise cost effectiveness and quality outputs.

Lane or traffic lane is the portion of the road carriageway, usually defined by road markings, for the movement of a single line of vehicles.

Lengthman or attendant is the person contracted to maintain a section of road.

Logical framework analysis is an analytical tool that links together the whole development process – making connections between the objectives of a programme or project, the inputs needed to achieve it and the ultimate outcome.

Net present value is the sum of the discounted costs and benefits. The higher the NPV the greater the project benefits.

Opportunity cost is the cost of using a resource for a particular purpose - measured in terms of the cost of forgoing the use of the resources for an alternative purpose.

Origin and destination surveys are field surveys that are used to determine where vehicles are coming from and where they are going.

Partial access is a level of service for roads with seasonal/temporary access for specialised uses.

Pilot survey is a preliminary survey undertaken to test whether a survey questionnaire has been properly designed.

Planning cycle or ***development cycle*** or ***project implementation cycle*** is a way of describing and relating the various stages that are involved in development projects.

Primary data is information that has to be collected through field surveys to fill data gaps.

Private good is the term used in economics to describe infrastructure and activities that are exclusively in private sector ownership, such as a private company or an individual house.

Primary roads are Class A and B national and inter-provincial highways.

Primary markets are small markets where the trade is characterised by direct sales of small quantities of produce by farmers to village traders and retail sales to rural consumers.

Public good is the term used in economics to describe infrastructure and activities that are exclusively in government (public sector) ownership, such as a road or communal water supply.

Public works are works undertaken by central or local government agencies for the benefit of the population in general, the infrastructure created remaining in the ownership of the agencies concerned, who assume responsibility for management, maintenance and, sometimes, operations.

Radius of curvature is the minimum horizontal curvature of a road that will allow vehicles to travel safely, related to the type of road, design speed and the topography.

Recurrent costs are all ongoing costs required to finance the operation of an investment, including staff salaries, utility costs (water, fuel, etc.), land taxes, building and equipment maintenance, loan repayments and interest on the capital borrowed.

Regression analysis is a statistical technique for relating sets of data together to test if one set of data has a close relationship to another.

Roadway is the portion of the road or highway, including shoulders, for vehicular use.

Route infrastructure inventory surveys are field surveys that describe the physical conditions of existing routes and the structures, such as bridges and culverts, on the routes.

Right-of-way is the overall width of a road, including its carriageway, shoulders and reserve.

Scoping is the second stage in environmental impact assessment - used to describe the present environmental situation and to define the focus of an EIA study.

Screening is the first stage in environmental impact assessment – used to determine if a full-scale EIA is needed.

Secondary data is information that has already been collected and published by others.

Secondary roads are roads linking provincial centres to the capital, to adjacent provinces and to other main industrial and tourism centres.

Sustainability is the continuation of an activity after capital funding has finished, which is invariably an issue of access to resources for maintenance and operations

Supervision is part of the monitoring process and refers to the periodic management of a project to verify that construction activities are being implemented according to the contract documents.

Targeted procurement is a contractual system incorporating social targets, which are set to meet policies on poverty alleviation, employment, geographical focussing and the use of local materials and services.

Tertiary roads are public roads that link adjacent districts.

Sub-tertiary roads are public roads that cater for the intra-district transport needs linking rural centres/communes to district towns (ST1), communes to each other (ST2) and communes to villages or villages to villages (ST3).

Special-purpose roads are roads which serve individual economic activities within a limited area, such as mining or forestry, or which are primarily required for national defence.

Transects are cross-sections of an area created during a rural assessment by systematically walking through the area with key informants.

Utility is the term used by economists to define how resources can be used.

Vehicle operating costs are the total of all the costs associated with the operation of a vehicle, including driver's wages, depreciation, fuel and vehicle repairs and maintenance.

Water users groups are community-based organisations established to manage and maintain small-scale for irrigation systems.

PART A: Sensitisation Course

1: INTRODUCTION TO DEVELOPMENT ENGINEERING

Contents

1. Issues covered in this lecture

- Overview of development engineering
- Focus of the lectures
- Terminology and key concepts
- Use of local resources
- Summary

OVERVIEW OF DEVELOPMENT ENGINEERING?

Development engineering is an alternative way of approaching engineering problem solving. Instead of looking at problems purely in terms of functional performance (such as whether a bridge can support a given load) it takes a broader view that all construction is a combination of social economic and technical factors. In the case of a bridge this might mean that its construction should create local employment at the least cost, but to an equivalent standard to that which would be obtained using more sophisticated materials and technology.

development engineering as an alternative approach

Thus, development engineering is not a replacement for other effective forms of equipment-based construction methods. It is an alternative approach to construction, which seeks to optimise the use of construction resources, including equipment and labour, but in a way that prefers to maximise employment generation, the use of local resources and other socio-economic benefits. It seeks to link the benefits of construction directly to the development of the communities for which it is intended. By this means it tries to achieve optimal employment generation and poverty alleviation through the realisation of cost-effective, and well-managed, labour-based and labour-intensive construction programmes within the mainstream of regular recurrent works programmes of central and local government and the private sector.

use of labour

The issue of maximising the use of labour for construction is a concept that is fundamental to the idea of development engineering. The basic reasons why the use of a labour-based technology could be beneficial are:

2. Reasons for using Labour-based Technology

- A greater utilisation of under-employed labour resources;
- Achievement of national development objectives to create social and economic infrastructure;
- A more appropriate and cost effective use of local materials and of intermediate technologies;
- A short and long-term impact (additional job creation) on the local economy in general, and specifically, on the construction sector;
- Consistency with the government's decentralisation and local financial autonomy policies and with a participatory community-based development process; and
- An increase in job skills and greater self-esteem.

targeting and screening

The purpose of using such labour-based-technology is not to "make work", but to create good quality infrastructure that is needed and would benefit by being executed using such technology. Thus, the screening and targeting of labour-based projects needs to be a rational process, which balances social, economic and technical factors. There are three main questions relating to targeting and whether the project is:

- Needed;
- In the right location; and
- An appropriate project to apply labour-based techniques.

choice of technology

The main objective of using a development engineering approach to designing a project could be to generate employment through the adoption of appropriate and cost-effective technologies. This will need to be based on an integrated and multi-disciplinary approach to the planning and design of infrastructure. The technical approach should focus on the use of local materials and improved "traditional" engineering technologies and (for land development activities) the use of biological treatments.

The range of technical options is likely to be extensive and, in implementation, allowance needs to be made for a considerable range of choices to be available, based on the local physical and socio-economic conditions. Targets and cost estimates should be indicative only and be adjusted based on implementation experience.

community involvement

Although a reorientation in development engineering towards labour-based technology is not necessarily technically complex, it does represent a considerable change in approach. The approach may not be universally accepted and substantial efforts will need to be made to motivate supervising engineers and communities. For community-based projects, the intended beneficiaries will need to be fully involved in project planning and implementation - the choice of technologies should not be largely driven by the implementing agencies.

Project targets and achievements should not be target driven and there has to be flexibility allowed in order to respond to beneficiary aspirations. An important issue to be resolved will be how to achieve a satisfactory level of community participation and involvement in selecting technologies, in their execution, and in the longer-term management and sustainability of the assets.

FOCUS OF THE LECTURES

Although these lectures focus on labour-based rural road engineering this is because of the large amount of published material available for this sub-sector. The arguments and principles could equally be applied to other sub-sectors of civil engineering such as infrastructure for irrigation and other rural infrastructure, such as soil conservation.

It also especially applies to urban applications - with which there is at present little experience, but whose importance is increasing because of the growing significance of urbanisation throughout the developing world. This is particularly the case in the context of rehabilitation or upgrading works in run down areas, road improvement, drainage, solid waste treatment, repairs of water supply systems and with some types of building construction.

TERMINOLOGY

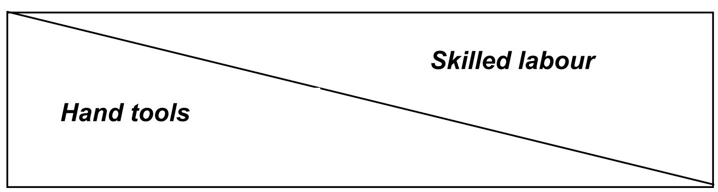
Development engineering uses a number of key concepts that it is essential to understand. The first term is "labour-based":

3. key concept - labour-based

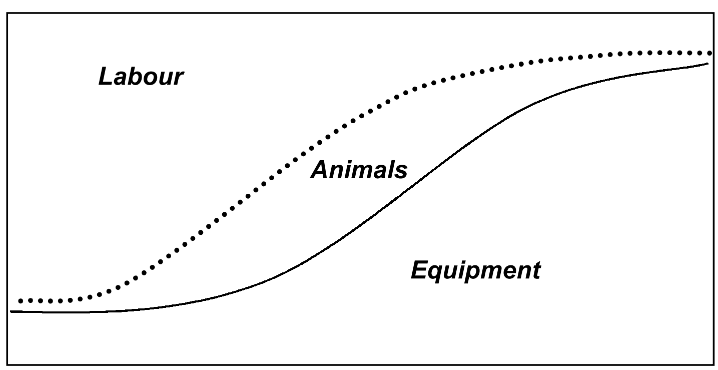
The term *labour-based* works can be equated to the notion *of employment-intensive* works. In labour-abundant economies, conditions that typify most developing countries, the term is also synonymous with the concept of *local resource-based civil works.* Labour-based works can also be described as *capital conserving.*

At its simplest, the term describes civil engineering activities in which the dominant resource used is *labour*. But as the following diagram makes clear, labour-based technologies, like equipment-intensive operations, are integral to all construction activities. It is not possible to have construction activities in which there is either no equipment (100 per cent labour) or no labour (100 per cent equipment). The main issue in development engineering is 'what proportions of labour and equipment are appropriate for different circumstances?'

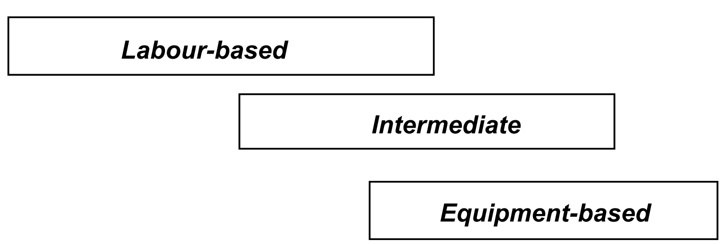
4. Classification of construction technology



a. Proportion of skilled labour and handtools



b. Motive power contributed by different sources



c. Range of appropriate technology

Until comparatively recently activities in which the dominant resource was labour might also be described as *labour-intensive.* Indeed the proportion of labour costs in the total expenditure on a project has been used as a measure of *"labour-intensiveness"* This is shown in the following table:

5. Labour-intensiveness of selected public works programmes in Burkina Faso, Burundi, Nepal, Rwanda and Tanzania

Activity		L-I Coefficients(*)
i.	Anti-erosion works	66.9-98.7
ii.	Reforestation	70.0-74.0
iii.	Wells, reservoirs, small irrigation works	41.0-76.0
iv.	Earth roads	45.6-62.0
v.	Building construction (schools etc)	38.2

Measures the % share of labour costs in total expenditures; does not indicate if labour is used efficiently and effectively, i.e. measures inputs not the efficiency of resource use or outputs

In this interpretation wage levels are critical since raising them is likely to *reduce* the total proportion of costs paid as wages, and *vice-versa,* since there will be a tendency for equipment to displace labour. An engineer would probably be more concerned with the *actual person-days worked.*

From the table it is apparent that if the proportion of wages is used as a measure of *labour intensity,* then some activities attain an intensity component of almost 99 per cent, whereas it can be as little as 38 per cent on nominally labour-based projects. Even on highway projects constructed in the same mountainous environment (where a certain amount of equipment might be expected) by different organisations, the labour component ranged from as little as 1 per cent to as high as 70 per cent. Conventional equipment-based rural road construction might average a 10 per cent expenditure on labour compared with about 65 per cent using a labour-based approach.

6. Key concept – labour-intensiveness

The proportion of total costs paid as wages can crudely measure the degree of labour-intensiveness. However, this does not distinguish between efficient and inefficient use of labour. This requires some idea of the productivity per unit wage and the quality of the resultant output. The degree of *capital-intensiveness* is the proportion of total cost spent on tools and equipment.

ILO approach

Currently the ILO defines a *labour-intensive* approach as one which *optimises* rather than *maximises* the labour content of a project. When labour-intensive methods are not providing products of adequate quality or the methods are not cost-effective, it is assumed that an appropriate mix of labour will undertake such works and equipment possibly with some animal powered support. In those cases the method is sometimes termed *labour-based/light equipment supported.* Thus in much of the most recent literature the two terms labour-intensive and labour-based have been used almost synonymously, but with the explicit assumption that the methods used will be cost-effective and end product quality will be fully adequate.

These definitions are important as they are intended to distinguish between the:

i. Temporary use of labour-based methods to provide short-term employment or income generation in times of crisis; and

ii. Creation of systems, procedures and capacities for sustainable employment generation, through local resource-based approaches in the context of longer-term development strategies, which are the activities with which we are concerned.

temporary use of labour-based methods

From the perspective of the engineer, activities that fit into category (i) are more correctly described as *labour-extensive* since they make an *extensive use of labour* i.e. large amounts, without necessarily using it very efficiently. In this respect they resemble the practices found in traditional labour dominant cultures in Bangladesh, India and Indonesia.

For such projects and programmes political priority is given to the short-term objective of immediate income generation for specific target groups over longer-term goals of better use of local resources, creation of productive assets and sustainable employment. Temporary institutional arrangements are then made for programme management parallel with the established implementation channels of public works programmes.

These programmes may be acceptable in the context of special relief efforts relying on substantial support by external donors. However, the temporary nature of such approaches, low unit labour productivity, and their poor long-term prospects makes them unsustainable in the long term.

sustainable employment generation

The emphasis in (ii) on *local resources* is also a common current theme. Under this interpretation *labour* is simply the most abundant resource with which most developing countries are endowed. The arguments for labour-based technologies can thus be equated with those for local resource-based technologies.

In more recent definitions of *labour-intensive* construction and maintenance the important issues of economic efficiency and product quality, as well as labour content, are emphasised:

7. Key concept – labour-intensive

Labour-intensive construction may be defined as the economically efficient employment of as great a proportion of labour as is technically feasible to produce as high a standard of construction as is demanded by the specification and is allowed by the funding available. *(Source: Prof. R.T. McCutcheon).*

USE OF LOCAL RESOURCES

Labour-based engineering can also be taken to mean local-resource-based, since labour is the most common and important locally available resource used. However, there are many other local resource possibilities and modern labour-based programmes give increasing emphasis to the exploitation and development of the full range of them which include:

8. Types of local resources

- Manpower/Womanpower
- Local institutions at different levels (local/central government, private sector, co-operatives, farmer's associations, communities & NGOs)
- Local entrepreneurs (petty contractors, industry, artisans, etc)
- Local skills (educational and vocational)
- Local materials (timber, stones, bricks, etc.)
- Locally-available equipment (including transport)
- Local finance (contributions in kind or funds)

value of local resource-based approach

A wider, local resource-based approach integrates local labour with other human, material, financial, vocational and institutional resources and know-how accumulated in the private sector or at the community and household levels. It aims at maximising the use of locally available resources, thus economising on foreign inputs that are subject to increasing degrees of conditionality. While foreign resources typically cover the major part of construction costs, maintenance is usually left to national resources, which remain chronically inadequate. This explains why infrastructure works are often still undertaken without provision for recurrent costs, causing them to fall quickly into disrepair.

The value of maximising the use of local resources is in the creation of productive local employment, as follows:

9. Strategy for greater use of local resources

Productive employment creation through:

- Skilled workers
- Semi-skilled workers
- Entrepreneurs
- Production of materials
- Substitution of local for imported energy

political obstacles to local resource-based approach

The full scope for applying local resource-based methods in key economic sectors and the potential impact on the balance of payments and on employment have so far not been fully recognised, either by national governments or donors. There are still a number of economic, financial, technical and political constraints creating a bias against these methods. Overvalued currencies may make foreign inputs seem less expensive than local resources. Undervalued real interest rates may favour loans for capital goods. Donor support may be limited to the foreign exchange cost of development programmes and tied to specific imports, pre-empting the choice of technology. Faster completion times and the rapid negotiation of foreign loans also favour capital-intensive construction methods.

The education of engineers and project planners is often biased towards capital-intensive techniques. Centralised decision making and investment controls discourage consultation with local communities. Political interests are often more easily served by capital-intensive approaches. Finally, because unemployment is a highly sensitive political issue, governments are naturally inclined, especially at times of crisis, to get emergency programmes quickly off the ground to achieve the primary short-term objective of generating incomes, without paying due attention to design or the real social cost of such programmes. There are numerous examples of this in South Asia and Latin America.

SUMMARY

The main points made during this lecture are as follows:

10. Summary and results

Summary: Labour-intensive construction = the effective substitution of labour for equipment

Result: A significant increase in the number of people employed per unit of expenditure

FURTHER READING

The student should refer to the following documents:

1. **Edmonds, G.A. and J.D.G.F. Howe** (1980). *Roads and resources: appropriate technology in road construction in developing countries.* London, (Intermediate Technology Publications Ltd.)
2. **Gaude, J.** et al (1987). *Rural development and labour-intensive schemes: impact studies of some pilot programs.* International Labour Review 126 (4/1987).
3. **Gaude, J. and S. Miller** (1992). *Productive employment for the poor.* International Labour Review 131, No. 1 (Special Issue).
4. **McCutcheon, R.** (1995). *Employment creation in Public Works: labour-intensive construction in Sub-Saharan Africa, the implications for South Africa*. Habitat International.
5. **Van Imschoot, M.** (1992). *Water as a source of employment.* International Labour Review 131, No. 1 (Special Issue).

11. Questions for students:

- *Why does the lecture series focus on rural road engineering?*
- *What do you understand by the term labour intensiveness?*
- *What do you understand by the term capital intensiveness?*
- *What are the consequences of using short-term labour-based methods?*
- *What are typical local resources used in the construction process?*

2: SCOPE OF LABOUR-BASED CONSTRUCTION

Contents

1. Issues covered in this lecture

- Introduction and overview
- Engineering in sensitive environments
- Labour-intensive methods in China
- Kenya rural access roads programme

INTRODUCTION AND OVERVIEW

The purpose of this lecture is to use slides to give a quick visual impression designed to show that labour-intensive methods are:

- Already used in a number of countries, with both low and relatively high wage levels.
- Not an interesting idea that might be tested but a technology which has been proven under almost every conceivable environment from flat desert conditions, to rolling hills, tropical rain forest, humid plantations, and the most rugged mountain terrain in the world.

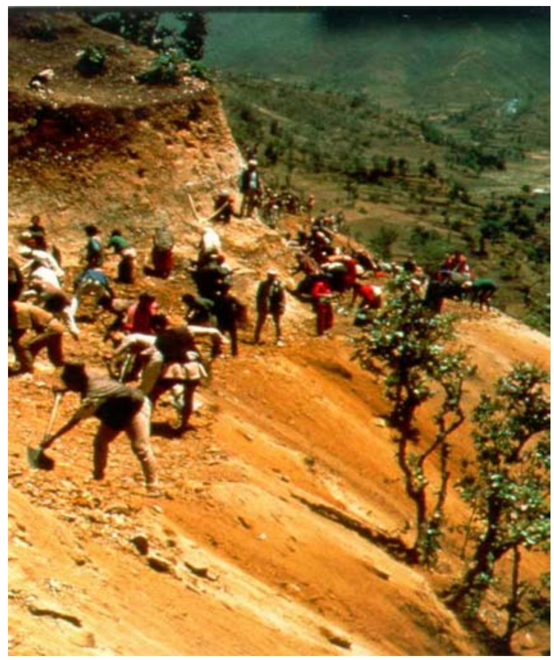
- ***Labour-based methods are the opposite of this! Note the absence of people***

- ***In many countries machinery has not been an overwhelming success, especially for low-cost rural infrastructure.***

- ***It is very difficult to operate equipment efficiently in remote locations with low-density networks***

- ***Apart from the problems associated with organising efficient maintenance the extreme difficulty of moving heavy equipment is characteristically underestimated.***

- ***Used under semi-desert conditions in Botswana.***
- ***Typical Rural Access Road in Kenya: providing access to smallholder farming areas.***



- ***Used in Nepal.***
- ***Where working conditions can be very tough.***

- ***Labour-based methods are used in the Philippines.***
- ***Being used in the rural areas of Thailand***

- ***And in the more urbanised areas of Thailand.***

- ***Labour-based road rehabilitation in the savannah region of Zimbabwe.***

- ***New road construction in the highlands of Ethiopia.***

- ***Typical rain forest in Ghana where there is a large programme of rural road rehabilitation and maintenance using small contractors.***

ENGINEERING IN SENSITIVE ENVIRONMENTS

This section provides an overview of the problems of engineering infrastructure improvements in extremely sensitive mountainous and hilly environments, which provides a comparative advantage to labour-based methods. There are two main reasons for the extreme sensitivity of the landscape:

- The relative youth of the mountains, speaking in a geological sense. They are still growing, and like children growing out of their clothes the Himalayas regularly shed their surface covering.
- An extreme of climate produces a highly weathered surface layer of material that is very unstable.

In such a sensitive landscape the engineering of any kind of physical infrastructure - roads, irrigation, and water supply - is fraught with difficulty. In the case of roads there is a real dilemma as to where and how to build:

- You might think it sensible to locate in the valleys where most of the people live. In some cases an apparently easy and stable terrain.
- Not true: there are numerous streams and small rivers and, apart from frequent and expensive bridges, there is a constant threat of this kind of event.

- The rivers themselves are also inherently unstable. Where has the road gone?
- In these circumstances the standard engineering advice is to locate the road up on the ridge.
- Problem - at some point you have to get up and down again. It is very difficult to safely locate and protect the hairpin stacks. And of course if one fails it is always the one at the top, which brings the rest down!

Initially attempts were made to find conventional engineering solutions to the environmental damage resulting from over-design and too rapid construction. The approach was even more conventional engineering! The search for cheaper and more lasting solutions to the problems of acute slope instability led to the evolution of a new concept:

Bioengineering *"the use of plants and vegetative materials for engineering purposes"*

The use of vegetation to control erosion was not in itself new, but the scale and systematic experimentation with their use was. It resulted from a multi-disciplinary approach that complemented rather than replaced conventional engineering measures. Bioengineering grew out of the common-sense observation that even in the Himalayas some slopes are stable.

- ***Tea slopes are rarely unstable due to the dense vegetation cover they provide. Disturbed slope after bioengineering treatment.***

- ***Not all applications were large scale: lines of grass planted on an unstable mudstone slope.***

- ***Diagonal grass lines planted on a small steep slope.***

- ***The uses of locally produced jute netting to protect new plants while root structures are establishing themselves.***

Conservation-oriented local roads improvement programme – "green roads"

The very high cost of early hill roads led to a number of major aid agencies withdrawing from their construction. However in 1985/86 the development of a more conservation-oriented approach was initiated which has been enthusiastically taken up and developed by local engineers. The basic principles of the approach are:

- Modest standards of access (8-9 months a year).
- Build slowly with conservation as the guiding principle.
- Initially only a foot track is carefully established and gradually widened to 3.5-4.5 metres. Time is regarded as servant and not a master.
- Unconventional drainage - no channelling of water through side drains and culverts: spread over the road surface.
- use local resources for construction - materials

- ***The process is labour-intensive: no machinery if possible + 80% in local wages.***

- ***Excavated material as possible is saved. A major use is for dry-stone retaining walls.***

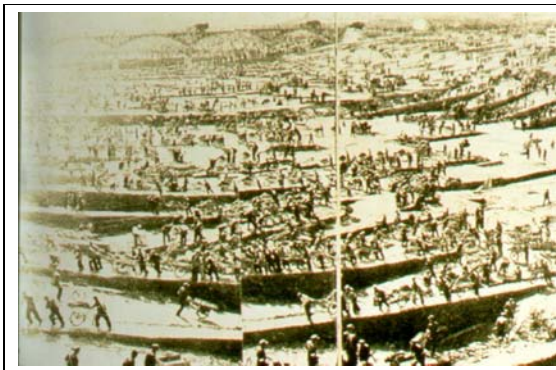
Result - costs 1/2 to 1/3rd those of poorer quality roads built by conventional methods. Note the absence of environmental damage due to construction debris.

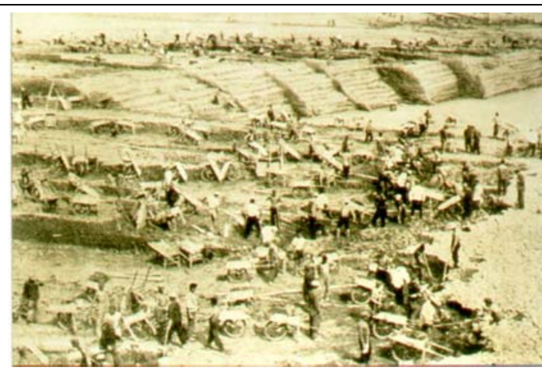
What has happened in Nepal is not a repudiation of engineering but a reassertion of basic skills. Faced with a situation in which the conventional wisdom clearly was not working satisfactorily engineers have been forced to fall back on their powers of observation, judgement and innovation.

- ***In general the structures are built first.***

LABOUR-INTENSIVE METHODS IN CHINA

The next slides illustrate labour-intensive methods in China in the early 1970s. The reproductive quality in not very good because they were taken from newspaper photographs.





- ***Note the vast scale of the works. The original photo showed a very much bigger site under the caption "1,000,000 people build the * * canal".***
- ***The construction is evidently highly organised and disciplined with considerable attention given to detail and pre-construction planning.***

- ***Note the use of planks to give the wheelbarrows a smooth path. Also the haul lengths seem to be much longer than would be feasible with western-style wheelbarrows**.*

- ***A reminder of China's tradition in construction. The Great Wall of China – note there are no gabions protecting the wall: monuments to engineering science.***

KENYA RURAL ACCESS ROADS PROGRAMME

The location of the Kenya Rural Access Roads Programme was the central most densely populated and fertile part of the country.

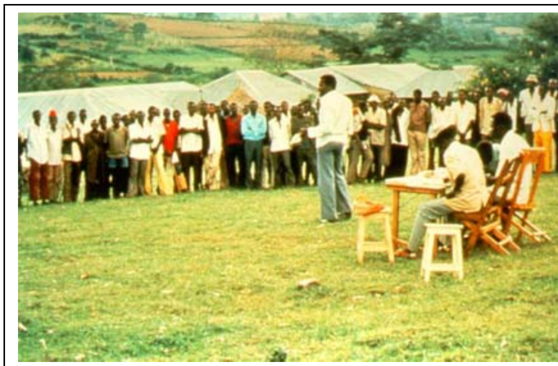
- ***This is very rich farming land.***

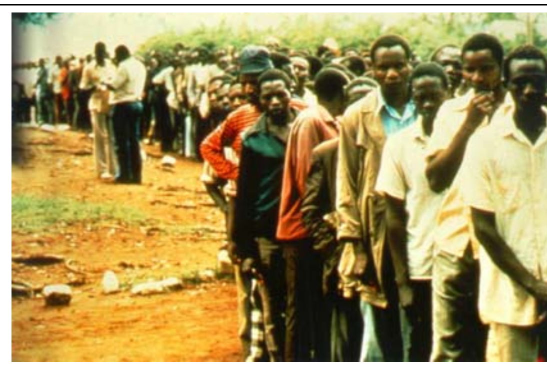
- ***Farmers could grow more food, which the country needed, but they were unable to transport the increased production to market along the existing tracks.***

- ***Even some main roads were in a poor condition. The slide shows a rural road that has been graded into a canal. The man is standing at the original road level.***
- ***Sensible work being carried out in an inappropriate place. It is almost impossible to drain water from such a location.***

New approach in the early 1970s

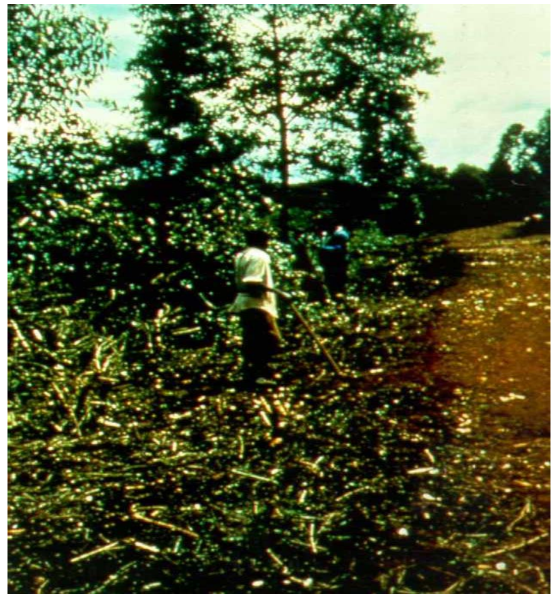
A new approach was clearly needed. This conclusion coincided with the end of ILO and World Bank work on labour substitution in civil construction. The Kenya government was receptive to the suggestion that more use should be made of local resources to improve and maintain the roads i.e. people. Such an approach also promised additional economic, social and political benefits in addressing an important and growing problem - unemployment. The first task was to recruit the labour.





- ***Explaining the rules of the game to prospective workers - wage rate tasks; conditions of employment.***
- ***Prospective workers lining up for selection by lottery.***

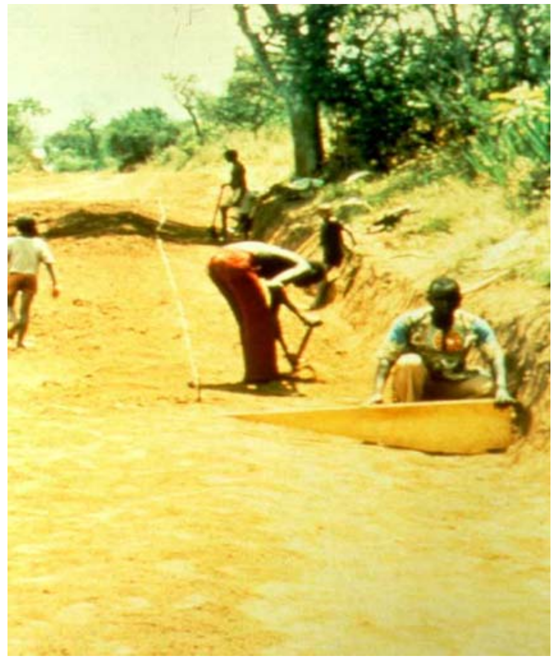
The stages of the method of construction developed for labour-based road works in Kenya contained a number of aspects which went against conventional construction practice, such as the avoidance of longitudinal haulage and the use of in-situ materials as far as possible. Since the correct alignment of even the simplest road requires proper engineering measurement, then direction by trained people is necessary.



- ***Note the 'sophisticated' equipment used for setting-out the alignment.***
- ***Clearing the road alignment.***

- ***You do not need a (power) saw to fell a tree: just dig a hole and cut the roots.***
- ***To estimate tasks correctly, then a level bench is constructed by lateral excavation and filling. This slide shows slots being cut into the hillside at 20m intervals.***

- ***Using string lines to establish the finished level of the bench on the down-slope side.***
- ***Digging rectangular section of side drain. Note pegs, stringlines and people spread out. An excellent example of labour-intensive construction.***



- ***Digging side drain with forked hoe, an excellent tool if the material is stony. Not a good example of labour-intensive construction because of the absence of string lines.***
- ***Checking the finished side drain using a template.***

FURTHER READING

The student should refer to the following documents:

1 **ICIMOD** (1991): *Mountain Risk Engineering Handbook (Parts I and II) and Awareness Document*. (eds.) B.Deoja, M. Dhital. B. Thapa, A. Wagner. (International Centre for Integrated Mountain Development).

2 **Howell, J. H., J.E. Clark, C. J. Lawrance and I. Sunwar (**1991): *Vegetation structures for stabilising slopes: a manual for Nepal.* Department of Roads, His Majesty's Government of Nepal assisted by Overseas Development Administration, United Kingdom.

3 **Lawrance, C. J** (1992): *Notes on selected principles, techniques and projects concerning bioengineering in Nepal.* Transport Research Laboratory, Working Paper WP/OSC/288.

4 **UNDP/ILO** (1992): *A manual for environmental measures for Hill irrigation schemes in Nepal.* Kathmandu, July 1992.

3: EVOLUTION OF CONSTRUCTION TECHNOLOGY

Contents

1. Issues covered in this lecture

- Technology development
- Why was equipment introduced?
- Lessons of history
- Developing country experience
- Development and technology

TECHNOLOGY DEVELOPMENT

The use of labour as the primary construction resource is an ancient tradition. Almost every continent of the world is endowed with examples of engineering structures constructed almost entirely by hand. Some - such as the Pyramids of Egypt, the Great Wall of China, the structures of the Inca and Aztec civilisations of South America and, in Cambodia, the enormous temple complex of Angkor Wat - were built centuries ago, yet they endure today as proof of the quality of their engineering. The scale and technical complexity of some of these achievements, especially the precision of the hydraulic structures, demonstrates that labour-based methods are inherently capable of achieving the same quality standards as those based on the use of equipment across a wide range of civil engineering activities.

more recent events

More recently the spread of the industrial revolution, which had its birthplace in the UK and then Europe, was greatly facilitated by the development of a dense network of canals and railways, which were also constructed almost entirely by hand. It was only towards the end of the 19th century, with the building of the Manchester Ship Canal (1889-1894), that steam powered machinery was introduced into civil engineering construction in the UK. This was a vast undertaking involving 16,000 workers, more than 100 steam excavators, and countless wheelbarrows and spades. It required an ever-changing 350-km network of rail tracks laid along the 36-m wide bed, and over 53 million m^3 of excavation.

WHY WAS EQUIPMENT INTRODUCED?

It is notable that the process of labour displacement progressed fastest in the USA. Per capita income in the USA first exceeded that of the UK and Germany, the leading industrial nations until that time, about 1875 and thereafter steadily outpaced them. Despite its open door policy on emigration, until well into the 20th century labour in America was in short supply and expensive to employ. Real wages rose steadily as did output, but this was not accompanied by any significant increase in the capital-output ratio. The experience of the USA disproves a popular fallacy:

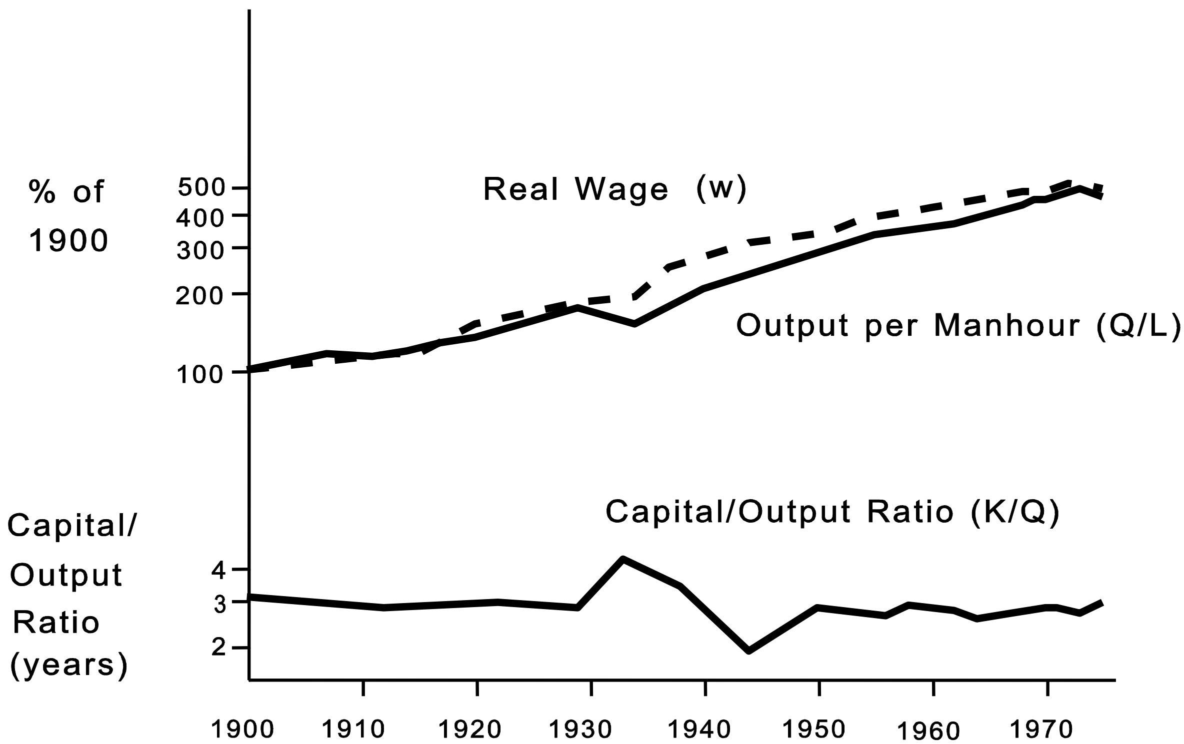
2. Key concept – machines replacing labour

Labour was displaced by machinery predominantly because it became scarce and thus expensive. Thus, the introduction of machinery was a consequence of economic advance, with the attendant increase in wages, rather than a cause of that progress.

It is a mistake to suppose that it was the use of machinery alone that enabled the USA to make such a rapid economic advance. In reality continuous technology advances and an optimum use of locally available resources was the stimulus to economic growth in developed countries. Constant and gradual productivity increases were achieved in this way and capacity was created in parallel with technical process. This illustrates the importance of using the optimal technology in a given set of circumstances. A wrong choice of the most capital or equipment-intensive technology may actually prove counter-productive in the current socio-economic development phase of many developing countries.

The basic trends in the USA during the last century, comparing wages and industrial output, are shown in the following graph:

3. Basic trends of USA development



USA private sector

There was another fundamental characteristic of the development of the UK and USA economies, which hastened the introduction of equipment. They were both dominated by the private sector and financed by commercial sources of capital. This made bank interest charges, and *thus speed* of construction, an important consideration. The predominance of large, centrally located projects and labour availability problems also seem likely to have influenced the introduction of equipment.

LESSONS OF HISTORY

The experience over 200 years of the USA, which has been one of the most outstanding examples of technological development, offers some instructive lessons for developing countries:

- The value for a country of having to rely on its own human and natural resources to survive and develop;
- The fact that nearly all big American industries started on a very small scale, often as one-man operations (e.g. Ford) and that the stimulus for innovation and growth came from within the organisation, not from outside; and

- The high rate of failure (over 90%) of US business enterprise.

DEVELOPING COUNTRY EXPERIENCE

A number of Asian countries, including most of the Indian subcontinent and Indonesia, have until recently experienced quite opposite patterns of civil engineering development. Stagnating real wages, especially in the rural sector, have kept construction linked to traditional labour-extensive practices. These practices encompass the organisation and management of work, working methods, and the tools and equipment used.

traditional labour-based working methods

Traditional working methods have been criticised as being of inherently low productivity, wages and thus motivation. While this is generally true, the methods have endured as a rational response to local resource capacity. In economies that have remained short of foreign capital with which to purchase equipment, but with abundant supplies of cheap labour it makes neither economic nor political sense to adopt equipment-based methods of working.

The type of conditions that have prevailed in developing countries is shown in the following diagram. It has been difficult to change these practices because of the absence of sustained efforts by governments and any real incentives for private industry

4. Traditional technology in developing countries

BEFORE

Technology in traditional labourbased countries

Indian experience

As early as 1955 the India Government had defined why the country should adopt civil engineering policies that would make use of as much labour as possible. These included the:

- Need to create employment, especially in rural areas;
- Need to stem the drain on foreign exchange resulting from equipment use; and
- Lack of skilled staff to operate, maintain and organise equipment-based operations.

Although some forty years later it is impossible to be sure, it seems no coincidence that these discussions took place in India, which was one of the first countries to experience both a high rate of population growth and a significant degree of landlessness. Today, with thirty per cent of its rural population without land, it has one of the highest proportions of landlessness in the world. It is not surprising therefore, that the Indian government was one of the first to set standards and specify methods of construction and maintenance of bituminous surfacing, especially surface dressing, are carried out by labour-based techniques, a practice that is rare outside the region. However, by continuing to rely on force account methods both productivity and quality of the operational techniques have made little progress and remain low.

African experience

Since attaining independence in the 1960s, the experience in Africa has been rather different than that of South Asia. The first decade of independence were boom years with rapidly expanding economies and road networks, which foreign aid agencies played a key facilitating role. The technology of road construction was often almost indistinguishable from that practised in the developed countries. It was essentially equipment-based, contractor-executed and consultant supervised.

highway construction in the 1960s

In the 1960s there was a strong wish by governments to establish the main highway networks as rapidly as possible. It was widely believed that this would accelerate economic and social development and thus provided some justification for this course of action. Moreover at this time, there were generally thought to be few alternatives in the technology that could or should be used. Governments had little influence on what construction process was adopted, although they were responsible for the maintenance of the new facilities. It was gradually realised in the 1960's that although appropriate transport facilities were the key to development, that investments in "transport affords unparalleled opportunity to make mistakes."

reliance on western construction technology

The reliance on western construction technology resulted in a decline in the use of labour-based methods that still existed in some countries. In Tanzania, for example, it was observed that much of the road network was developed at a time when labour-based methods were the major component of the Regional District Road Organisations. But since the 1960's there had been a drift towards an increased physical and psychological dependence on mechanical means of road maintenance, resulting in a decline in the management and control of the manual maintenance workers

impact of oil price increases

The problems of a heavy dependence on equipment became apparent within a few years of the first oil crisis in 1973-74, although it took the second oil price increase of 1979 to really confirm this. However, in adopting an increasingly equipment-based construction and maintenance technology in the 1950s and 1960s African countries were merely following the conventional development theories of the time in advocating the use of equipment rather than labour-based construction.

DEVELOPMENT AND TECHNOLOGY

In the 1950s and 1960s the growth of the Gross National Product was widely considered to be the primary goal in planning for the development of developing countries. Technology was discussed, if at all, mainly in terms of its contribution to this goal. Economists argued that capital-intensive techniques would lead to faster growth. This was because they were associated with a higher rate of investment surplus than relatively labour-intensive techniques. This is essentially the argument discussed below:

5. Key concept: cost of equipment operation

Underlying the widespread attempts to introduce capital-intensive technologies into civil construction was a fundamental misunderstanding of the real cost of operating equipment in developing countries and the factors conditioning its productivity

Whilst the emphasis on "investment surplus" was theoretically correct it overlooked a number of other implicit assumptions. The most important related to:

iii. The real cost to the country of investing in either equipment or labour, the tendency being to under-estimate the former and over- estimate the latter; and

iv. The exaggerated efficiency of investing in equipment in societies unskilled in their use and maintenance.

take-off theory

Another argument in the 1960's was that advanced countries had all passed the stage of "take-off into self-sustaining growth". Underdeveloped countries that were still in either the traditional society or the "pre-conditions" stage had only to follow a certain set of rules of development to take off in their turn into self-sustaining economic growth. These arguments were powerful to newly independent governments, particularly the promise of self-sustaining economic growth, and they altered policies accordingly.

For example, a common pre-occupation in the 1960's was with the need to increase food production. There was a manor emphasis on increasing the area under agricultural production and on the intensification of cultivation. This led to huge investments in the setting up of capital-intensive plantations.

misplaced faith in equipment

It was widely believed that such schemes could only be carried out using modern earthmoving machinery such as bulldozers, levellers, and mechanical shovels. There was strong theoretical and institutional support for the drive towards equipment, as the "modern" way of constructing and maintaining roads and other civil engineering infrastructure, and against the use of "backward" labour. The events of the 1970s and 1980s, with the dramatic deterioration of road networks in developing countries, were to show that the faith in equipment was misplaced.

appropriate local technological capacity

A fundamental oversight during the 1960-1980s was the need for developing an appropriate local technological capacity. Technology transfer was widely seen as a relatively straightforward and short-term process after which advanced equipment could be expected to function with the efficiency and at the utilisation levels associated with its country of origin. Underlying this believe was a misunderstanding of the real cost of operating equipment in developing countries and the factors conditioning its productivity. These factors will be examined in later lectures.

use of machines

The following concept summarises some of the basic issues raised in this lecture:

6. Key concept: use of machines

"Rich countries use machines because they are rich"

"They are not rich because they use machines"

FURTHER READING

The student should refer to the following documents:

1 **Francis, A.J.** (1988). *Appropriate engineering technology for developing countries.* (Research Publications)

2 **Schumacher, E.F.** (1963). *Small is beautiful: a study of economics as if people really mattered.* London, (Abacus Books).

3 **International Bank for Reconstruction and Development** (1974): *Study of the substitution of labor and equipment in civil construction. Phase II Final report.* Staff Working Paper No.172, International Bank for Reconstruction and Development. January 1974.3 volumes

4 **ILO** (1963): *Men move mountains: an account of a research project concerned with manual methods of earthmoving.* International Labour Office, Management Development and Productivity Mission to India.

7. Questions for students:

- *What are examples from your own experience of the traditional use of labour in construction?*
- *Why was equipment introduced in the USA in the 19th Century?*
- *What lessons might be learned from looking at technological development in the USA?*
- *What have been the problems with traditional working methods in developing countries?*
- *What was the impact of highway construction in the 1960s?*
- *What are the implications from looking at the real cost of equipment?*
- *What do you understand from the term appropriate local technological capacity?*

4: BASIC CONCEPTS OF LABOUR-BASED ROAD WORKS

Contents

1. Issues covered in this lecture

- Terminology and key concepts
- Substitution of labour for equipment
- Study conclusions on the choosing technology

TERMINOLOGY AND KEY CONCEPTS

The justification for current labour-based project and programme activities in the roads sector derives from extensive research and experimentation, especially in the early 1970s. An appreciation of the background to and outcome of this work is useful because it addressed two issues which were crucial to the establishment of labour-intensive roads works: namely their *technical* and their *economic* efficiency.

definition

To repeat the definition in previous lectures, labour-intensive road construction may be defined as:

"the economically efficient employment of as great a proportion of labour as is technically feasible, to produce as high a standard of road as demanded by the specification and allowed by the funding available".

In road construction, it is useful to think of the labour-intensive approach as the effective *substitution* of labour for equipment. The substitution of labour for equipment is carried out in such a way that there is neither an increase in economic cost nor a decrease in the quality of the required product. The question of whether labour can be technically and economically substituted for equipment is usually referred to in the literature as the 'choice of technology' issue and will be discussed in later lectures.

2. Key concept: Labour-intensive works

Labour-intensive work programmes aim at devoting as high a proportion of programme costs to unskilled and semi-skilled labour as possible without jeopardising the technical quality of the product demanded by the specification. Value-for-money is achieved by the intensive use of labour often using innovatory techniques of work and control

origins

The decision of India in 1955 to adopt civil engineering policies favouring the use of labour was of seminal importance because it triggered off a period of experimentation with labour-based methods. It began in 1962 with work-studies of earth moving undertaken in India by the ILO.

studies in Tanzania, India and Indonesia

In the late 1960s an important study was conducted in Tanzania, which revealed some of the problems and opportunities underlying the choice of technology issue in practice under African conditions. The study is important in indicating the over-confidence which the prevailed about the use of equipment-based methods in quite hostile conditions in remote rural areas. It also demonstrated that even without adequate training or experienced supervision labour-based substitution was able to achieve comparable performance.

Formal experimental studies in the road sector first took place in 1972 in India and Indonesia in the context of the World Bank's *"Study of the substitution of labour and equipment in civil construction"* which was initiated in 1971. The ILO studies comprised a mixture of desk and fieldwork involving technical experiments with labour and equipment.

opportunities in the road sector

The road sector was thus at the forefront of the employment and choice of civil engineering technology debate. Indeed early in this debate civil engineering in general was identified as one of the industries which entailed the employment of a significant proportion of a country's work force and was, therefore, worthy of attention to investigate its employment potential. About 70% of public works in developing countries is devoted to civil works projects, and 50 to 60% of most countries' capital formation is in construction: houses, hospitals, schools, power-stations, roads, railways, dams, and ports. The amount of labour used on construction sites tends to be greater per unit of investment in poorer countries. However, the actual level of employment, as a proportion of population, rises as one moves from the poorest to the richest countries, as the following table illustrates:

3. Employment in construction related to income

Gross national product per capita	*Employment in construction (per 1 000)*
$ 500	4 to 7
$ 1 000 - $ 2 000	23
+ $ 2 000	28

The importance of the civil engineering industry as an employer of large numbers of people does not address the question as to whether it could employ more people other than via the expansion of the economy as a whole. After all, the industry is already labour-intensive by comparison with, say, the petrochemical industry. But the employment potential of the civil engineering industry invited attention to a possibility of *the reverse substitution of labour for equipment.*

SUBSTITUTION OF LABOUR FOR EQUIPMENT

In 1971 the World Bank initiated a research programme into the substitution of labour for equipment in road construction. Answers were sought to two main questions:

- Under what circumstances, and for what operations, is it *technically feasible to* substitute labour for equipment?
- Under what circumstances is it *economically feasible to* substitute labour for equipment?

The research work was conducted in three phases. The first phases, of the study confirmed the *technical feasibility* of the substitution of labour for equipment for a wide range of construction activities. Together these represented 80-90% of the direct costs in the case of surfaced roads, and 85-98% of the direct costs in the case of unsurfaced roads.

> **4. Key concept: technical feasibility of substituting labour for equipment**
>
> It is *technically feasible* to substitute labour for equipment for 80 - 90% of the direct costs in the case of surfaced roads, and 85 - 98% of the direct costs, in the case of unsurfaced.

However, economic feasibility, which depends on relative prices and productivity, could not be assessed because of a lack of adequate information on the productivity of labour under different conditions. A series of detailed and careful investigations were therefore made into all aspects of road construction - especially the excavation haulage and placement operations which normally dominate costs - and the technical advantages and disadvantages of both labour and equipment were clearly identified. Main findings were as follows:

lack of intermediate techniques

(a) Techniques currently in use in civil construction were either highly labour intensive or highly equipment-intensive; no significant "intermediate" techniques are practised. Where attempts have been made to combine traditional labour-intensive methods with modern equipment operations, the resulting "mixed" method obtains such inefficient use of the equipment that it requires even more capital than a fully equipment-intensive operation.

not economically competitive

(b) Traditional labour-intensive techniques currently in use were not economically competitive with modern capital-intensive techniques, even in labour abundant economies, when labour is 'shadow priced' (this means that actual wages are reduced to represent their economic value) at a fraction of market wages. This is because (i) existing labour-intensive techniques are employed in an atmosphere where the emphasis is on employment creation rather than efficient use of labour, and (ii) the methods used are primitive and do not use technology effectively, if at all. These factors result in extremely low labour productivity.

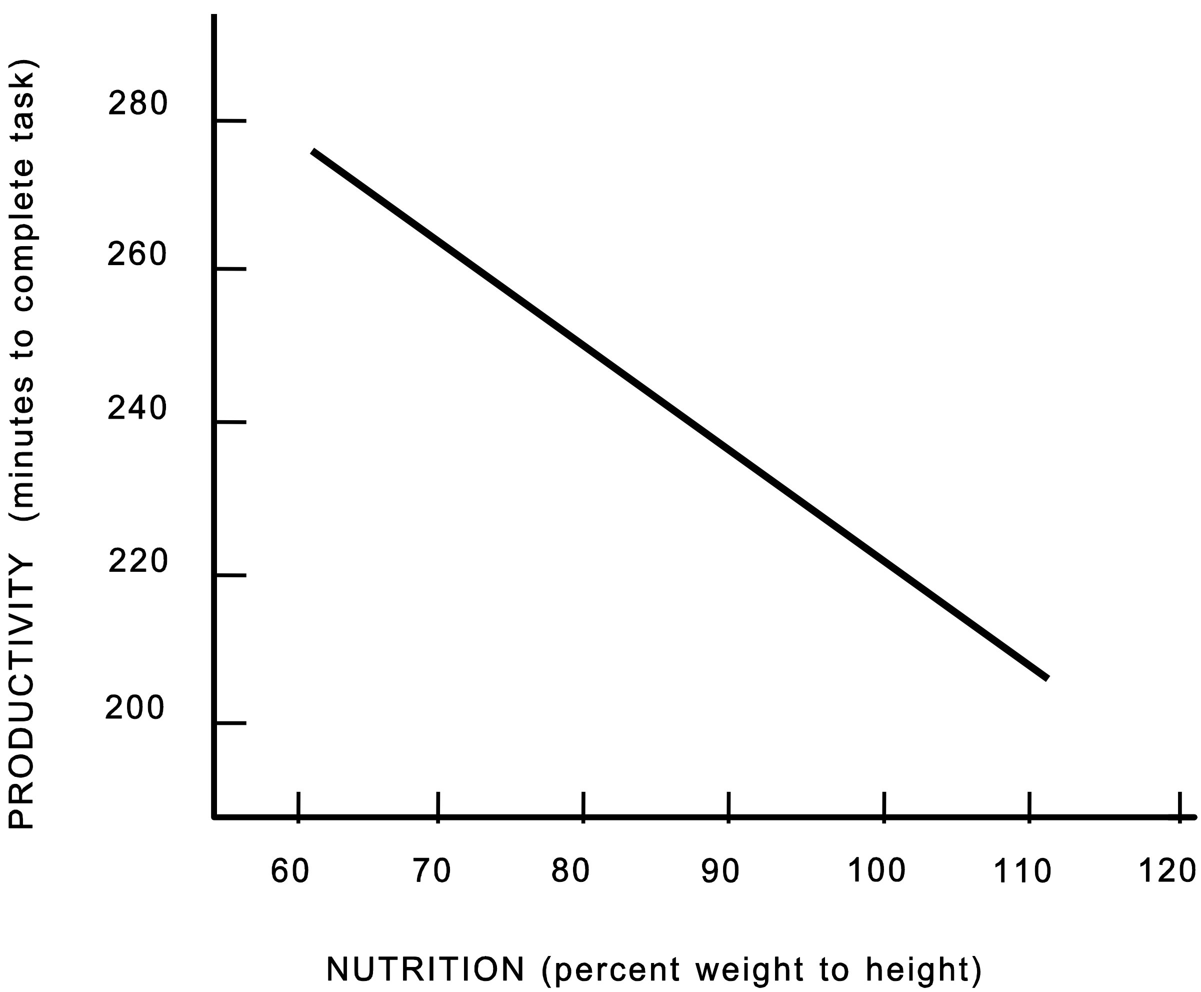
lack of appropriate management skills

(c) Management and supervision of a large labour force requires special skills, experience and organisation, quite different from those in equipment-intensive operations. Labour-intensive methods should not be attempted without careful advance planning, organisation and training, particularly in regions where these methods have not been commonly practised.

labour shortages (d) Even in countries with labour abundance there are frequently shortages of labour at different times and places. Indeed, the social cost ('shadow value') of labour varies widely in space and time. Unless construction authorities are prepared to pay higher wages during peak periods (e.g. the harvesting season), projects may suffer costly interruptions. Using 'shadow value' correction of market prices becomes a complicated issue and the application of a single norm could lead to harmful results.

health and nutrition (e) Health and nutrition standards have a significant impact on productivity of the labour force. For example, anaemia, induced by a combination of parasitic infestation and dietary deficiency, has been shown to be widespread and often severe among male construction workers. Experiments suggest improved nutrition programmes can have a significant impact on labour productivity in such cases. The following graph illustrates this point.

5. Nutrition Impact on Workforce (Indonesia)



STUDY CONCLUSIONS

Finding (a), (c) and (e) supported those from the earlier ILO studies. However, the most important conclusion was that traditional, labour-based methods were not competitive with modern equipment. The construction technology had stagnated. It neither used appropriate equipment when quality considerations dictated it, nor did it make the best use of labour.

There was, however, an important qualification. Modified labour-intensive methods would become economically competitive if labour production increased roughly three-times or more relative to the equipment prices and wage levels. It was also recognised that these changes could not be expected to come about without outside intervention:

> **6. Key concept: market forces**
>
> *"Market forces, as they operate in practice, are not likely to lead to improvements in countries where strong interest groups have already grown up behind existing practices".*

This statement has proved to be correct. The Indian sub-continent remains an area where petty contractors under the nominal supervision of government engineers primarily execute roadwork. Working practices have remained primitive, especially in rural areas, because of the difficulty of changing vested interests.

choice of "inappropriate" technology

Three main factors can be identified as having a decisive influence on the choice of inappropriate technology.

- Current construction technology may be so rigid that optimal methods are still highly equipment-intensive despite the presence of abundant cheap labour;
- Distortions in market prices may tend to overstate the true cost of labour (i.e. this is really the "scarcity value" of labour) where there is a labour surplus and understate the cost of equipment; or
- The institutional framework within which such decisions are taken is inefficient and either overlooks or ignores the relative costs of the different methods.

technological development

The dominance of the first factor is attributed to the fact that global technological development does not move in the direction of technology more suited to labour abundant economies. In fact it is quite the reverse and there seems, increasingly to be a labour-saving bias in technological change, whether in high-tech industries or the agricultural sector. A notable omission observed in the World Bank studies were intermediate technologies offering improved efficiency over fully manual methods, but with more flexibility to accommodate higher labour inputs than conventional equipment.

market prices

Important examples of distortions in market prices affecting the choice of civil engineering technology are the prices of skilled and unskilled labour, capital, inputs purchased with foreign exchange, and inputs subject to taxation.

7. Key concept: distortions in costs

Private contractors and government agencies may normally be expected to base their decisions concerning the choice of technology on market prices. Thus, where the market inflates the true cost of labour and deflates the true cost of equipment, the result must be choice of more equipment-intensive technology than is economically desirable.

institutional rigidities

Institutional rigidities may be more important than relative prices in determining the choice between labour and equipment. In particular where, as is often the case, the public sector is both the major demander and supplier of construction services it is in a position not only to define design and quality standards of output, but also to set the pattern of technology. Often tendered contracts are let on the basis of prices and quantities of inputs organised in a specified fashion guided by traditional practices. Both the client and the contractor may be reluctant to risk using techniques not proven by experience. With this type of industry structure innovation does not come rapidly and traditional methods are not likely to respond to even major changes in prices.

overall conclusions

Several practical obstacles can be identified to the assumption that appropriate technology would emerge if decision-makers could be presented with prices reflecting the scarcity cost of the resources used. The main measures recommended to influence choice of technology are:

- Improvements in the productivity of labour by improved management and incentive pricing schemes; and
- Development of improved intermediate technologies.

FURTHER READING

The student should refer to the following documents:

1 **Edmonds, G. A.** (1979): *The Construction Industry in Developing Countries.* International Labour Review (Geneva: ILO, May-June).

2 **Edmonds G. A. and D. Miles** (I 984): *Foundations for Change. Aspects of the construction industry in developing countries.* London, (Intermediate Technology Publications).

3 **G.A. Edmonds and J.D.F.G. Howe**, editors. (1980) *Roads and Resources: Appropriate Technology in Road Construction in Developing Countries*. London, (Intermediate Technology Publications).

4 **ILO** (1963): *Men who move mountains: an account of a research project concerned with manual methods of earthmoving.* ILO, Management Development and Productivity Mission to India, 1963.

5 **Lal, D.** (1978): Men or machines: *a study of labour-capital substitution in road construction in the Philippines.* Geneva, (ILO).

6 **Müller, J.** (1970): *Labour-intensive methods in low-cost road construction: a case study.* International Labour Review. Vol. 101, No.4. pages 359-375.

7 **McCleary, W.A.** (I976): *Equipment versus employment: a social cost-benefit analysis of alternative techniques of feeder road construction in Thailand.* (International Labour Office).

8 **McCutcheon, R.M.** (*1995): Employment Creation in Public Works: Labour-Intensive Construction in Sub-Saharan Africa; the implications for South Africa;* Habitat International.

9 **Rieger, H. C. and B. Bhadra** (I *978): Comparative evaluation of road construction in Nepal.* Centre for Economic Development and Administration, University, Kathmandu, Nepal.

6. Questions for students:

- *What do you understand by the term "labour-intensive" works?*
- *Why has the use of equipment in developing countries often been "over-optimistic"?*
- *What is the general trend in employment with increases in personal income?*
- *What are the two main questions to consider in substituting labour for equipment?*
- *What kind of factors might prevent labour substitution occurring?*
- *Are market forces likely to help or hinder the promotion of labour-based technology?*

5: DETAILED ASPECTS OF USING LABOUR FOR ROADWORKS

Contents

1. Issues covered in this lecture

- Principles of labour substitution
- Suitability for substitution of civil works construction
- Labour standards and labour-based roadworks
- An overview of the labour supply
- A case study of employment in Cambodia

PRINCIPLES OF LABOUR SUBSTITUTION

The feasibility of substituting labour for equipment was analysed by ILO in 1973 working in parallel with the World Bank. Two categories of technological development were identified:

- Where the substitution of equipment for labour had been essential; and
- Where it had not been essential.

In the former case it would not be feasible to carry out the reverse substitution of labour for equipment; in the latter it would be possible.

essential substitution of equipment

Essential substitution of equipment for labour, and thus the inapplicability of reverse substitution, would result from any of the following conditions:

- Creation of a totally new product by an industrial complex, e.g. the plastics industry, bio-engineering, or chemical transformation;
- Where the system of machinery was such that:
- It was more accurate than was ever achieved before;
- It resulted in no manual transportation being required from one part of the process to another, i.e. no breaks in continuity; and
- A complete product resulted from the new process.
- Plant costs per unit of output decreased with output.

reverse substitution of equipment

By comparison, reverse substitution of labour for equipment would be technically feasible if the industry still involved:

- A product produced by machines that were essentially a more or less altered edition of an old handicraft tool;
- A product still produced by the mere mechanical fitting together of partial products.

2. Key concept: reverse substitution

Reverse substitution of labour for equipment would be technically feasible if the industrial process involves a product produced by machines which were essentially a more or less altered edition of an old handicraft tool, or a product still produced by the mere mechanical fitting together of partial products.

SUITABILITY FOR SUBSTITUTION OF CIVIL WORKS

Looked at from this perspective civil construction was promising: the products were time honoured and mostly individual, the machines were magnified versions of simple handtools, and the production

CONSTRUCTION

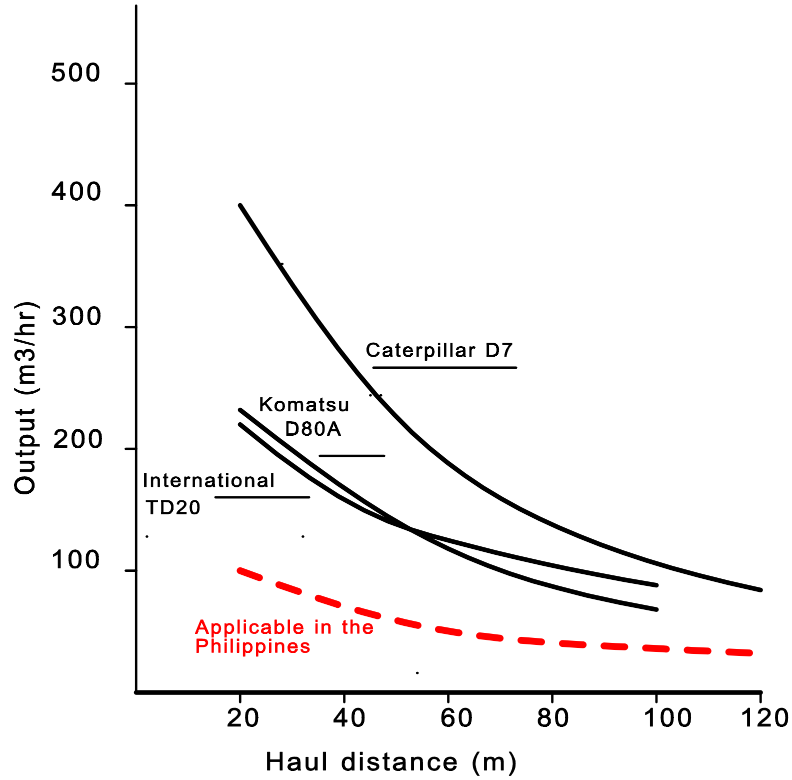
were magnified versions of simple handtools, and the production process was littered with possibilities for delay and breaks in continuity. Earthworks (excavation, loading, haulage, unloading and spreading) were particularly interesting and accounted for up to 50% of expenditure on civil construction. Other promising avenues for exploration included production of aggregates and pavement construction. There seemed to be a basis for the technical feasibility of the reverse substitution of labour for equipment in civil construction in general.

Thus by careful modification of existing techniques it may by possible to so increase the productivity of labour so that it is as cheap to use labour-intensive as the equivalent capital-intensive methods.

productivity of labour and equipment

There are two aspects to the choice of technology issue: the productivity of labour and that of equipment. During the early years, the onus was on those who suggested that labour might compete with equipment to prove that labour was not as incompetent as it seemed from observing activities in countries where labour use was traditionally inefficient. .

3. Equipment performance



Comparison of recommended and actual machine output in the Philippines

datum for comparison

The "datum" for comparison was always assumed to be the outputs obtained from highly efficient equipment. But during the mid-1970s it became increasingly clear that these were rarely obtained in developing countries. The output achieved by new equipment over a short period of time was definitely greater than could be achieved by a poorly organised group of labourers using low quality tools and inappropriate techniques. However, in most developing countries the average output achieved by equipment over a long period of time was not so impressive, especially when compared with well-organised and equipped labour. The previous graph demonstrates this point.

equipment productivity and utilisation

The degree to which equipment was not able to realise the levels of output claimed by the manufacturers, varied from the World Bank's assessment for bulldozers of 25% of the productivity quoted by equipment manufacturers down to 5% productivity (and less) observed in some instances. It was also realised that there was a complicated set of factors which limited the productivity and utilisation (and thus the productivity) of equipment. These factors included procurement procedures, foreign exchange (affecting the timely availability of fuel and spares), mechanics, workshops, trained operators, and efficient planning and management. Under "normal" conditions in many developing countries the actual productivity's achieved using equipment for road construction are so poor that they are outclassed by well-organised labour-intensive methods. The smaller the operation and the more remote its location, the greater the advantage of labour over equipment.

4. Key concept: comparative productivity

Under normal conditions throughout many developing countries the actual productivity's achieved using equipment for road construction are so poor that they are outclassed by well-organised labour-intensive methods. The smaller the operation and the more remote its location, the greater the advantage of labour over equipment.

'break even' wage rates

The economic feasibility of labour-intensive methods depends on the 'break even' wage rates. The break-even cost is the amount at which the cost of performing a task by manual labour equals the cost of performing the same task by equipment. Daily wage rates are the largest element in determining cost of a labour-based operation. Thus, wage rates are a convenient yardstick for early assessment of relative cost-effectiveness of labour, compared with equipment.

result of World Bank and ILO studies

In 1984 extensive studies and test work carried out by the World Bank and the ILO concluded that:

- In countries with minimum wage levels of up to US$ 2 per day, suitable types of civil works should be executed by labour-intensive work methods, unless there are specific reasons against it (non-availability of required labour force in the project area);
- Where the minimum wage ranges between US$ 2-4per day, use of unskilled labour should be conscientiously considered; and
- With minimum wages slightly above US$ 4 per day, the appropriate mix of labour and equipment may still tend towards labour-intensive use under certain circumstances (for example in the case of construction work involving small quantities in remote areas).

recent changes in costs

In 1994, a decade later, equipment and transport prices more than doubled in US$ terms for most developing countries, while labour wages generally decreased. This implies that the wage level thresholds mentioned above could also be significantly increased, making labour-based approaches a potentially viable option (provided that there are labour surpluses in the project areas) in developing countries with wage rates below US$ 4.00 per day. Similarly, serious consideration should be given to employment-intensive construction and maintenance alternatives when wage rates fluctuate between US$ 4.00 to US$ 8.00 per day. However, they need to be applied with caution since they clearly vary with local circumstance, the activity and task, and the type of programmes or projects.

linking of payment to production

Since the early emphasis on wage levels more fundamental concepts that govern the successful use of labour-based methods have been established – in particular the linking of payment to production. This implies that workers will only be paid on the completion of a given task, or per unit of actual production, and not just per day employed. The concept established is that conditions of employment are linked to production rather than duration. Workers do *not* become permanent and pensionable employees after 3-6 months. Often this is contrived by an enforced break in employment of a day, after so many days, so that the succeeding work period is a "new" contract.

5. Key concept: linking payment and productivity

For the successful use of labour-based methods it is essential that payment and conditions of employment be linked to production and not the duration to work.

LABOUR STANDARDS AND LABOUR-BASED ROAD WORKS

The use of labour-based technologies is a recognised strategy for creating job opportunities in areas with high rates of unemployment and underemployment. However, the jobs created are normally of a temporary nature and most are employed as casual workers. Often this is the first formal employment they have encountered.

casual workers

Casual workers are rarely represented in workers associations or aware of their rights under labour laws. This makes them particularly vulnerable to exploitation. As for any type of work, labour-based road works must be executed under terms consistent with national labour legislation. It is, therefore, important that public sector managers and private employers trained to plan and manage labour-based works and, consequently, likely to be engaged in recruiting and employing workforce, have some basic knowledge in this area.

Casual workers on labour-based road projects are normally paid according to the minimum wage legislation of the country concerned. This applies also in the case of payment by result since the wage fixed for the task may be equal or 'higher than the basic payment and the bonus is either in the form of cash or free time. When determining the wage rate for casual workers on road works there are several issues to be considered in addition to the wage legislation:

6. Determining wage rates

- Labour-based road projects often create additional job opportunities and cash income. It is essential, therefore, that they do not compete with and extract workers from traditional economic activities in the area
- Wages represent some 40-60% of the total project costs, and evidently, determine the economic feasibility of using labour-based methods.
- It is important that wages are high enough to attract workers and to ensure satisfactory productivity rates. Unless workers are paid correctly and on time working morale will deteriorate quickly.

economic arguments for respecting national laws

Apart from protecting human and workers' rights, there are also economic arguments for respecting national laws. Workers who are treated fairly are likely to develop a sense of loyalty with the employer; consequently, their motivation and productivity is likely to rise. In this respect, it is essential that the terms of employment are fully explained to the workers, and it is preferable- that they be provided with a personal employment form.

worker exploitation

The risk of worker exploitation may be higher when private contractors execute labour-based works. It is, therefore, essential that labour issues are dealt with in contractor training programmes and that the contract includes clauses on relevant labour standards and, not least important, is properly monitored by the client. The contract should also have a clause saying that if the contractor does not respect national labour legislation, the contract can be terminated and the licence to bid cancelled.

national laws and regulations

When planning labour-based activities the Ministry of Labour should be consulted on national laws and regulations. Liaison with the Ministry should also be sought as advisors during execution of works and officials from the Ministry should be invited to training courses to talk about and discuss labour issues.

international labour standards

The ILO has developed a system of International Labour Standards, which takes the form of Conventions and Recommendations. The Conventions are open to ratification by the member countries. Once ratified, a Convention is binding, for the country. Recommendations, on the contrary, set non-binding guidelines to orient national policy and practice.

There are two main groups of International Labour Standards: *basic human rights standards* such as prohibition of forced and child labour, freedom of association, equality of opportunity, and treatment that in no way can be violated; and *technical standards that* can only be promoted. There are six areas of International Labour Standards that are of particular relevance to the implementation of labour-based infrastructure work:

7. ILO Conventions

- Forced Labour
- Equality of Opportunity and Treatment
- Freedom of Association
- Child Labour
- Wages
- Social Security

Further details on these conventions are provided in the attachment to this lecture.

AN OVERVIEW OF LABOUR SUPPLY

As assessment is needed as part of the design process of labour availability for setting the wage rate and examining the implications of a minimum wage rate. The aim of the overview (carried out as a part of preliminary investigations for a project) is to determine whether a detailed assessment of labour supply issues is required and the nature of the detailed assessment.

8. Checklist of tasks to determine labour availability

1. Obtain broad understanding of rural economic activities and employment opportunities from discussions with local agricultural officers, planning officials and village leader.
2. Make an assessment of labour availability to determine whether a more detailed study is required including investigating other sources for off-farm work.
3. If the project wage rate can be set independently of other wage rates, study wage rates in comparable activities to recommend appropriate wage rate and state if a more detailed study is required
4. If a statutory minimum wage must be paid, examine implications for project cost
5. State whether a more detailed study is required and set out the issues to be studied

overall assessment

An overview carried out on these lines will usually conclude by stating whether a more detailed assessment of labour availability and related issues is needed. If a more detailed study is needed, the particular issues should be clearly set out. The following are typical issues for more detailed consideration though there may be other issues peculiar to a particular situation:

- Assessing labour availability throughout the year and seasonally taking account of the size of the local labour force as well as assessing alternative employment opportunities and tradition of off-farm employment;
- Setting project wage rate taking account of prevailing rates;
- Considering the effects of the project being constrained to pay the statutory minimum wage rate;
- Assessing the effect on other economic activities of project employment, and

- Determining whether a socio-economic survey is required

A CASE STUDY OF EMPLOYMENT IN CAMBODIA

In 2000 a field study was carried out among 109 road construction and maintenance workers in Siem Reap province. The ILO-sponsored study aimed to estimate the impact of wage earnings from labour based rural infrastructure works on employees and their families.

scope of the study

57% of the workers interviewed were male, 43% were female. Most were rural farmers who were busy on their farms during the rainy season, but have difficulty finding other income opportunities during the dry season. There are almost no other income opportunities available in rural areas and it is especially difficult for women to find off-farm employment. Rural road construction and maintenance works like those sponsored by the ILO Upstream Project, are one of the few wage earning possibilities with equal opportunity and equal pay for men and women. For rural farmers, labour-based works can fill an important need for extra income, especially during the dry season.

recruitment

Local small-scale contractors carried out the infrastructure works. Site supervisors play a major role in the recruitment and direct management of workers. Most workers heard about the job opportunity through neighbours and friends who knew one of the supervisors (58%). The supervisor directly recruited another 20% of workers. 14% heard about the work exclusively through public announcements and 7% through village meetings. This indicates the importance of connections in recruitment. A lottery system was not used for selection. Most workers were between 17 and 25 years old (64%), reflecting the emphasis on young, strong people in the selection process.

income groups

A majority of 54% of the workers interviewed belonged to poor families, 30% belonged to slightly better off families and 16 percent to the poorest families. Factors that may limit opportunities for the poorest to gain employment are not knowing the supervisor and the high family member dependency ratio among this group. The study found a dependency ratio of 1.04 for the poorest workers, against 0.34 for the better-off workers. Labour based construction works are likely to attract workers from households with relatively more productive household members and these are mainly the poor and better-off groups.

wage labour and voluntary labour

The study concluded, from workers' interviews, that development approaches insisting upon voluntary labour in Siem Reap Province often encourage forced labour. Forced labour further limited the poorest families' opportunities to gain wage income, as they had to contribute labour to the village chief for communal works. Most workers felt very negative about contributing labour under these conditions.

working conditions The present working conditions under contractors were compared with the previous government direct implementation system. Many workers felt that working conditions were harder and working times stricter under contractors. (Direct implementation refers to the previous system, where infrastructure works were carried out by the public sector and not by local contractors). However, there were few complaints about current working conditions or payment. A majority of 51% preferred payment in cash, 44% preferred payment in cash and kind or entirely in kind. Cash payment was preferred because cash is easier to carry than rice or because of negative experiences with payment in kind. Workers who preferred payment in kind mostly lived far from a market and needed rice. Several workers indicated a preference for payment in kind to avoid the temptation to spend the income on entertainment.

use of earnings In all cases the wages earned were handed over to the wife or the female head of household. This money was pooled with other incomes. Wages were mostly spent on basic items, firstly food, secondly clothing, thirdly medicine and fourthly on education. Food was an important expenditure for all wealth groups. The poorest were more likely to buy basic food items like rice, salt, oil and fish paste, whereas the better off buy more nutritious food like fish and meat. Spending on medicines was ranked second by the poorest, whereas the better off spent very little on medicines. This reflects their better health compared with the poorest and is probably related to their more nutritious food intake. Debt repayment was an important spending for the poor. The most important difference between men and women is revealed by the third priority expenditure - debt repayment for men and medicines for women. This suggests that women are mainly in charge of health care spending, while men are responsible for debt repayment.

Little salary remained for productive investment. Only the better off seemed to use the income in a more productive manner, as their fourth expenditure was on farm tools. However, the fact that the incomes were mainly spent on food demonstrates the importance of extra income for the survival of poor rural farmers in Siem Reap province during the dry season.

FURTHER READING

The student should refer to the following documents:

1 **Miller, S. K.** (1992): *Remuneration systems for labour-intensive investments: Lessons for equity and growth;* International Labour Review, Vol. 13 1, No. 1, pp 77- 93.

2 **Vaidya, K. G.** (1983): *Guide to the assessment of rural labour supply for labour-based construction projects;* CTP 21, World Employment Programme, ILO Geneva

3 **Vaidya, K. G. and Sarma, M.T.R.** (1983): *Assessment of labour availability in the Lao People's Republic,* CTP 28, World Employment Programme, ILO Geneva.

4 **Vaidya, K. G.** (1987): *Labour-based road construction and maintenance in the Lao People's Democratic Republic: assessment of labour supply and project cost evaluation;* CTP 72, World Employment Programme, ILO Geneva.

5 **Zweers, J. and A. Kassie** (2000). *Employment in ILO Supported Road Construction and Maintenance: The Impact of Wage Earnings on Workers.* Socio-Economic Series No. 2. ILO Upstream Project/Ministry of Rural Development, Phnom Penh.

9. Questions for students:

- *Under what technical conditions is reverse labour substitution desirable?*
- *What used to be the comparative "datum" for judging whether labour substitution was viable?*
- *What are the likely wage rates at which the application of LBT is likely to be economically feasible?*
- *Why is the linking payment and productivity important?*
- *Why is it necessary to understand national labour laws?*
- *What are the essential features of the ILO Convention on Discrimination related to gender?*
- *What is the purpose of undertaking an assessment of labour availability?*
- *What were the main uses of income earned from working on projects in Cambodia?*

ATTACHMENT – ILO CONVENTIONS

FORCED LABOUR

There are two relevant Conventions, the *"Forced Labour Convention, 1930 (No 29)* " and *"Abolition of Forced Labour Convention, 1957 (No 105)*". The first Convention defines forced labour as "all work that is exacted under the menace of a penalty and for which a person has not offered himself voluntarily". Among the five types of compulsory work to which this Convention does not apply, subject to specified conditions and guarantees, are minor communal services, certain civic obligations and emergency work. The second Convention is supplementary to the first and prohibits the use of forced or compulsory labour in five specific cases. One of these is relevant to labour-based infrastructure works as it relates to mobilising labour for purposes of economic development.

An issue that deserves attention is the use of unpaid labour as a self-help contribution. Only in special cases is this approach in line with the Conventions on forced labour. This is, for example, when a community identifies road improvement and maintenance as a top priority and applies for external assistance (for supervision, construction materials, tools) to complement the labour mobilised for this purpose. In most other cases the use of unpaid labour for road works goes against the spirit of the forced labour Conventions. It should be noted in respect of works carried out by unpaid labour, that such works tend to be inefficient, have high overhead costs and inferior quality results.

EQUALITY OF OPPORTUNITY AND TREATMENT

The main Conventions are the *"Equal Remuneration Convention, 1951 (No 100)*" and the *"Discrimination (Employment and Occupation) Convention, 1958 (No 111)* ". The first lays down the principle of equal pay for men and women for work of equal value. It is important to note that this principle goes beyond equal pay for men and women doing the same job; it means that men and women who do jobs which have the same value - whether the same or not should be equally paid.

The second deals with hiring and access to vocational training, prohibits any exclusion, distinction or preference based on race, colour, sex, religion, political opinion, national extraction or social origin. Employment decisions based on inherent job requirements and measures aimed to remedy discrimination, often called "positive discrimination" are, however, not considered as discrimination.

In recruitment of the workforce for labour-based work, it is important to avoid accusations of corruption or favouritism if there are more job seekers than required which is often the case, one must proceed with a selection process which is generally felt to be fair. A recommended recruitment system that has been tried out in several countries is to arrange a secret ballot.

Participation of women on labour-based road projects depends largely on the area in which the works take place and tends to range between ten to thirty per cent. Some projects set a minimum target for female participation. The basic requirement in any case is that women are given equal opportunity to apply for a job and that they are not discriminated against in the selection process.

FREEDOM OF ASSOCIATION

The relevant Conventions here are the *"Freedom of Association and Protection of the Right to Organise Convention, 1948 (No 87)*", *the "Right to Organise and Collective Bargaining Convention, 1949 (No 98)* ' and the *"Rural Workers' Organisation Convention, 1975 (No 141)*". These Conventions cover right to organise; protection of workers exercising this right; non-interference by workers' and employers' organisations in each other's affairs; promotion of voluntary collective bargaining; and freedom of association for rural workers and encouragement of rural workers to organise and participate in economic and social development.

CHILD LABOUR

The "Minimum Age Convention, 1973 (No 138) " specifies the minimum age for admission to employment shall not be less then the age of completion of compulsory schooling; normally not less than 15 years. Developing countries may, however, specify a minimum age of 14 years. For any work that is likely to jeopardise the health, safety or morals of young persons, the minimum -age is set to 18 years - or 16 under certain circumstances. For light work, the minimum age can be set to 13 or 12 in developing countries.

WAGES

Two Conventions are relevant: *"Labour Clauses (Public Contracts) Convention, 1949 (No 94)* " and *"Protection of Wages Convention, 1949 (No 95)"*. The first applies to contracts involving public funds that are awarded by a central public authority to another party that employs workers. Such contracts must contain clauses which ensure that the workers' wages, hours of works and other work conditions are not less favourable than those established for work of the same character by national legislation, collective agreements, or the general level in the trade or industry concerned

The second Convention protects workers against excessively low wages by the requirement to establish a system of minimum wages. The wage level should take into account the needs (basically food, shelter, clothing) of the workers and their families. Part of the wage may be paid in kind, usually in the form of food rations. This can be a powerful incentive in areas with a shortage of basic consumer goods and high inflation rates. According to a policy agreement between ILO and the World Food Programme, food rations should not be more than 50 per cent of the total wage. The cash portion should be not less than 50 per cent of the wage prevailing in the area or the applicable minimum wage for particular work. The payment can, however, be wholly in food in cases where the workers are the direct beneficiaries of the work, for example on self-help schemes.

SOCIAL SECURITY

The *"Social Security (Minimum Standards) Convention, 1952 (No 102) "* aims to establish minimum levels of security benefits. It covers nine branches that can constitute a complete social security scheme: medical care, sickness, unemployment, old age, employment injury, family, maternity, invalidity and survivors' benefits. In view of the nature of labour-based roadwork, the medical care, sickness and employment injury branches appear to be the most relevant.

Social security protection arises mainly in the case of casual workers as other categories are usually covered by general social security schemes. It is sometimes difficult to extend coverage to workers who are employed on a temporary basis and whose remuneration may be paid wholly in kind or who work voluntarily without receiving any payment at all. In such cases it may be necessary to consider the possibility of establishing a solidarity fund to provide satisfactory insurance coverage. In the case of private sector execution, the contractor is normally obliged through the contract to pay an insurance to cover any accident or injury to the workforce.

It is also important to take preventive measures to reduce the risk of injury. Arrangements to be made for this purpose would include: information to workers about hazards, safety training of supervisory staff, provision of protective clothing, use of good quality and ergonomic hand tools and equipment, etc.

6: PRINCIPLES OF ROAD MAINTENANCE

Contents

1. Issues covered in this lecture

- Purpose of road maintenance
- Basic causes of deterioration of roads
- Maintenance systems
- Contracting methods used in labour-based maintenance

PURPOSE OF ROAD MAINTENANCE

The three main purposes of road maintenance are to:

- Prolong road life and postpone the day when renewal will be required
- Reduce the costs of operating vehicles on roads; and
- Keep roads open and enable greater regularity, punctuality and safety of road transport services.

Management of road maintenance operations is a complex and demanding undertaking for responsible road authorities. Both the engineer and maintenance contractor must be fully aware of the basic maintenance management techniques and the reasons behind them. Fundamental to this understanding how roads deteriorate, before it is possible to set up proper maintenance systems and establish an effective maintenance management process.

BASIC CAUSES OF DETERIORATION OF ROADS

There may be many reasons why roads deteriorate and it is necessary go through a series of logical steps to diagnose the problem. Once it is known why a road, or part of the road, deteriorates, it will be much easier to apply the correct measures to repair it.

example of maintenance problem

For example, suppose a culvert outlet always silts up after heavy rainfall. If the cause is not investigated of this frequent silting up, or diagnosed wrongly, it may need labour after every storm to clean out the drain. This is very costly and wasteful. By understanding the principles of road drainage, it may be possible to carry out a few investigations and find out that this culvert outlet has a gradient of only 0.5 per cent although it would be possible to have a gradient of 3 per cent. The correction of this gradient would initially cost the equivalent of 4 workdays, but afterwards would result in it hardly ever needing to be cleaned and a substantial amount of working time would result.

deterioration mechanisms

What does deterioration and failure of roads actually mean? Deterioration of roads is the worsening of roads over a period of time due to a variety of causes. Deterioration leads to defects of the road structure. The three main mechanisms for degradation are:

2. main mechanisms for degradation

- Degradation of carriageway (rutting and potholes)
- Silting of the drainage system
- Erosion of the drainage system

The main causes of deterioration can be summarised as follows:

- Rainfall
- Steep gradients
- Flat gradients
- Traffic
- Pavement construction
- Vegetation.

Each factor does not affects different parts of the road structure in the same way:

3. How deterioration effects the road structure

- Rutting, potholes and deformation of the carriageway is mainly caused by traffic.
- Steep gradients and rainfall mainly cause loss of gravel.
- Rainfall, steep gradients and a lack of vegetation cause erosion of the drainage system.
- Silting of the drainage system is also caused by rainfall, flat gradients, and to some extent, by vegetation.

The first two factors affect the carriageway and the second two the drainage system. So it is possible in the planning of maintenance to separate carriageway maintenance from the maintenance of drains.

failure of roads

Failure of roads occurs if one of the major construction parts of the road structure does not function; it can then be defined as an occurrence that leaves the road impassable, or at least defective. The main mechanisms of failure that can happen to a road are:

- Total failure of a section of pavement;
- Erosion of the shoulder extending into the carriageway; and
- Failure of the cross-carriageway drainage system

The causes of each type of failure are of a different nature, and can be divided into four main groups:

- Accidental obstructions
- Inadequate construction

- Drainage erosion
- Drainage silting.

A general view of the causes and their potential effects on earth and gravel roads is given below. Inadequate design or construction causes most of these failures. It usually requires substantial work if the road is to be restored to a serviceable condition. Both the pavement structure of a road and the volume of traffic which it carries are more relevant to the initial design of the road and to its periodic maintenance than they are to the calculation of its routine maintenance inputs.

4. Causes of failure and their effects on earth and gravel roads

Cause Failures	*Accidental obstruction*	*Inadequate construction*	*Drainage erosion*	*Drainage silting*
Pavement failure		• inadequate earthwork over weak subgrade • no stabilisation on steep gradients • insufficient camber		
Shoulder/ carriageway erosion	• embankment failures blocking side drains	• gradients too steep with inadequate scour checks • no grass on shoulders or in base of side drains	• increasing erosion channels in base of side drains	• overflow of silted side drains
Cross-carriageway Drainage failure	• accidental blockage of culvert • accidental blockage of mitre drains	• inadequate culvert construction • inadequate mitre drains • inadequate gradient of culvert and culvert inlet/ outlet leading to silting	• erosion of side drains leading to collapse of culvert headwall	• blocked culvert • blocked mitre drains

MAINTENANCE SYSTEMS

Maintenance contracts are allocated according to the basic maintenance operations:

5. Types of maintenance

- Routine maintenance
- Periodic maintenance
- Emergency maintenance

It is necessary to distinguish between these maintenance operations to be able to:

- Set priorities and plan maintenance work
- Organise maintenance work
- Quantify maintenance work
- Estimate maintenance work for funding purposes
- Allocate maintenance work to the maintenance personnel

routine maintenance These are normally small-scale operations with limited resource requirements, usually performed at least once a year on a section of road. Routine maintenance consists of relatively unskilled activities, except for grading, which is a skilled operation. It is necessary to define all routine maintenance activities clearly in order to be able to:

- Quantify the activities
- Instruct the activities to the maintenance personnel
- Control and monitor the activities effectively.

The need for routine maintenance activities must be estimated, and the execution of the work must be planned and controlled. The following table provide checklists of routine maintenance activities for unpaved and paved roads respectively in approximate order of priority, although this can differ from case to case.

6. Routine maintenance activities for paved and unpaved roads

unpaved roads	***paved roads***
1. Inspection and removal of obstacles	1. Inspection and removal of obstacles
2. Cleaning of drainage structures and their inlets and outlets (culverts, splashes, etc.)	2. Cleaning of drainage structures and their inlets and outlets (culverts, splashes, etc.)
3. Repair of culvert headwalls, approaches and aprons of splashes	3. Repair of culvert headwalls, approaches and aprons of splashes
4. Repair of culvert drains/off-shoot drains/catchwater drains and excavation to original sizes	4. Repair of culvert drains/off-shoot drains/catchwater drains and excavation to original sizes
5. Cleaning of side drains and excavation to original size	5. Cleaning of side drains and excavation to original size
6. Cleaning of catchwater drains and excavation to original size	6. Cleaning of catchwater drains and excavation to original size
7. Filling of pot-holes in carriageway	7. Patch and reshape shoulder (gravel shoulder)
8. Repair of shoulder and slope erosion	8. Patch surface edge
9. Light reshaping of carriageway (camber formation, corrugation, ruts, etc.)	9. Patch pot-holes, (including patching of local severe ruts/depressions)
10. Maintenance of erosion controls in drains	10. Seal cracks
11. Cutting of grass on shoulders and side drains	11. Sand off bleeding areas
12. Clearing bush	12. Bush clearing and grass cutting

periodic maintenance

These activities need to be carried out on a road, or a section of a road, after a number of years. Periodic maintenance operations on gravel roads, especially re-gravelling, are usually contracted out. The following table provides a checklist of periodic maintenance activities for which separate work units or sub-programmes could be established.

7. Periodic maintenance activities

- Heavy reshaping of road or road section (by labour, drag or towed grader)
- Installation or reconstruction of small drainage structures
- Rehabilitation of road or road section
- Rehabilitation of major structures (bridges, drifts)
- Reshaping and regravelling/resealing of road or road section
- Provision of gravel stacks along the road to be used for routine maintenance activities

To take on a regravelling contract the contractor needs access to expensive equipment, which involves considerable costs; thus these contracts entail a large risk.

emergency maintenance

These activities are required from time to time on a section of road whenever sudden and unforeseen damage occurs. In most cases this requires the deployment of additional resources. By definition, emergency activities cannot be forecast during the client's annual maintenance needs assessment, so they cannot be priced directly into the annual maintenance contract. However, it is possible for the client's engineer to reserve a certain percentage of the routine maintenance funds for emergency cases, and include a provisional allocation for emergency maintenance in the contract.

Normally the contractor will be required to include a schedule of unit rates in the contract submission, and these will provide the basis for calculating payments for any emergency work that may be authorised. In order to plan realistically and organise the emergency activities when they happen it is necessary to identify the extent and kind of damage as fast and as exactly as possible.

8. Emergency maintenance activities

- Reconstruction or repair of damage to culverts splashes resulting from washouts, erosion or breakage.
- Reconstruction or repair of damage to structures resulting from washouts, erosion, breakage or damage from high floods.
- Clearing of landslide, tree fall or rock falls.
- Reconstruction or repair of damage to a road section resulting from washout or serious erosion.
- Reconstruction or repair of damage to drainage systems resulting from serious silting up or erosion
- Reconstruction or repair of damage to erosion protection resulting from serious washouts, landslides, etc.

Emergency assessment: This assessment is often left to the routine maintenance contractor, as the contractor is required to inspect the road regularly and to inform the client immediately if any emergency arises. The assessment should give sufficient information to:

- Estimate the input of resources (manpower, material, equipment and tools);
- Estimate the financial requirements;
- Develop an operational plan and organise the work immediately; and
- Control and monitor the work.

CONTRACTING METHODS USED IN LABOUR-BASED MAINTENANCE

More road authorities contract out routine maintenance, as it is difficult for them to carry out the work economically using direct labour (force account). Road authorities are usually centrally organised and cannot effectively control dispersed maintenance activities. Small-scale contractors based in these locations should be able to offer a cheaper and more reliable service. Although routine maintenance contracts can never be a big business, they offer a continuous and steady workload, which is very attractive for a small-scale contractor using a labour-based approach.

There are basically four different types of labour-based contract:

1. Single lengthperson contract: A contract for a defined section of a road (1 to 2 km) is given to an individual who is provided with hand tools and supervised regularly by a gang leader, who monitors the condition of the road, directs operations, make report and authorises payment.

2. Petty contract (or labour group): A contract is given to a very small-scale contractor who in turn employs a small team (5 to 10 labourers) to maintain a defined section of a road (5 to 20km).

3. Small-scale contract for particular road: A contract is given to a small to medium-sized contractor, who employs labourers to maintain a particular road or a longer road section (20 to 100km).

4. Small-scale contract for a specified road network: A contract is given to a small-scale contractor to maintain a specified road network, e.g. a full maintenance area covering all earth and gravel roads (100 to 300km of roads).

Contract types 1 and 2 might be arranged with individuals or a labour co-operative or community group. Types 3 and 4 are most likely to be of interest to a professional labour-based contractor. Before deciding how to approach the issue of the type of contractual arrangement to use, the engineer should consider the following factors:

9. Factors in deciding on contractual arrangements

- The supervisory capacity of the organisation; how many supervisors does it you have? What is their background?
- Whether transport is available for all of them
- Whether there are traditional factors which affect the way work can be organised (for example, labourers may prefer group working)
- The distribution of people along the road (e.g. in villages or in scattered homes).

FURTHER READING

The student should refer to the following documents:

1. **Andersson, C.A., A. Beusch and D. Miles** (1996). *Road maintenance and gravelling (ROMAR) using labour-based methods - Handbook.* Intermediate Technology Publications, UK.
2. **Hagen, S. and C. Relf** (1988): *The District road improvement and maintenance programme-better roads and job creation in* Malawi. International Labour Organisation, Geneva.
3. **PIARC** (1994). *International Road maintenance Handbook, Volumes I-IV.* Revised by R. C. Petts of Intech Associates under assignment to the Transport Road Research Laboratory, UK.
4. **TRRL OVERSEAS UNIT** (1987): *Maintenance Management for District Engineers,* Crowthorne, Overseas Road Note 1, 2nd edition, Transport Road Research Laboratory, UK.

10. Questions for students:

- *What are the main purposes of road maintenance?*
- *What are the three main reasons for road deterioration?*
- *What are the four causes for road failure?*
- *What are three types of road maintenance systems?*
- *What are typical emergency repair activities?*
- *What is a lengthperson and what type of maintenance do they undertake?*

7: MAINTENANCE MANAGEMENT AND CASE STUDY IN CAMBODIA

Contents

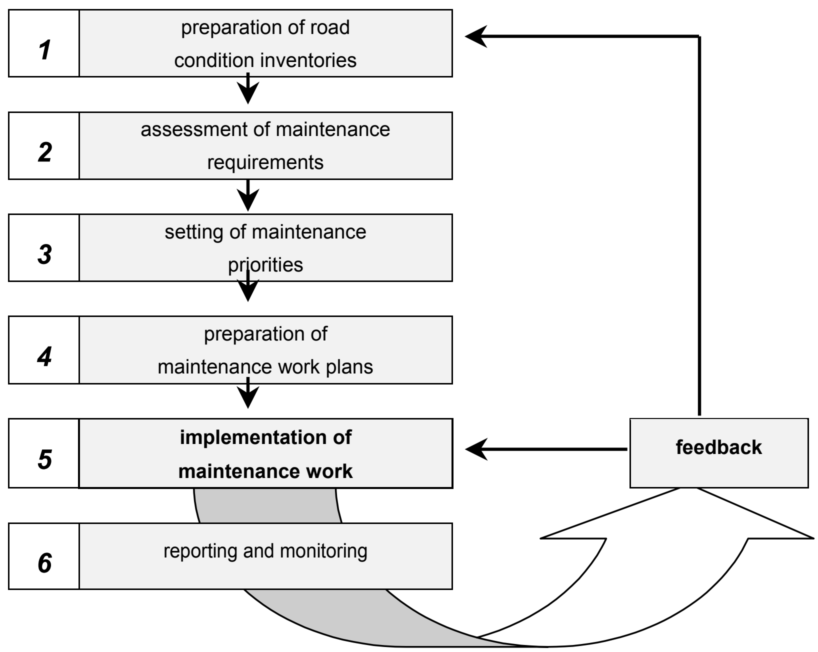
1. Issues covered in this lecture

- Maintenance management cycle
- Preparation of work plans
- Safety measures for work sites
- Maintenance and sustainability: a Cambodian case study

MAINTENANCE MANAGEMENT CYCLE

All maintenance operations require careful planning, supervision and monitoring. The maintenance management cycle illustrated below shows the required activity phases in a logical sequence, from the client's viewpoint:

2. The maintenance management cycle



The steps in the maintenance cycle are as follows:

road condition inventories

Road Condition Inventories are prepared by the client and should list and describe all the important features of a road. The recorded data provides the basic reference for all subsequent inspections and plans. A complete routine maintenance contract should also include a condition inventory of the road. An example of the factors included in such an inventory is shown as an attachment at the end of this lecture.

assessment of maintenance requirements

The assessment of maintenance requirements has to be carried out by the client in order to identify the work that has to be done on a particular road. This assessment, which in principle is an inspection of the road's defects, is usually carried out on an annual basis. The assessments are used as basis for the preparation of detailed contracts and operational plans for routine and periodic maintenance. This regular assessment is necessary in order to:

- Make objective and quantified assessments of the condition of each road;

- Review maintenance activities carried out since the previous inspection;
- Determine routine maintenance activities for each road for the next period, and to issue contracts based on the actual maintenance needs; and
- Determine the periodic maintenance activities to be carried out for the next period.

priorities for road maintenance

An annual assessment of maintenance requirements will identify the necessary work. Before maintenance activities can be planned an important intermediate step must be undertaken - the client has to allocate the limited resources available to achieve the desired result. Usually the financial resources available are not sufficient to carry out all the maintenance activities identified during the assessment. It is therefore necessary to set priorities for what maintenance activities and which road sections are most important.

absolute priority

Absolute priority is usually given to emergency maintenance activities, and a certain percentage of the available routine maintenance funds are set-aside for it. This should then also be considered in any contract, and often the item 'miscellaneous' is meant to cover emergency maintenance activities. The client should instruct the contractors how and when this item can be use based on signed written instructions.

For the contractor, it is important to know that the client usually gives highest priority to routine maintenance of the drainage system. Neglected drainage work can quickly lead to a deterioration of the road.

first priority

In simple terms, the first priority in routine maintenance is to make sure the rainwater runs off the road quickly and easily, causing as little damage as possible. Other activities, such as grass cutting, bush clearing and slope maintenance are usually of lesser concern to the client and therefore receive a lower priority.

PREPARATION OF WORK PLANS

For road maintenance, as for all other activities, it is always advantageous to prepare a work plan. There are two major types of road maintenance plan: long-term and short-term.

long-term plans

The long-term plans are the general routine maintenance and the periodic maintenance plans. The general routine maintenance plans are based on an assessment of the maintenance requirements. The assessed requirements form the basis for the bill of quantities of a maintenance contract. The client's engineer establishes long-term maintenance plans. The client knows what resources are available over a longer period of time.

The engineer also prepares long-term plans for periodic maintenance activities, such as regravelling. Based on data obtained from the annual assessment, it is possible to forecast when, for example, a further layer of gravel will be required, as in the following example:

3. Example of assessment for regravelling

An assessment shows that the existing gravel layer of a certain road is presently on average 5cm thick, while the thickness of the layer when the road was gravelled 5 years ago, was 15cm. Based on that, the engineer

> *assumes that the yearly gravel loss is about 2cm. If nothing is done the road will have completely lost its gravel layer within 2-3 years. The engineer does not want the road to deteriorate completely so regravelling has to be undertaken one or, at the latest, two years from now.*

short-term plans or operational plans

Short-term plans are the operational plans that *the contractor* has to prepare for the execution of the contract. The basis of these plans is the bill of quantities; the work standards and the time frame for the work as specified in the contract.

reporting and monitoring

Monitoring and reporting on the work carried out is important both for the client and the contractor:

- The client expects to get information on the quality and quantity of work carried out by the contractor.
- The contractor must receive information on resources actually spent and productivity achieved.

importance of good records

Therefore it is of vital importance to have good records of all site activities. *Without good records the contractor cannot control his site.* The reports have to give information on materials on site, labour, equipment and vehicles. Knowing how much money the contractor is spending daily is an important aspect of reporting as well as monitoring all work done for a certain period of time (per day, per week, etc.),

Merely measuring work done and recording resources used are not sufficient for a good monitoring process. These data must be compared with the targets set in the plans. A comparison of set targets against achieved work gives a clear indication of performance. Such an analysis must feed back into both the current work process and the planning of further work.

SAFETY MEASURES FOR WORK SITES

Many road work activities are potentially dangerous and it is necessary to minimise the risks by ensuring that:

- Temporary traffic signs and protection are provided and correctly located on site for the works duration.
- All equipment and vehicles are parked off the carriageway or behind protective barriers and signs, when not in use.
- No materials are left in a dangerous location and that the road adjacent to the work site is kept clean and swept of any debris arising from the work.
- All excavations are protected for the benefit of all road users, equipment and workers.
- Ensuring that all operators are trained in the operation of their equipment.
- Operators and labourers are informed of the potential risks of, and procedures for, working with or close to machinery.
- Traffic-control operations are properly carried out and that the road users are not unnecessarily delayed.
- Where work on the carriageway or shoulder remains unfinished

overnight, proper warning lights are arranged and, if necessary, protected.

- All sites are left tidy and cleared of debris when the work is completed.

diverting traffic

Very often it is not possible to divert traffic in developing countries as the road network is not dense enough and the construction of diversions is too expensive. Therefore roads are usually to be kept open to traffic. Before work starts, warning signs, barriers and cones must be placed around the work area. Work should be carried out on one side of the road at a time, allowing traffic to pass on the other. Signs must be placed in the following order:

4. Positioning road signs

- ‘Road works Ahead' signs should be placed 200 metres in front of the work area.
- 'Road Narrows' signs should be placed 100 metres in front of the work area.
- 'Speed Limit' signs should be placed at start of the work area.
- Barriers should be placed at each end of the work area.
- Cones should be placed in a taper at the approaches to the work area and at a maximum spacing of 10 metres along the middle of the road next to the work area.
- 'End of Restriction' signs should be placed 50 metres beyond the work area.

MAINTENANCE AND SUSTAINABILITY: A CAMBODIAN CASE STUDY

In 2000, the ILO launched the Rural Road Maintenance Initiative (RRMI) which provided technical advice to PDRD and others concerned with the rural road programme in Battambang and Banteay Meanchey provinces. Formerly, ILO was active in these provinces during 1993-1998, constructing roads and establishing a maintenance system for the roads..

present maintenance responsibility

In 1998, the road maintenance was entrusted to local government and local communities, in the belief that they would be able to construct and maintain infrastructure that is important to them, including rural roads. However, since 1998 no other programme of systematic maintenance has been initiated in those provinces. As a part of the RRMI, the Battambang PDRD and the ILO Upstream Project in late 2000 and early 2001 conducted a road condition survey and inventory in Battambang province

throwing away good money after bad.

Based upon the results of the survey of the donors and concerned agencies it was found that in Battambang from 1998 to 2000, approximately US$4.48 million of resources was invested in rural roads and rural transport infrastructure. Some investments were directed towards Sub Tertiary 3 roads and rural road cross drainage structures. However these investments made little sense if they facilitate connection to a higher order tertiary road network that is in poor condition. On average the full cost of maintenance for a rural road in Cambodia is estimated to be US$1,625/km per year. That is, a little over 10% of the cost of construction. Maintenance costs are variable and this figure is probably close to a maximum cost. Thus, an average expenditure of US$276,250/yr (or in total over those three years $828,750) would have at least preserved the length of maintainable rural roads at 170km. Thus, spending $828,750 in maintenance would have prevented the need to spend $870,000 to restore the network.

other disbenefits

Further, as every dollar not spent on maintenance increases vehicle-operating costs by US$2-3, this means that the local economy was penalised in additional transport costs of more than US$1.7M. Another loss to the local economy was the potential employment that the road maintenance activities would have generated to the local population. To maintain the 170km of rural roads over three years using proper labour-based methods would have yielded approximately 86,700 workdays of employment. Again these figures and costs are indicative and do not include the time value of money. If only 18% of the total actual expenditure on rural roads and rural transport was made on the maintenance of the 170km of rural roads since 1998, these costs could have been avoided. It is evident that there were ample resources available in the province to preserve the road network and to even expand it.

declining maintainable stock of assets

The important point is that while US$4.5M worth of resources was invested in rural road and rural transport infrastructure, the overall total value of the maintainable stock of assets declined. In addition, the local economy suffered heavy increases in vehicle operating costs and lost employment opportunities. The situation in Battambang is not unique, if one were to project the implications of this report to the national level; the waste of resources would have significant implications for national development.

so what went wrong?

How can such a large investment in rural roads and rural transport infrastructure made in the name of rural development have produced such poor results? There are undoubtedly many factors that have led to this outcome. Many of the investments are made on a project basis, to achieve specific individual project objectives, without consideration for the broader priorities of the rural road sub-sector such as maximising the rate of return on the investments made. For example, an agency that is working in a commune, as a part of a rural development project, may build a road to improve the access to that commune. Since they control the budget independently of the PDRD they may proceed to build the road regardless of whether or not the particular road will increase the value of the road network over other alternative investments. While new roads are being constructed existing roads are being left to deteriorate. Those new roads in turn are neglected while even more new roads are constructed. In Battambang the current deterioration is exceeding the road construction rate.

bias of rural road investors

Clearly, there exists a bias by rural road investors to use resources for the construction of new rural roads over using some of those resources to maintain existing assets. This bias may originate from a number of factors. One reason may be the effort of projects to maximise their impact during the relatively short project life span. After all the need for maintenance on rural roads is forever. It is common for projects to implement road works, to make an official hand over of the road works to the local government or to the community and to then move on. The projects are not often around to face the consequences of the inability of the local entities to carry out the maintenance as promised.

hard work volunteered for free by someone else.

A cornerstone assumption made by many rural road investors is that local communities will continue the maintenance of the local roads because they are the owners and beneficiaries of the roads. Community participation and contribution as with decentralisation, needs to be encouraged selectively to be sustainable. A recent ILO report (Zweers) found that: "With all participation, it needs to be recognised that this (rural road maintenance) is an on-going rather than a one-off exercise. However, it should be expected that the inputs from self-help labour would diminish over time. It has therefore proved difficult to use self-help schemes for on-going maintenance; most experience is with construction."

5. Summary of the Battambang experience

v. The current practice of investing in rural roads in Battambang province has been demonstrated to be unsustainable without a programme of maintenance.

vi. The problem in Battambang is not a shortage of resources for rural roads, indeed there were ample resources directed to rural roads and rural transport infrastructure.

vii. Decentralising rural road investments to the commune or the village level or on a project basis may not result in the resources being invested in a systematic and efficient way that takes account of the functioning of the road hierarchy and the transport network.

viii. The reliance on local communities to contribute voluntary labour may have detrimental effects on achieving development goals.

ix. The implications of the Battambang experience if projected to a national level are significant.

x. Considering the value of the assets and the magnitude of the investments, rural roads qualify as big business and need to be seriously managed as such.

FURTHER READING

The student should refer to the following documents:

1 **Andersson, C.A., A. Beusch and D. Miles** (1996). *Road maintenance and gravelling (ROMAR) using labour-based methods - Handbook.* Intermediate Technology Publications, UK.

2 **Edmonds, G.A. and de Veen, J.J.** (1982): *Road Maintenance: Options for Improvement,* Geneva, ILO.

3 **ILO** (2001). *Rural Road Investment, Maintenance and Sustainability.* ILO Upstream Project, Phnom Penh.

4 **Johannessen, B.** (undated): *Labour-based Road Construction and Maintenance Technology: Module 2 – Technical Planning.* Prepared by ILO for the National Polytechnic Institute, School of Communication and Transport, Lao Democratic Republic.

5 **PIARC** (1994). *International Road maintenance Handbook, Volumes I-IV.* Revised by R. C. Petts of Intech Associates under assignment to the Transport Road Research Laboratory, UK.

6 **TRRL OVERSEAS UNIT** (1987): *Maintenance Management for District Engineers,* Crowthorne, Overseas Road Note 1, 2nd edition, Transport Road Research Laboratory, UK.

7 **Zweers, J. and A. Kassie** (2000). *Employment in ILO Supported Road Construction and Maintenance: The Impact of Wage Earnings on Workers.* Socio-Economic Series No. 2. ILO Upstream Project/Ministry of Rural Development, Phnom Penh.

6. Questions for students:

- *What is the purpose of a road inventory in maintenance management?*
- *How would you prioritise road maintenance activities?*
- *What are some of the typical safety measures that need to be taken in road maintenance?*
- *How should traffic diversions in rural areas be organised?*
- *What has been the impact of not undertaking maintenance works in Battambang?*

ATTACHMENT – ROAD CONDITION INVENTORY

INVENTORY CONTENTS

The *road condition inventory* contains all the details of each individual road in the network. The following items should be recorded:

road geometry

xi. Alignment
xii. Profile
xiii. Cross-section

pavement and subgrade characteristics

xiv. Soil conditions
xv. Gravel and other surface dressing
xvi. Condition

drainage features

xvii. Culverts
xviii. Drifts/fords
xix. Mitre drains
xx. Catch water and cut-off drains

structures

xxi. Type
xxii. Size
xxiii. Location (chainage)

junctions

xxiv. Location
xxv. Type of connecting road

climate

xxvi. Rainfall
xxvii. Wind

traffic

xxviii. Annual average daily traffic

maintenance

xxix. Details of routine maintenance i.e. names of contractors
xxx. Details of rehabilitation and urgent maintenance works (such as date and location)

STRIP MAPS

It is helpful to supplement road inventories with simple drawings like *strip maps*. Such diagrams are useful in the office when preparing the operational plans. It helps management see at a glance the whole situation of a particular road.

CONDITION SURVEYS

The inventory needs to be regularly updated by undertaking *road condition surveys*. Using these surveys road authorities can make an objective and quantified assessment of the conditions of each road, to assess previous maintenance works and to determine the routine and periodic maintenance to be carried out in the next construction season. The types of condition surveys needed include drainage, running surface and structural surveys. The methods for undertaking these surveys are discussed in later lectures.

Source: ***Johannessen, B****. (undated): Labour-based Road Construction and Maintenance Technology: Module 2 – Technical Planning. Prepared by ILO for the National Polytechnic Institute, School of Communication and Transport, Lao Democratic Republic.*

8: SENSITISATION COURSE

SAMPLE QUESTIONS

*The student should answer nine questions, choosing at least one question from each of the six groups. The time set for the examination is **90 minutes** and the student should spend about 10 minutes in answering each question. Put the exam question number at the top of each answer – for example 2 b).*

1. INTRODUCTION TO DEVELOPMENT ENGINEERING

a) *Why did the lectures focus on rural road engineering rather than other types of civil engineering construction?*

b) *What do you understand by the terms labour and capital intensiveness?*

c) *What are typical local resources used in the construction process in Cambodia?*

2. EVOLUTION AND SCOPE OF LABOUR-BASED CONSTRUCTION

a) *What do you understand by the term bio-engineering and when is it particularly appropriate to use such technology?*

b) *What are examples from your own experience of the traditional use of labour in construction in Cambodia and what have been the problems and advantages with using such traditional working methods?*

c) *What do you understand from the term appropriate local technological capacity?*

3. BASIC CONCEPTS OF LABOUR-BASED ROADWORKS

a) *What do you understand by the term "labour-intensive" works, as compared to labour-based works?*

b) *Why has the use of equipment in developing countries often been "over-optimistic?*

c) *What are the issues that need to be considered in substituting labour for equipment and what kind of factors might prevent labour substitution occurring?*

4. DETAILED ASPECTS OF USING LABOUR FOR ROADWORKS

a) *Why is the linking of payment methods to labour productivity important?*

b) *Why is it necessary to understand national labour laws?*

c) *What is the purpose of undertaking an assessment of labour availability and what are the basic steps that would need to be followed in making the assessment?*

5. PRINCIPLES OF ROAD MAINTENANCE

a) *What are the three main reasons for road deterioration and how will these cause road failure?*

b) *What are three main types of road maintenance systems?*

c) *What are typical emergency repair activities on roads?*

6. ROAD MAINTENANCE MANAGEMENT

a) *What is the purpose of undertaking a road inventory in maintenance management and what type information is recorded in the road inventory?*

b) *What are some of the typical safety measures that need to be incorporated in road maintenance programmes?*

xxxi. *From the case study undertaken by the ILO in Battambang, what has been the overall impact of not undertaking regular maintenance works?*

ITC DEVELOPMENT ENGINEERING COURSE

PART B: Orientation Course

9: DEVELOPMENT POLICIES OF THE MINISTRY OF RURAL DEVELOPMENT

Contents

1. Issues covered in this lecture

BACKGROUND

This lecture introduces the official development policies of the Ministry of Rural Development (MRD) and how they relate to issues of development engineering.

5-Year Socio-Economic Development Plan

The approach of Government towards rural development in Cambodia is contained in the 2nd 5-Year Socio-Economic Development Plan of the Ministry of Rural Development (MRD). The plan recognises the social and economic importance of transport improvements through the provision of well-maintained feeder roads. The plan stresses the importance of rural roads to increasing agricultural production, to consolidating the links between rural and urban areas, and to increasing access to education, health care and water supplies. As many rural roads in Cambodia are in poor condition the intention in the plan is to rehabilitate and maintain roads using labour-based appropriate technology, maximising the use of local resources and benefiting the local population by generating employment and income. The plan also recognises that without routine maintenance costly periodic rehabilitation will be required.

Policy for Rural Roads

The MRD policy on rural roads was formulated after a consultation process with key stakeholders in the rural development sector. The views and needs of village communities and rural road users were incorporated in a draft policy document, prepared through a series of consultation visits and workshops. This document set out the guiding policy objective on rural roads, provides detailed statements on all key issues regarding maintenance and development of the rural road network, and includes explanations of the rationale on which the policies are based. Ultimately, the rural road's policy will become part of a National Transport Policy.

Goals of the Policy for Rural Roads

As an overall goal, the MRD is responsible for facilitating the improvement of rural social and economic conditions. The mission statement of the MRD for achieving this goal in relation to rural roads is as follows:

2. Mission Statement

"The MRD Department of Rural Roads will contribute to this goal by increasing rural access through cost-effective investment in the maintenance and development of rural roads, routes and transport infrastructure."

WHY HAVE POLICIES?

It is necessary for the MRD, as for any large organisation, to have a policy, to provide a framework for its operations.

- To set out the objectives and scope of responsibility of the MRD.
- To focus the senior management's activities on developing and implementing the strategies which will enable those objectives to be achieved.

- To act as a 'benchmark' to evaluate the validity of individual initiatives.
- To develop appropriate and affordable measures to meet the demands made on the sector and to match financial, human resource, physical and operational constraints.
- To help MRD staff to understand, and react positively, to instructions, guidelines and activities implemented and promoted by the MRD.
- To enable the recipient communities to be able to understand (and respond to) the initiatives being undertaken on their behalf and for their benefit.
- To enable partners, such as NGOs, donors, community organisations and other government organisations to co-operate with and enhance the efforts of the MRD in a constructive way.

SUB-DECREE ON RURAL ROAD POLICY

The basis on which the MRD is responsible for the development and implementation of policies for rural roads and routes in Cambodia, through the establishment of a new Department of Rural Roads (DRR), is defined in Royal Government's Sub-Decree of September 2001. The Sub-Decree has thirteen articles and the main features of the Sub-Decree as they effect development engineering practice are contained in Articles 1-4.

Article 1 This article provides for the creation of the DRR, under the Technical Department-General in the MRD, to be responsible for functions and duties related to rural transport infrastructure. In the provinces and districts new Offices (ORR), and Groups (GRR) of Rural Roads were created under the PDRD Director and the DORD Chief respectively. The MRD is responsible for the management of all rural transport infrastructure in the country; which is defined as roads that carry a traffic volume of less than 50 (two axle, four wheel) motorised vehicles per day as well as paths and access ways to them. Subject to this traffic volume condition, the MRD, through the DRR and its provincial and district organisation, is responsible for:

3. MRD's responsibilities for road maintenance

- District to district roads (tertiary roads)
- District to commune roads (sub-tertiary 1 roads)
- Commune to commune roads (sub-tertiary 2 roads)
- Commune to village roads (sub-tertiary 3 roads)

The scope of MRD's activities includes the structures, as well as all paths and access ways to the roads in rural areas. The types of works envisaged are:

- Maintenance (routine and periodic).
- Repair (emergency and spot).
- Rehabilitation.
- Improvements and construction.

Article 2 This article details the Department of Rural Road's specific responsibilities. These include responsibility for:

- *Management*.
- *Setting policies*, including promoting the preferred technology for all rural roads works as being labour-based. MRD is also responsible for: (i) setting construction and geometrical standards; (ii) specifications and contracting rules and procedures for hiring consultants and contractors, (including encouraging use of simplified rules to engage local contractors using LBAT); (iii) environmental and safety standards; and (iv) gender, social vulnerability protection, and labour standards.
- *Arranging and procuring appropriate financing* to carry out the yearly work programmes and to finance the Five-year Prospective Plan of rural transport infrastructure. This includes short and long-term financing needs, arranging government allocation of financial resources and arranging the timely transfer of funds to the Provincial Offices of Rural Roads to pay contractors and consultants. MRD is also responsible for obtaining supplementary financing from donors and other sources, as well as assisting Village and Commune Development Committees to design, develop and institute self and own-financing methods.
- *Co-ordinating projects and investment activities* of donors, international bilateral and multilateral lending agencies, NGOs and others engaged in rural roads works.
- *Planning,* reviewing and approving, in consultation with the Council for Agricultural Development, the maintenance (routine and periodic), repair, rehabilitation, improvement and construction Yearly Work programme and a Five-year Prospective Plan for rural roads. This includes assessing the costs and benefits, and prioritising the works in the Yearly Work programme to maximise the economic rate of return of investments; and reviewing traffic counts and condition inventories carried out on the rural roads to confirm the extent of the network under the responsibility MRD.
- *Monitoring and evaluating* the execution of the Yearly Work programme, especially cost effectiveness of the works, appropriate use of resources, and compliance with environmental and road user safety directives, and with gender, labour, and social vulnerability directives.
- *Enforcing* compliance with standards, specifications, and procurement/contracting directives.
- *Developing* the technical and management skills necessary for the staff at all levels to carry out the management of the rural roads network.

Article 3 This article details the procedures that the Department of Rural Road needs to follow in;

- *Developing* the technical and management skills necessary for the staff at all levels to carry out the management of the rural roads network.
- *Planning* and approving maintenance works in the Yearly Work programmes and Five-year Prospective Plans in consultation with District Office's Group of Rural Roads and with the Provincial Rural Development Committee. The preferred method of prioritising works is to use the Integrated Rural Accessibility Planning (IRAP) tool.
- *Establishing* the costs of the works work programme and preparing the Yearly Work programme budget, as well as the figures for the Five-year Prospective Plan.
- *Processing and analysing* the periodic traffic counts and condition inventories carried out on the network of rural roads by the Rural Roads Groups in the Districts.
- *Contracting and superintending* the execution of the rural roads works. This is to use the most appropriate technology, preferably labour-based appropriate technology (LBAT), by labour-based contractors contracted following the procedures prescribed by the DRR and supervised by consultants hired according to the rules prescribed by the DRR.

Article 4 This article defines the responsibility of the District Office's Group of Rural Roads in:

- *Planning,* in consultation with the Village and the Commune Development Committees, the Yearly Work programme and Five-year Prospective Plan and submitting the proposed work programme and the Plan to the Provincial Office of Rural Roads.
- *Carrying out* periodic traffic counts on the rural roads network.
- *Carrying out* periodic condition inventories of the rural roads in the network.

RATIONALE FOR RURAL ROAD POLICIES

Roads are the dominant mode of transport in the rural areas of Cambodia. The maintenance, rehabilitation and appropriate development of the network of rural roads and routes are an essential pre-requisite for the economic and social development of these areas. Improved rural access is directly linked to poverty alleviation. Rural roads and routes will consume the largest proportion of the investment in rural development in the near future. The Royal Government of Cambodia recognises that this investment, while necessary, involves considerable risks. Without an appropriate and applied framework of policies, strategies and controls, much of the investment could easily be misdirected or wasted.

Road Categorisation Road categorisation reflects the role and importance of an individual road so that it can be assigned to the appropriate road authority. This allows appropriate resources and technologies to be allocated for maintenance and development. The functional categorisation of the rural roads and routes in the Sub-Decree allows for classification and reclassification of individual roads by Ministry of Rural Development in liaison with partner organisations, particularly the

Ministry of Public Works and Transport.

Road Ownership Rural roads and routes are currently not defined, inventoried or gazetted on a national basis. Road margins (the extent of road property and right of passage) are not defined. Development against roads is uncontrolled and can lead to long term problems including squatters, safety, effective drainage provision and road utilisation. Responsibility for road assets is not clearly defined in law. Ownership should be vested with the organisations motivated and best able to manage individual roads in an environment of limited resources.

Road Management Responsibility The rural road network is an extensive, expensive and fragile asset, vital for rural development and the economic and social well being of the rural communities. Without active and appropriate management and maintenance the asset will rapidly 'waste', reversing recent rehabilitation benefits and severely constraining all other rural activities and initiatives. Royal Government of Cambodia policies of decentralisation and use of the private sector are recognised in the allocation of road management responsibilities.

Financing Road Maintenance and Construction Rural roads are typically 'low initial cost - high maintenance' assets. In recent years there has been very limited recurrent funding available for regular and preventive maintenance of the national road network. Without adequate and timely maintenance financing and resources, the road network assets will waste. Despite planned increases in Government funding for road maintenance, this will still be insufficient to adequately maintain the entire national road network in the near future. Therefore, all reasonable, additional potential sources of financing or resources for road maintenance must be investigated and mobilised. Short/medium term donor assistance and external expertise will probably be required to develop local maintenance financing and capabilities.

The Ministry of Rural Development will ensure that resources for maintenance are identified and deployed as a prerequisite before any new construction is authorised. MRD works with the local stakeholders to identify those who benefit most from the improved rural transportation assets and thereby facilitate the mobilisation of funding, resources and expertise and co-ordinate investments in an equitable manner along the lines of user/beneficiary pays. MRD co-ordinates with Ministry of Public Works and Transport to ensure investments in rural roads are in harmony with the improvements of the National and Provincial roads, thereby adding value to the overall transport network.

Technology for Rural Roads Currently, and in the foreseeable future, heavy equipment technology is too expensive, problematic and unsustainable for rural roadworks in Cambodia. There would also be considerable socio-economic penalties involved with the use of this in-appropriate technology. The Royal Government of Cambodia's primary policies focus is on job creation and productive employment to reduce poverty. In Cambodia the feasibility, quality and cost-effectiveness achievable with Labour-based appropriate technology (LBAT) has been demonstrated clearly. Current and prospective Cambodian labour wage rates will make LBAT very attractive in financial and economic terms for many years to come for all rural road works. The Ministry of Rural Development has committed itself to this approach and is rapidly developing the experience and expertise in the application of this technology for rural roads. Any potential disadvantages of labour and intermediate equipment methods can be overcome with appropriate management arrangements.

Setting and Monitoring Standards and Specifications

Inappropriate standards and specifications could considerably increase maintenance liabilities for the Royal Government of Cambodia and the rural communities. Standards and specifications if set too high, could lead to uneconomic investments and poor use of scarce resources, and if set too low, to premature asset wasting and degrading of rural infrastructure. Gravel surfacing will not be affordable and sustainable for many rural roads and routes. However, there is a range of proven alternative road surfaces that are labour intensive and offer good cost-effective 'whole-life' solutions for different situations in Cambodia. Spot improvement strategies will be necessary on some lower category roads due to severe resource constraints. This will mean that interim improvements may focus on structures and drainage measures, leaving attainment of surfacing standards until further resources become available.

Planning and Prioritising Maintenance and Construction Works

As a starting point for the planning of rural roads and routes investments, the preservation of the existing assets through appropriate emergency, routine and periodic maintenance arrangements will have better economic returns than new construction and should be given priority over construction works. Government policy requires the minimisation of overall costs of infrastructure and operations. It is essential to consolidate the existing serviceable networks before rehabilitating and developing further links.

Rural transport infrastructure will be planned to achieve the Ministry of Rural Development's mission to increase rural accessibility. This will be achieved using accessibility planning and prioritisation to identify affordable, maintainable, sustainable rural transport infrastructure, and the appropriate location of essential services. Due regard will be made to accessibility needs, transport modes used and serviceable linkages to other networks. These interventions will include spot improvements of limited 'bottlenecks' on lower category roads as a strategy to combat limited resource availability.

It is intended that routine maintenance systems will be established on all rural roads that are improved. Through an effective routine maintenance programme considerable savings can be made both to the road users and to the road managers. The DRR will promote the use of the local private sector to assist with planning and prioritisation operations, in accordance with Government privatisation policy. Although the planning responsibility will primarily be with the road owner or manager, the DRR will provide guidance in all aspects of works planning and prioritisation. The use of the IRAP process will involve the views and priorities of stakeholders at each appropriate level of road hierarchy.

Carrying out Maintenance and Construction Works

Government of Cambodia's policy is to promote the use of the local private sector. Local Small Scale Contractors (SSC) will provide the most cost-effective approach for road maintenance, rehabilitation and construction works if a suitable ‘enabling environment’ is established. The community may be motivated to contribute resources to the maintenance of certain roads where the community is the primary beneficiary of the road being serviceable. However this must be achieved in an equitable way that does not penalise or burden any section of the community. Properties fronting roads have considerable economic benefit from this situation. It may be possible to encourage these owners to carry out vegetation and drainage maintenance as a contribution to the upkeep of their asset. This would not be a significant burden and would be preferable to raising taxes to pay contractors to achieve the same result.

Standards and specifications must be complied with for safety considerations, and to avoid increased maintenance burdens in the future.

Social, Gender and Vulnerable Groups Issues

The MRD believes that it has taken an important step in selecting LBAT as the method for improving the rural transport infrastructure. In so doing it has created the possibility of the participation of many socially and/or physically disadvantaged people in meaningful and dignified employment opportunities at all levels of the planning, construction and management process. The MRD policies are in line with the Royal Government Cambodia's Labour Laws and the policies that cater for the needs, participation and employment of disadvantaged groups. Equal employment opportunities is given to males and females with particular efforts made to provide employment opportunities for disabled persons.

The Royal Government of Cambodia has signed a number of the core international labour conventions that govern employment and these need to be respected. However, such policies often represent a minimum commitment and MRD will endeavour to maximise the socio-economic opportunities and the benefits that come with improved rural transport infrastructure.

Environment and Sustainability

Appropriate environmental impact assessment techniques should be used to evaluate investments in the rural road sector. The following are the most common environmental concerns that arise when the rural roads and routes are improved in Cambodia.

- Laterite is an appropriate low-cost, short term surfacing for rural roads. However the reserves of this naturally occurring material are limited nationally. Furthermore, depletion of laterite gravel resources is rapid due to high gravel surface-material loss caused by high road surface traffic and weather. This is not sustainable in the long term. Dust emissions in dry season can also lead to health and contamination problems.
- Staged construction and alternative low-maintenance surfaces (although higher in initial cost) may provide better solutions in whole life cost, environmental and sustainability considerations. Low-maintenance surfaces would also reduce future maintenance funding, resource and organisational requirements.
- Blocking or constricting natural and man-made watercourses can be damaging to the environment and the established irrigation

and agricultural regimes. Particular care requires to be taken in the siting and design of all structures and embankments to minimise the effects on existing watercourses.

- Efforts should be made to minimise the environmental effects of quarrying and to reinstate the land for other uses where possible after removal of the road materials.

Road Safety

Deaths, accidents and physical damage from road accidents are a considerable human cost and drain on the national economy. Initiatives can and must be made to reduce the unacceptably high rate of accidents on rural roads through improved road safety. These include the use of low-maintenance surfacing to reduce dust and improve traffic safety in the dry season, and the design and location of roads to minimise conflicts between traffic categories, pedestrians and animals. The MRD will also assist other organisations through the application of the 4 'E's concepts:

- Engineering,
- Education,
- Encouragement,
- Enforcement.

Performance Monitoring

Independent monitoring of the physical and financial performance of all organisations involved in the rural road sector should be arranged to ensure value for money from the limited resources available. Regular review and updating of the Policy and Strategies led by the Ministry of Rural Development and with the participation of the stakeholders will enable the Ministry of Rural Development to lead an effective investment programme.

FURTHER READING

The student should refer to the following documents:

1 **Ministry of Rural Development,** (1999). *Policy for Rural Roads.* MRD, Phnom Penh.

2 **Ministry of Rural Development,** (2000). *National Program Framework for Rural Development of Ministry of Rural Development.* MRD, Phnom Penh.

3 **Ministry of Rural Development,** (2000). *2nd Five-Year Socio-economic Development Plan 2001-2005*. Ministry of Rural Development, Phnom Penh.

4 **Royal Government of Cambodia,** (2001). *Sub-Decree: On the Establishment of a Department of Rural Roads in the Ministry of Rural Development*, Council of Ministers, Phnom Penh.

4. Questions for students:

- *Why are rural road policies necessary?*
- *What types of rural roads are MRD responsible for maintaining?*
- *What are the specific responsibilities of the DRR in setting policies?*
- *Who needs to approve the Yearly Work programme and a Five-year Prospective Plan for rural roads?*
- *What problems can arise with regard to the ownership of roads?*
- *What questions relating to environment and sustainability may need to be addressed?*

10: THE CHOICE OF TECHNOLOGY ISSUE

Contents

1. Issues covered in this lecture

- Background to the issue
- Notion of technology
- Bias in the choice process
- Choice as a rational process

BACKGROUND TO THE ISSUE

By the early 1980s there was abundant evidence that labour-based methods were both technically and economically suitable for the construction, rehabilitation and maintenance of rural roads. Moreover, with the steady decline in the economic conditions experienced by many developing countries throughout the 1980s it became progressively more advantageous to use them so as to capitalise on local resources, or, from another perspective, to make less demands, for the same output, on increasingly scarce foreign exchange.

why are there differences between countries?

Why, therefore, were labour-based methods not the automatic choice in countries such as Nigeria, where vigorous programmes of rural road development were taking place, or Ethiopia and Tanzania which were experiencing severe economic difficulties? Whilst there were some countries such as Botswana, Kenya, and Malawi whose commitment to labour-based methods went from strength-to-strength, in others there was either a deep reluctance to start at all or activities were confined to limited scale pilot and demonstration projects. Why?

is the choice deliberate?

What was it that made one group of countries, with certain kinds of resource endowments, choose to employ a type of technology which was in sympathy with those resources, whereas other countries with similar resource endowments continued with technologies which were evidently at variance with their available resources? These and similar questions are often discussed under the heading, of 'the choice of technology issue'. In many such discussions the supposition is that the technology a country, or an organisation, uses at a particular point in time or for a programme or project it is about to execute, is the result of a deliberate *choice* process which selects that which is most appropriate' to needs.

2. Key concepts: Decisions on choice of technology

- Treating choice of road construction and maintenance technology as an objective (rational) process implies that decision making will take place in an unbiased way.
- *“A price has to be paid for anything worthwhile: to direct technology so that it serves man instead of destroying him requires primarily an effort of the imagination and an abandonment of fear " (E.F. Schumacher, Small is Beautiful)*

Reality is, for a number of reasons, very different. The most important of those reasons include confusion as to the notion of technology itself; bias in the choice process; and the not uncommon situations of no effective choice being available. This lecture concludes by re-considering choice as though it was a rational process in which labour-based methods are an option.

THE NOTION OF TECHNOLOGY

Experience over the last three decades or so has shown that terms such as 'technology', 'appropriate technology' or 'technology transfer' are much more complex than they might seem at first consideration.

definitions

Technology has been conceived as 'the method of production in use' or 'the application of a scientific fact or principle for some useful purpose'. Both of these definitions are too simplistic since they convey the idea of technology as a benign or neutral process.

Other definitions are more complex: technology is the science and 'art of getting things done through the application of skills and knowledge'. It is 'a spectrum, with ideas at one end and techniques and things at the other, with design as a middle term'. Implicit in this definition is the idea that technology does not just mean 'tools' or 'techniques' it is also 'processes' and 'products'. A further distinction can be drawn (using a terminology associated with computers) between hardware - tangible products like roads and machinery - and software improvements in organisational forms and institutional structures.

limitations of technology transfer

The failure to appreciate the true nature of technology and thus the difficulty inherent in its 'transfer' lies behind the numerous-examples of waste and inefficiency that all developing countries have experienced on a considerable scale. These include:

- Factories and machinery that have only ever achieved a fraction of their potential output.
- Whole fleets of different equipment without proper servicing facilities/and spare parts problems.

The fact is that simply shipping in equipment with some spares, even accompanied by skilled mechanics and operators for a stay that can be measured in a few years or months, is not enough to 'transfer' the technology.

Western equipment-intensive technology

Technologies are embedded in, and carry, social values, institutional forms, and culture-even as they reflect resource endowments and the organisation of production. Western equipment-intensive technology was devised primarily to save labour in the face of rising wage costs; it could hardly be appropriate for districts or regions troubled with a large labour surplus and very low wage rates. Moreover, technology in western countries has grown up over several generations along with supporting services, like modern transport and communications, accountancy and marketing. It could hardly be appropriate for districts or regions lacking these features.

appropriate technology

The ‘appropriate technology’ movement that stressed the importance of fitting a technology's resources requirements to local resources grew out of recognition of the misfit of physical characteristics of imported technologies to recipient environments.

3. Key concept: Summary of choice issues

The failure to appreciate the real complexity of the term 'technology' and thus the difficulty inherent in its 'transfer' lies behind the numerous examples of waste and inefficiency that all developing countries have experienced on a considerable scale. Technologies are imbedded in, and carry, social values, institutional forms, and culture even as they reflect resource endowments and the organisation of production. Western equipment-intensive technology was devised primarily to save labour in the face of rising wage costs; it could hardly be appropriate for districts or regions troubled with a large labour surplus and very low wage rates.

BIAS IN THE CHOICE PROCESS

In most developing countries the evolution of the construction industry, particularly road construction, has suffered from a long-standing, and thus deep-rooted, bias in the choice of technology. Much of the bias has a colonial origin since the people who were responsible for starting and executing road programmes were from industrialised countries, and the emphasis was naturally on the equipment-intensive methods with which they were familiar and which rapidly became the accepted way of doing things.

reasons for bias

Bias towards and near total reliance on equipment-based, high-technology construction methods has survived in the post-colonial period for a number of reasons:

- The desire of politicians and engineers to emulate the more advanced countries.
- The tendency among international consultants and contractors to favour construction methods with which they were familiar.
- The biases inherent in the conditions and stipulations of international and bilateral assistance agencies.
- The educational background of the technical leadership in most developing countries. Often this was acquired in engineering schools that advocated the latest technological methods.
- The background conditioned planners and engineers to favour the use of heavy equipment in all circumstances.

attraction of equipment based methods

Equipment-based methods were perceived to have productivity, costs, and performance that were predictable; they were associated with high quality results; and they were surrounded by an aura of technological progress. Hence, the use of equipment in construction was particularly attractive and in some cases unavoidable, since financing would not otherwise have been forthcoming.

the most common of these biases are:

Political: the choice of technology may be restricted by a strict adherence to a certain ideology. Such an ideology may classify local resource-based technologies as backward or even neo-colonialist.

Economic: often the prices of foreign imported goods bear no relationship to their actual value to the economy. Equally overvalued exchange rates, and wage rates which do not reflect the actual cost of labour, result in an economic framework which favours the choice of imported goods against the use of local resources.

Institutional: the systems and procedures related to the administration and organisation of infrastructure projects is generally modelled on those used in the developed countries. Consequently, they are not designed to fit the environment in which they operate. The payment, for example, of large groups of unskilled labour is something that most public works departments have difficulty coping with.

Attitudinal: this factor is often the most important element in the effective application of a new technology. If the technology has not been part of either the education or experience of those who are asked to apply it then there is little motivation to give it a real trial.

the 'no choice' situation

Apart from self-interest much of the bias against labour-based technologies is, of course, founded in ignorance either of the alternatives available or of the lessons of history. The result is what has been called the 'no choice situation'. Many people sincerely believe that there is only one optimum way of doing things, or that it is only necessary to get the 'prices right' for the market to ensure that the correct technological solution is selected. Neither of these views is true, but too often the choice of technology and the means of obtaining it is made by those least implicated in the outcome of those decision. One reason for the no choice situation lies in the narrowness of engineering education. Equipment-intensive methods are enshrined in the curricula of universities and other technical institutes.

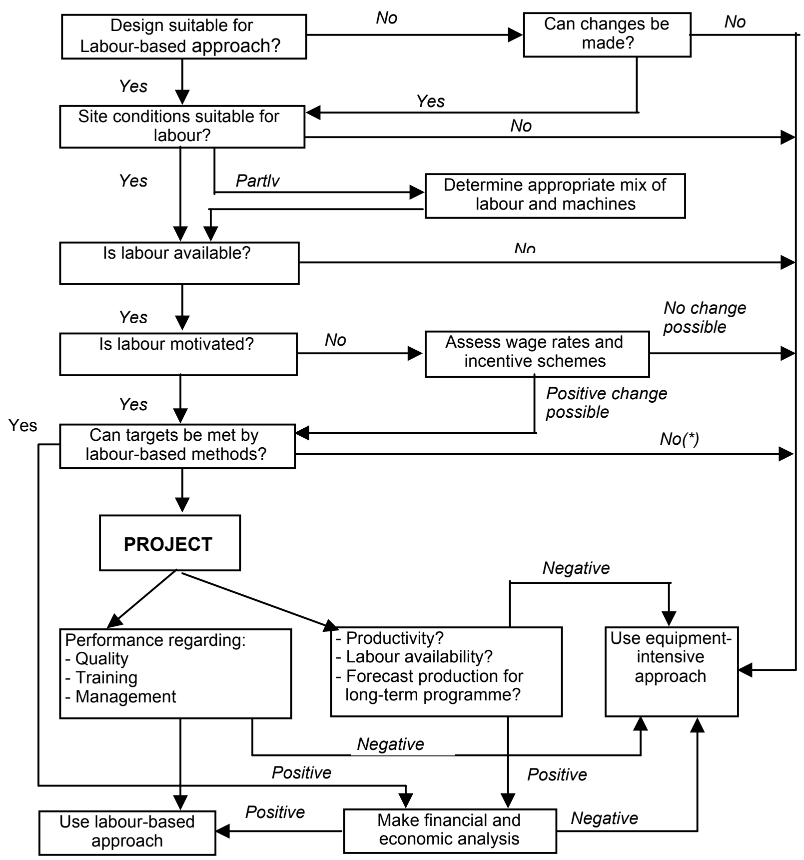
CHOICE AS A RATIONAL PROCESS

Given an unbiased approach to the consideration of technological options it is still the case that, in a given set of circumstances, the choice of technology is conditioned by a number of factors:

- The design.
- The site conditions.
- The availability and motivation of the workers.
- The quality standards to be applied.
- The required speed of construction.
- Finally, the costs of the different approaches.

The following chart can be used to make choices as to what mix of labour - and capital-intensive technologies should be used for individual projects. However, most road organisations are policy oriented and do not analyse their overall approach or the appropriateness and cost-effectiveness of alternative strategies.

4. Decision-making regarding technology choice



In some cases, even when circumstances are generally favourable, there may be a need for a pilot project to link productivity and quality norms to the specific circumstances in which the programme is to be implemented and to organise preparatory activities such as training. Prior to the stage of deciding, that a pilot project might be advisable answers are required to eight questions:

1. Has the design suitability been assessed?
2. Can design changes be made?
3. Are site conditions suitable for labour?
4. Is it an appropriate labour/equipment mix?
5. Is labour available?

6. Can labour be motivated?
7. Are wage rates and incentive schemes appropriate?
8. Is achievement of production targets possible?

The means by which answers to these questions can be sought will be briefly discussed below and some aspects will be further elaborated in other parts of the course. Moreover, it should be noted that for maintenance, the design and site conditions aspects carry less weight, and the choice should therefore primarily be based on the remaining factors. Scrutiny of these shows that the non-technical aspects are primarily concerned with labour issues. This is evidentially a vital subject, but its importance and complexity are frequently underestimated.

has the design suitability been assessed?

The likely future emphasis on rehabilitation and maintenance reduces somewhat the importance of this question. However, behind it is experience over the past two decades, which has shown that in its present form the design process is not technology neutral. It has a built-in bias in favour of capital-intensive/labour saving technologies, because engineers often automatically assume that these will be employed. Labour-intensive and local resource based technologies are either not considered at all, or it is attempted to fit them to designs which are inappropriate for execution by such technologies. This puts them at a disadvantage and has allowed their viability to be called into question.

The most important aspect to establish is what assumptions regarding methods of execution are explicit, or implicit, in the design. If these are clearly machine-based then the choice process must give special emphasis to the next stage 'can design changes be made'. There is, however, an important consideration regarding design philosophy. People are much more adaptable than machines. Therefore, the design can assume less standardisation: thus, instead of having to design using slightly pessimistic assumptions the construction can be more easily modified to suit actual conditions as they arise. This is especially important given the trend towards spot improvement policies for road works.

can design changes be made?

Assuming there are no institutional and contractual reasons why changes cannot be made then the whole design from general concept to detailed specifications should be re-assessed with a view to establishing and choosing between all technically and economically feasible options. Sometimes trials will be necessary to do this. Particular attention will need to be given to the location of the road, especially the alignment, so as to minimise earthworks. The geometric design standards should be scrutinised and the extent to which equipment-intensive methods are implicit (e.g. shape, dimensions and even the position of the drainage ditches) established. Each part of the design specification should then be examined to consider if labour-intensive substitutes are feasible.

5. Examples of possible design changes to roads

- Road-base specification options should include Telford base and water-bound macadam.
- Retaining wall design options should include masonry and gabions.
- Gravel surfacing specifications should include options for the use of as-dug material and should allow the varying of the thickness of the surfacing depending on its quality
- Bridge designs should allow for the use of locally grown timber.

are site conditions suitable for labour?

There are some obvious considerations such as extremes of temperature, remoteness, unhealthy working environments (malaria, denge fever, bilharzia), insecurity, presence of land mines or danger from wild animals. Limitations were placed on the use of labour in Himalayan India due to the extreme altitudes and associated rock and cold temperatures. In Botswana the problem of high late morning and mid-day temperatures was addressed by starting work at daybreak.

Technical factors conditioning the use of labour are more to do with site specific operations, the quantities and difficulty of the operations, and the way in which it is possible to organise them. For some operations equipment has a clear advantage and in other cases the same is true of labour:

6. Technical feasibility checklist

Difficult for Labour:

- long distance haulage
- compaction
- surfacing of roads
- mixing: stabilisation, high-quality pre-mix
- production of certain aggregate grading
- high strength concrete

Difficult for Equipment:

- stone pitching
- excavation in confined spaces
- selection of materials for excavation
- brick crushing, and soling

is it an appropriate labour/equipment mix?

The choice will vary with the design options that are feasible, the tasks and activities deemed suitable for labour under the prevailing site conditions, the output targets it is desired to achieve and the types of equipment that are available. It is assumed that all selected options are technically capable of achieving defined standards and that they are an economic use of the resources required. Experience shows that potentially labour can execute:

- All but 10-20 % of direct costs on bitumen and concrete roads i.e. 80-90 % by labour;
- All but 2-15 % of direct costs on earth and gravel roads i.e. 85-98 % by labour.

is labour available?

Labour supply for road work is highly dependent on the seasonality of agricultural activities, the availability of other wage work opportunities, population density and the prevailing wage rate. When a wage rate compares favourably with other wage work opportunities, a greater supply of labour will result. However, in this case regular wageworkers, which are predominantly male, tend to displace the more disadvantaged workers. While an appropriate wage is needed to retain regular labourers, special efforts to recruit disadvantaged rural residents, especially women and the landless need to be made or they will be crowded out. This has been the general experience 'in public works programmes in developing countries.

can labour be motivated?

Labour motivation is closely linked to the regularity and level with which remuneration is received. Numerous studies have shown that the failure to pay wages when they are expected is very de-motivating. This is a crucial point and cannot be stressed too strongly. Whilst no employer wishes to pay more than necessary, the basic wage must be at a level labourers accept as fair compensation for the work they are required to do. It should also relate sensibly to that available from other employment opportunities in the surrounding area. There is no substitute for a quick tour of the affected areas and discussions with local community leaders and employers.

There is clear evidence that whilst payment of a fixed daily wage, almost irrespective of output is administratively simple, it results both in low productivity and high costs. For example, experience in Botswana with the haulage of material by wheelbarrow indicated that per unit of output daily wage payment is 2.5 times as expensive as task work. Labour-based projects have adopted task-work as the main work incentive i.e. the payment of an agreed sum for the completion of a fixed amount of output.

are wage rates and incentive schemes appropriate?

In most cases output would almost certainly be considerably increased if it were possible to introduce “piece-work” (this is. payment for the actual amount of work done). Until recently this has not been possible. The difficulty was that it was thought to require a fairly sophisticated system of work measurement and verification. However, a relatively simple piecework scheme was introduced experimentally in Tanzania. It only applied to the more difficult tasks for which it had proved difficult to obtain and keep labour. A common characteristic of these tasks is that the workloads are easily measurable in units of length, area or volume and thus they are suitable for piecework. Such tasks comprise:

7. Suitability for piecework

- Stripping and grubbing;
- Excavation to level;
- Ditching;
- Back sloping;
- Sloping;
- Camber formation; and
- Culvert laying.

These activities account for about 40-60 % of the total labour input. The principle is that there is not a continuous and thus individually varying system for measurement and payment of work. Each activity is offered in a standard "piece" or "package" of work, similar to the notion of a task. However, workers can elect to do 1, 2, 3 or maybe more such pieces or packages each day, as they feel able. All other activities would continue to be done on a normal task-work basis.

is achievement of production targets possible?

Theoretically if enough labour is available then this should not be an issue. It is simply a question of mobilising the necessary labour to meet a particular schedule. Only if the supply of labour is limited, or for other reasons it is not feasible to employ more than a certain number - restricted supervision capacity, or limited supplies of tools, etc - should the issue arise. However, even in these situations care should be taken to establish exactly why the production targets are so critical. If an area has not previously been served by road transport, or services have been suspended for years, then why do a few extra months matter so much?

FURTHER READING

The student should refer to the following documents:

1 **Coukis, B.** (I *983): Labor-based construction programs: a practical guide for planning and management;* World Bank Publication. London (Oxford University Press).

2 **Edmonds, G.A.** (1990): *Technology choice.* (in) "Appropriate development for basic needs"; London (Thomas Telford).

3 **Schumacher, E.F.** (1963): *Small is beautiful: a study of economics as if people mattered;* (Abacus Books).

4 **Smillie, I. (1991):** *Mastering the machine: poverty, aid and technology; London,* (Intermediate Technology Publications).

8. Questions for students:

- *What are some of the disadvantages of adopting Western equipment-intensive technology?*
- *What are some of the types of bias towards reliance on equipment-based technology?*
- *What are the basic factors involved with making a rational choice of technology?*
- *How is the neutrality of design suitability affected by initial technical assumptions?*
- *What are some the design changes that might be included in a labour-intensive road specification?*
- *What factors affect labour availability and motivation?*

11: TOOLS AND EQUIPMENT FOR LABOUR-BASED CONSTRUCTION

Contents

1. Issues covered in this lecture

- Introduction
- Tools and equipment and labour productivity and costs
- Guide to Tools and Equipment for Labour-Based Road Construction
- Durability of tools
- Improving tools
- Slide show showing examples of simple equipment

INTRODUCTION

Studies by the ILO and World Bank in the early 1970's among countries that traditionally emphasised the use of labour in civil construction and maintenance showed that the simple tools and equipment used were a significant factor in constraining labour productivity. The World Bank also concluded that:

"market forces, as they operate in practice, are not likely to lead to improvements in countries where strong interest groups have already grown up behind existing practices".

This means that somebody orders and someone else makes and supplies the existing tools and equipment. They can be expected to defend their interest to continue doing, so with all the resources they can muster. The clear implication is that the Government must provide the motivation and driving force for changes to be made in the implements available to labour

2. Key concept: Poor quality

The poor quality of tools and equipment is often a significant constraint on the productivity of labour. It is unlikely this situation will change without sustained and determined efforts. Often the most severe obstacle is the bureaucratic procedures that insist on lowest tender price rather than conformity to an acceptable technical specification as the deciding supply factors.

TOOLS AND EQUIPMENT AND LABOUR PRODUCTIVITY AND COSTS

Whether the use of manual labour is cost-effective and competitive with the use of equipment depends on two factors: the cost of a work-day and the productivity or output achieved per work-day. While the wage rate varies with local circumstances and is usually fixed, a great deal can be done to raise productivity. Some of the most important factors affecting this productivity are:

factors affecting productivity

- The quality of supervision;
- Use of incentives to motivate workers;
- Good site Organisation and management;
- Proper planning, programming, administration and reporting; and last but not least
- *The quality and design of the hand tools and implements used for carrying out the work. "Tools and equipment are generally poorly designed, badly made and rarely maintained" (World Bank)*

good tools

Good tools will enhance the productivity of labour and should be of such design that they can effectively perform the function for which they are intended. Also they should be durable, safe in use, and sufficiently strong to withstand "normal abuse". However, few attempts had been made to investigate to what extent "good" tools are preferable to "poor" tools.

- What is it that distinguishes a "good " from a "poor" tool?
- Can the higher cost of "good" tools be justified by increases in their average life and increases in workers' productivity?

First, it is useful to define how a good tool is produced. Most important, clear specifications are necessary to provide guidance on the:

- Design features.
- Composition of the raw materials.
- Production methods to be used.

The producer should then be in a position to procure the raw material of the desired quality. Furthermore, he needs the manufacturing equipment to produce the tool to the required design and quality. The more sophisticated the tool becomes or the higher the demands on its quality, the more sophisticated the manufacturing equipment will be.

GUIDE TO TOOLS AND EQUIPMENT FOR LABOUR-BASED ROAD CONSTRUCTION

It is necessary to define in detail what "good" tools are. For this reason the ILO has produced a "Guide to Tools and Equipment for Labour-Based Road Construction". This Guide not only catalogues the tools and equipment available for civil construction works, but also provides advice on their design, manufacture, use, testing and maintenance.

3. Scope of ILO guide

- Handtools
- Surveying and setting-out equipment
- Site preparation equipment
- Earth and gravel excavation equipment
- Rock excavation equipment
- Rock crushing equipment
- Haulage equipment
- Spreading equipment
- Watering equipment
- Compaction equipment
- Soil stabilisation equipment
- Bituminous surfacing

The production of the ILO Guide means that major progress in the area has been made. However, there are other problems to be overcome. Existing regulations and tender procedures usually favour the purchase of the cheapest items on the market. Those responsible for the purchase of hand tools and equipment are normally not the ones who will be using them and also are generally not experts on tool specifications. Tools having a similar appearance may be in a totally different price range. The reasoning that higher unit costs may be justified by increased productivity and that the purchase of improved tools of a greater durability will eventually lead to a reduction of overall construction costs is only likely to be accepted when substantial evidence is provided.

A study by the ILO in 1981/82 in Kenya defined the relationship between tool quality/design and their durability/productivity. It provided data on the minimum requirements in respect of material quality and design feature. The performance of four different types of traditional and improved hand tools was monitored under carefully controlled conditions in the field. The hoe, the forked hoe, the pickaxe and the shovel were chosen to be tested. These are the tools most commonly used for excavation, the activity representing the bulk of civil construction work.

The figures used in the comparison that follows are derived from the field test results. Experience from a number of labour-based projects suggests that they can be considered as representative for the conditions usually encountered in developing countries. of most interest is the comparison of the relative importance of the two factors which decide the cost of moving one cubic metre of earth, i.e. (i) the cost of the tool per cubic metre moved and (ii) the labour cost per cubic metre:

4. Estimating labour/tool cost ratio

(a)	Cost of new tool:	40 currency units
(b)	Life of tool (in terms of number of m3 moved)	280 m3
(c)	Cost of tool per m3 moved	0. 143 currency units/m3
(A)	Cost of one man-day	12 currency units
(B)	Production per man-day	4 m3
(C)	Labour cost per m2 moved	3 currency units

Ratio labour/tool cost per m^3 = 4/0.143 = 21

This example serves to illustrate the relative importance of the initial cost of the tool and the cost of the labour. In this case the ratio labour/tool cost per m^3 is in the order of 20. *Thus a 5% increase in productivity justifies a 100% increase in the cost of the tool. That is the expected productivity increase due to a better design and quality of the tool is extremely important and can easily justify the higher unit cost of improved tools.* In practice such an increase in the price normally paid for 'traditional' tools, or simple equipment, can mean a very much greater chance (several hundred per cent) in the life and level of productivity that can be achieved with the implements.

DURABILITY OF TOOLS

From an economic point of view, the durability of the tools might appear to be of secondary importance, although it clearly bears some relation to price (i.e. quality). However, unless the procurement and delivery systems function very smoothly (which is not the case on the average construction site), the frequency of the necessary replacement will greatly affect productivity. Time losses due to workers trying to repair broken tools, fix handles or simply walking, to the site store to replace tools, can be reduced enormously when good quality tools are used. Poor quality tools also negatively affect productivity in another way. *The ILO study clearly showed that workers tend to use such tools more gently if it is clear that they cannot withstand rough treatment.*

The durability, or the useful life span, of the tool depends on two factors: its resistance to gradual damage (rate of wear) and its resistance to sudden damage (breakage). The study has clearly demonstrated that the latter has a greater influence on productivity. Furthermore, while the rate of wear is the determining factor as regards durability where good quality tools are concerned breakage has a far greater influence on the average life span of tools of a lesser quality. However, as already noted, the workers tended to use such tools more gently once it became obvious that they could not withstand rough treatment. This naturally, has repercussions on the productivity achieved with these tools. The more carefully the tool has to be used the more productivity will be affected.

5. Key concept: tool life span

The useful life span of a tool depends on two things: its resistance to gradual damage or rate of wear, and its resistance to sudden damage or breakage. The latter factor has the greatest influence on labour productivity. Rate of wear is the factor determining the durability of good quality tools, but breakage has a far greater influence on the average life span of poor quality tools.

IMPROVING TOOLS

Thus there are overwhelming-economic arguments to support interventions in the 'established market' so as to improve the quality and perhaps also the types of tools and equipment in use. Poor quality tools lead to low labour productivity due to:

causes of low labour productivity

- Inefficient and slow working methods because workers either have to 'nurse' the implement through the day, so as to maintain some sort of continuity of output, or because they seek to protect themselves from injury; or
- Frequent interruptions to productive work due to fatigue, the need to re-sharpen tools, or to replace broken components; and
- Limitations on the amount that can be excavated, thrown, cut or carried in a single movement due to the inherent poor design or weakness of the implements.

6. Key concept: cost-effectiveness of tools

Tolerance of poor quality implements is not a cost-effective management strategy since it leads to the unproductive use of the most expensive part of the labour and tool or equipment combination.

working practices

Working practices, including the ways tools and equipment are used, also have a strong influence on productivity. In some cases it is necessary to instruct individual workers in the way of using a given tool or piece of equipment. Other circumstances require that careful organisation of an entire group of workers is necessary

quality requirements

For the main striking tools used in the initial clearing and excavation activities shovel, hoe, pickaxes mattock, hammer, axe - two quality related factors are crucial to the productivity that can be achieved with the implement:

- Resistance to gradual damage (rate of wear); and
- Resistance to sudden damage (breakage).

The type of materials and methods used in their manufacture critically affects both of these factors. If the materials are fundamentally wrong, then no amount of care in manufacture can produce a good tool. Conversely even with the best materials inappropriate manufacturing processes will result in a poor implement that will not permit high productivity to be achieved.

Specifications

The fundamental reason, why in many countries the tools and equipment used by labour are of a very poor quality and design, lies in the practice of purchasing to lowest tender cost almost irrespective of technical considerations. This practice has to be superseded by tendering practices based on *minimum technical specifications* and cost with the first factor forming the most important condition; i.e.

tools and equipment should first have to comply with certain minimum technical criteria before the question of their price is considered.

7. Key concept: Improving traditional tools

Experience from studies conducted by the World Bank is that improvement to 'traditional' quality tools and equipment can result in productivity increases of a 100%, possibly up to 300-400%. Improvement of traditional quality wheelbarrows in Ethiopia, costing some 20% of the original price, increased their life from a few weeks to several month, or more than 1,200%.

The implication of this experience is that paying 5 or even 6 times as much as has been normal can often be justified in terms of increased production and durability. In reality many countries do not have such specifications. It was with this in mind that the ILO developed the "Guide to Tools and Equipment for Labour-Based Road Construction".

8. Key concept: Rule of thumb

As a rule of thumb: *the more intensive the working environment the more sophisticated and costly will be the tool specification.*

effecting changes

The difficulty of persuading local tender boards of the need to change existing practices should not be underestimate. This is especially so when, as is normally the case, substantial increase in price results.

Carefully designed demonstration trials are a useful means of overcoming inertia to change. This usually means commissioning the production of a batch of high quality implements or even the temporary import of a batch. Comparison of the cost and durability of 'normal' and quality implements being utilised under the same working conditions is usually sufficient to convince any sceptics in government and among the tender board of the need to establish sound local technical specifications.

EXAMPLES OF SIMPLE EQUIPMENT

The purpose of this section is to use slides to show some typical simple equipment used in labour-based construction.

- *Headbaskets still dominate haulage in the Indian sub-continent: rare elsewhere.*

- *Wheelbarrows are useful up to about 200m depending on the quality of the haul route and the wheelbarrow quality.*

- *Most wheelbarrows are poorly made for the intensive use which is normal on road works, such as that depicted.*

- *Handcarts (2 wheels) are better for intensive use, but need a firm flat surface if they are to be operated efficiently*

- *Single-axle tractor hauled trailer: rarely used for this purpose outside of China.*

- *Tractor-trailer haulage is widely used for labour-based gravelling. A simple, rugged specification is crucial. This Zimbabwe prototype has side doors for unloading.*

- *Compaction by hand is rarely efficient. It can only really be justified for limited and sensitive areas such as bridge abutments.*

- *The opposite extreme and equally inefficient for the small scattered work sites with limited daily outputs.*

- *Pedestrian operated compactors have proved very versatile.*

- *Single-axle tractor hauled dead-weight compactor (Thailand).*

- *Experimental single-axle tractor towed light grader (Thailand).*

- *Towed grader that is increasingly being used for low-cost maintenance.*

FURTHER READING

The student should refer to the following documents:

1 **de Veen, J., J. Boardman and J. Capt** (1982). *Productivity, and Durability of Traditional and Improved Hand Tools for Civil Construction.* ILO, Geneva

2 **ILO** (1981): *Guide to tools and equipment for labour based road construction* and maintenance. ILO, Geneva.

21. Questions for students:

- *Why is it not sensible to use poor quality tools?*
- *What do you understand by the term labour/tool cost ratio*
- *Why is the durability of tools important?*
- *What are the basic quality requirements of a striking tool like a hammer?*
- *Up to what sort distance of haulage is a wheelbarrow useful?*

12: SIMPLE EQUIPMENT DEVELOPMENT FOR ROAD CONSTRUCTION

Contents

1. Issues covered in this lecture

- Introduction
- Equipment development
- Haulage of materials
- Compaction
- Light grading

INTRODUCTION

One of the major misconceptions about labour-based methods is that equipment is not used at all. In fact, a basic principle of the labour-based approach is that one should use the mix of labour and equipment technology that is appropriate to the local economic environment.

economic reasons for developing simple equipment

Thus, because of differences in the level and degree of economic development the labour/equipment technological mix appropriate in Thailand, for example, is unlikely to be the one that is equally suited in Malawi. As an economy develops, wage rates increase and labour-based methods become less appropriate for a range of activities. Therefore, in those countries with more advanced economies, one would expect to see a range of equipment being developed to replace at least some of the labour. This is exactly what has been happening in Thailand demonstrating that one of the reasons for the development of simple equipment is *economic.*

Technical reasons for developing simple equipment

A second reason is *technical.* In the early years of labour-based techniques, emphasis was placed on equalising excavation across the cross-section of the road. This was to reduce the need for hauling equipment. Equally compaction was avoided if possible, again to reduce the need for machines. The success of labour-based methods resulted in their use on roads carrying ever-higher levels of traffic. These roads have larger cross sections and, with higher traffic levels, require compaction. Also, where roads have to be constructed in deep cut there is need to evacuate the soil. This is not very efficient without equipment.

2. Key concept: Equipment utilisation

The development and utilisation of equipment in civil construction can be shown to depend on two sets of forces: *economic,* due to rising wage levels, and *technical,* resulting in enhanced design and construction specifications.

EQUIPMENT DEVELOPMENT

There have been a number of sporadic, and only loosely co-ordinated, efforts to test and develop simple equipment for a variety of labour-based activities. Important research-oriented innovations took place in 1972-74 under the World Bank study of labour-equipment substitution. Since that time most new developments have taken place on ILO projects under operational conditions. This has necessarily limited both the scope and amount of effort; nonetheless much has been achieved.

main simple equipment The main activities for which simple equipment has been sought have been for material's haulage, compaction and light grading. These have been tested as part of investigations into alternative road maintenance strategies for road networks as a whole using labour-based methods and tractor-drawn equipment.

HAULAGE OF MATERIALS

In 1981 the ILO published comprehensive guidelines on tools and equipment for labour-based road construction and maintenance in general, and on the design and manufacture of simple means of haulage. Since that time there have been a number of initiatives to improve the reliability and range of both non-mechanised and mechanised means of haulage.

3. The World Bank guidelines on haulage distances	
0 - 200 metres (m)	Wheelbarrows.
200m - 2km	Animals.
2 km - 5km	Tractors and trailers.
More than 5 km	Trucks.

headbaskets For short hauls of 30 metres or less, particularly in difficult terrain, the headbasket is near optimum as a means of haulage. The headbasket is simple and very cheap, and its manufacture can generate additional local income. It offers little scope for improvement other than to find ways of introducing it to the many areas, especially in Africa, where it is not at present used.

wheelbarrows The wheelbarrow is probably the single most useful item of equipment for labour-based road construction and has been used for haul distances up to 200 metres in Lesotho. However, many of the wheelbarrows commonly in use are of an extremely inefficient design and are poorly manufactured. The weight distribution is inefficient and restricts haul length, and the size and type of wheel is ill suited to construction sites.

Recent work in Botswana has focussed on revising the guidelines on task rates for haulage by wheelbarrow and donkey cart. Preliminary results for wheelbarrows show that productivity with task work is considerably higher than with daily paid work, the latter being almost twice as expensive. Some 60% of all hauling by wheelbarrow was found to be over a distance of 40 metres or less, with 80% within a distance of 80 metres. Within this haul distance productivity was 11.5 m^3/man day. On the basis of sample observation the average load is 50 litres and average working time is 5 hours. Women carried out almost half the work and their productivity was the same as that of the men.

animal carts Animals can be a most appropriate source of power for haulage yet, except in a few areas, they are rarely used for construction. In the countries where animal carts are common there is a growing appreciation that the scope for improving their general design is considerable. The major drawbacks of the traditional vehicles are poor axle bearings, excessive unladen weight, the absence of a braking device, poor weight distribution over the cart length, and no system of tipping or bottom discharging. But in many cases, the worst part of the design is the crude harnessing device. It has been estimated that a better harness design could often double the output of the animal.

donkey drawn carts

Early work on the Botswana pilot project concentrated on the development of donkey drawn carts for haul distances longer than were feasible by wheelbarrow, generally considered to be a maximum of 200 m. A system of using carts was successfully developed and used. The main conclusion of the study were that:

- A two-wheeled tipping cart of 0.5ml capacity hauled by four animals was optimal.
- Up to 500 metres, donkey-drawn haulage was financially competitive with alternative tractor and trailer systems even when unrealistically high gross utilisation rates were assumed for the latter.
- At more realistic utilisation rates donkey-drawn haulage was found to be financially competitive up to 2.5 kilometres.
- Since most haulage was in fact less than one kilometre it was concluded that the occasional longer haul could easily be absorbed into normal work and there was no justification for tractor-trailer purchase.

These findings have been corroborated in a study in Tanzania of haulage by contractors. Animal haulage - using donkey drawn carts of 0.5 to 0.6-m3 capacity - was found to be less costly, up to haul distances of 3 kilometres, than the equivalent equipment-based gravelling. The carts had two shafts for hitching to a single donkey. A second animal could be attached to assist on steep inclines or just as an additional help. A wooden saddle placed on the donkey carried the weight of the cart. The cart could be tipped by raising the shafts off the animal(s).

tractors and trailers

Providing haul distances do not exceed about 5 km the tractor-trailer combination has proved very attractive for labour-based construction. The main reason is that one tractor can be used with several trailers for transporting materials. Since the trailer can be unhitched, the more costly tractor does not have to stand idle while the trailer is being loaded. However, experience has shown that the trailers need to be very carefully constructed if they are to withstand the rigours of a construction site.

Tractor size: The early preference was for 45 horsepower (hp) tractors and tipping trailers of 2.8m^3 capacity. More powerful tractors, of up to 80 hp - and larger trailers of up to 4.5 m^3 - are now sometimes used for especially demanding operations such as grading or rolling, although the main limiting factor seems to be local availability and easy of servicing rather than power. Also, the manoeuvrability of the larger units can also be problematic in hilly terrain due to the difficulty of turning the combination around.

Non-tipping trailers: The use of non-tipping trailers is now favoured due to problems experienced with the hydraulic systems of tipping trailers. Current experience is not in favour of double axle trailers as they are difficult to manoeuvre and are too heavy for normal agricultural tractors when fully loaded.

Power tillers: The power tiller, or single-axle tractor, is a new machine that is thought to have considerable potential for labour-based methods. They are simple, and can be produced locally if there is a basic manufacturing capacity. So far they have been used mainly in Asia (Thailand) - where the use is very common to haul water tanks (bowsers), rollers and scraper blades - due to their widespread application in rice farming.

haulage summary

The following table gives an indication of the order-of-magnitude values for the haulage characteristics of different modes of transport that might be used for carrying construction materials.

4. Indicative Characteristics of Haulage Transport

Transport mode	*Load – kg.*	*Speed – km/hr*	*Range – km.*
Head load	20	5	10
Wheelbarrow	100	4	1
Hand cart	150	4	5
Bicycle	60	10	20
Donkey cart	400	6	15
Ox cart	1,000	5	10
Motorcycle	100	50	50
Power tiller	1,000	10	15
Pick-up	1,200	80	200
Light truck	12,000	80	200

Source: **Starkey, P.** (2001): *Local Transport solutions: peoples. paradoxes and progress.* Rural Travel and Transport Program of the Sub-Saharan Africa Transport Policy Program (SSATP Working Paper No. 56). The World Bank, Washington DC.

COMPACTION

For minor rural roads, which are usually the focus of initial efforts to introduce labour-based methods into countries where they have no recent history, compaction is often considered unnecessary. Earthworks are allowed to consolidate naturally and compact under the influence of traffic. This is normal on most Food-for-Work projects.

importance of compaction

However, in most situations compaction is unavoidable if the long-term integrity of the structure is to be guaranteed e.g. around bridge abutments and culverts, or with deep fills. The difficulty of achieving a satisfactory degree of compaction has been a issue in designing labour-based operations - since in many countries the conventional plant (i.e. self-propelled steel-tyred rollers) are:

- Too heavy and difficult to transport to scattered sites;
- Have outputs that are too high to make their use economic for labour-based operations; or
- Are incapable of coping with the rough formations which labour-based operations can result in if not carefully controlled. The latter is one of the reasons why earthworks in Asian countries like Bangladesh are seldom compacted.

manual compaction

Detailed performance data for different types of manual compactor (1, 2 and 4 man) have been evaluated. It is difficult to give precise results because these vary with the material, moisture content, height to which the rammer is raised, design of rammer and number of passes. However, 90-95 % standard maximum compaction can normally be attained by between 4 and 8 passes.

Both in Bangladesh, and elsewhere, simple manual compactors of 7-

10 kg weight were found to be most convenient with concrete or steel rammers being more durable than those made of wood. Because they also normally have a smaller 'imprint' they also apply a higher degree of compaction effort.

compaction in the Kenyan Minor Roads Programme

The Minor Roads Programme improves classified roads to all-year access and road user costs become a factor of high importance. A simple form of compaction was therefore considered necessary. Since compaction with equipment such as tractor towed dead weight rollers, self propelled vibrating rollers, etc. was considered less suitable for a labour-based programme, a steel roller which could be pulled by labourers or animals was developed. The roller consisted of a hollow steel drum, which could be filled with water for operation and emptied for easier transport from site to site. The weight of the empty roller was 500 kg and when filled with water 1,200 kg. The width of the drum was 90 cm. Field trials with this roller have shown the following results.

- *0-5% gradient: 8-12 labourers, 4-6 donkeys, or 2 oxen.*
- *Up to 10% gradient: 18 labourers.*

On gradients of more than 5% animals were unable to restrain the roller while going downhill. Compaction was done without watering. Although the moisture content of the compacted soils was usually less than the optimum moisture content, 8-12 passes achieved a density of 95% of the maximum dry density. In dry areas or on stony or sandy soils the roller was less effective. Labourers, donkeys or oxen could tow the roller.

Lesotho experience

Similar trials in Lesotho had mixed results. They used a simple concrete roller 45 cm in diameter and 90 cm wide, pulled by labourers. The gravel was watered to bring the moisture content to an optimum, and compaction was done in layers of 7.5 cm. Whilst satisfactory compaction of the top 15 cm layer was achieved after ' a reasonable number of passes the trials were abandoned in favour of conventional self-propelled rollers. The main reasons given were that:

- It was only satisfactory for fine gravel which is uncommon in Lesotho,
- A large amount of labour was needed on the normal gradients, which generally exceeded 4%; and
- Superior performance of power-rollers. No cost comparisons appear to have been made

Indian experience

The feasibility of animal-drawn compaction had been demonstrated in the World Bank studies on labour substitution in 1972-74 in India. Details of the most promising roller from the trials in India showed only slightly inferior performance to a standard 6-10 tonne dead weight power roller as long as the thickness of the layer to be compacted did not exceed 15cm.

compaction in Ghana

Pedestrian vibratory rollers have been used for compaction in labour-based road works in Ghana on cut-to-formation, camber formation and for gravelling activities. During formation activities the fill materials were compacted in layers not greater than 15cm at a time. The water content in the loose material was checked and if necessary water applied before compaction. After formation, the camber was formed using materials excavated from the side ditches and slopes. A 7% camber was to be achieved after compaction.

The compaction for camber formation and gravelling was done half-road-width at a time. This enabled the traffic to move on the other half width of the road. Compaction was done from the outer edge of the road towards the centre of the carriageway. The roller tracks were to overlap each other about 10cm side to side. As a rule of thumb, any point along the carriageway should be compacted without vibrating for one pass and then with vibration for another five passes before the final pass, which was done without vibrating. The moisture content before compacting should be checked and if necessary watered. Along the edge of the road compaction was done manually by hand rammers. Compaction tests were carried out and 98 % density was achieved after compacting using the above method (conforming to Ghana standard requirements).

5. Key concept: Compaction

It is necessary to be very careful in deciding compaction requirements based both on traffic, soil and weather conditions. Compaction only by consolidation and traffic is not a ways satisfactory, but mechanical compaction represents a major additional and recurrent investment.

LIGHT GRADING

In many developing countries, the motorised grader is the principal item of equipment for maintaining unpaved roads. However, they are not usually available due to inadequate funding resources, mainly for spare parts and maintenance facilities, and the shortage of the skilled manpower required for the maintenance of this equipment. This low level of availability has led, particularly in African countries, to inadequate maintenance operations on the majority of the unpaved road networks.

wheeled agricultural tractors

Research in the early 1980s suggested that for many secondary and tertiary road networks, routine and some periodic maintenance could be carried out using wheeled agricultural tractors as the sole power units, towing mechanical graders, gravel haulage trailers, water bowsers and rollers as required VP. There is a long history of using tractors for light grading either with a blade mounted on the tractor itself or with an independent towed grading unit.

U.K. Forestry Commission

In the U.K. the Forestry Commission uses tractors with a special extended chassis to enable a light grading blade to be mounted between the front and rear sets of wheels. These vehicles are used to grade its large network of earth and gravel surfaced roads.

experience in Zimbabwe

Local manufacturers in Zimbabwe currently fabricate a 2 tonne mass towed grader. A number of other African countries namely Malawi, Zambia - and to a lesser extent, Ghana, Tanzania and Kenya - also use the Zimbabwe manufactured grader. It is normally towed with a 50-75 hp agricultural tractor. They are generally used for removing corrugations on earth roads or returning gravel from the shoulders to the carriageway, on gravelled roads with traffic volumes of up to 200 vehicles per day. One overseer, 20 men with one tractor, one trailer and one blade are responsible for the maintenance of 300 km of road. These towed graders have proved to be extremely reliable with a minimal requirement for spare parts.

experience in Tanzania and Thailand

Experimental work in Tanzania indicates that the grader uses 5 passes on each side of the carriageway with a *maximum* cut of 10 cm. It can cover a distance of 2 km. of road per day. An experimental study in Thailand indicates that the performance of the towed grader in reducing surface roughness is similar to that achieved using the motorised graders.

experience in Kenya

In Kenya, a local manufacturer is currently producing a heavier towed grader of approximately 5 tonnes mass. These are fully trailed units with greater load transfer on to the tractor driving wheels, whilst the longer distance between the hitch point and rear wheels ensures a more even grade. These units require a 100 hp 4WD tractor. They can effectively replace motor graders for reshaping and maintaining the camber of earth and gravel roads. Daily output is lower than that of a 125hp motor-grader, but the combination has lower capital and running costs, easier maintenance, significantly higher availability and the flexibility of using the tractors for a range of other activities.

experience in South Africa

The most recent, simplest and cheapest of devices for restoring the condition of earth and gravel surfaces is reported from South Africa. It consists of a “drag” made of alternating fluted rubber scrapers and steel reinforcing cables, which is used to maintain roads susceptible to corrugations. One man can operate the method and any suitable vehicle (e.g. a light van) can be used for towing. The vehicle simply requires a towing hitch or other device over which a chain can be fixed. The speed of the towing vehicle is very important and should be limited to between 7-10 km/hr. The decrease in surface roughness after one pass averaged between 30-40%. It proved to be most successful on fine-gravel and sandy roads with few or no stones. These materials are common in more arid areas. The cost of road rehabilitation using this drag is estimated at about 12% that of a normal grader.

FURTHER READING

The student should refer to the following documents:

1 **Barwell, I. J. and G. Hathaway** (1986): *The Design and Manufacture of Animal Drawn Carts.* London (Intermediate Technology Publications Ltd.)

2 **Coukis, B**. (I983): *Labor-based construction programs: a practical guide for planning and management;* World Bank Publication. London (Oxford University Press).

3 **Dennis, R.** (undated): *Handtools for Labour-based Roadworks: Guidelines for selection and procurement.* MART Publication, Loughborough University, England.

4 **ILO** (1981): *Guide to tools and equipment for labour based road construction* and maintenance. ILO, Geneva.

5 **Karlsson, L.** (1987): *Compaction by Labour Compatible Equipment; Pilot Project on Labour-based Road construction and Maintenance in Thailand.* World Employment Programme CTP 64, ILO, Geneva.

6 **Larcher, P. and R. C. Petts** (undated): *Selective Experience of Training, Contracting and Use of Intermediate Equipment for Labour-based Roadworks.* MART Working Paper No. 2, MART-ILO, Loughborough University, England.

7 **Petts, R. C. and T. E. Jones** (1990): *Towed Graders and Tractor-based Maintenance of Low Volume Roads*. Fifth International Conference on Low Volume Roads.

8 **Starkey, P.** (2001): *Local Transport solutions: peoples, paradoxes and progress.* Rural Travel and Transport Program of the Sub-Saharan Africa Transport Policy Program (SSATP Working Paper No. 56). The World Bank, Washington DC.

6. Questions for students:

- *What are the two main factors that effect the development of simple equipment?*
- *In what circumstances is the use of wheelbarrows appropriate for materials haulage?*
- *Should you use a tipping trailer in conjunction with a tractor for materials haulage?*
- *What are the disadvantages of using self-propelled steel-tyred rollers for compaction?*
- *In what circumstances might manual compaction methods be appropriate?*
- *How can agricultural tractors be utilised for grading activities?*

13: CASE STUDY OF LOW-COST ROAD SURFACING

Contents

1. Issues covered in this lecture

- Background
- Concerns regarding use of gravel
- Available alternatives surfacing
- Scope of the LCS review

BACKGROUND

Lecture 9 raised the issue of the sustainability of using laterite as a low-cost surfacing for rural roads. Alternative low-maintenance surfaces are available that may provide better solutions. This lecture describes a case study of a Low Cost Road Surfacing (LCS) Project funded by the British Government that is investigating and demonstrating alternatives in Cambodia, Vietnam and Thailand.

The outcome of the LCS Project will be the development of international guidelines on alternative road surfaces to be constructed and maintained using local labour and materials resources, and simple equipment techniques, where this approach is both feasible and appropriate.

rationale for the LCS project

In countries such as Cambodia the majority of the national public road network is unpaved. This proportion can typically be up to 90% or more. In addition, there are many unadopted or unclassified roads and routes that also provide a vital service for the rural communities and the poor. Many of these routes are not surfaced. However, where provided, the usual constructed running surface for these roads is selected natural gravel or cementitious material such as laterite. These naturally occurring materials are usually excavated from pits or quarries and hauled by trucks or tractors and trailers to be laid on the previously shaped formation or road surface. They are then watered to achieve a suitable moisture content and compacted to form an 'all-weather' running surface.

the problem

Unfortunately the agents of weather and traffic cause the laid material to be eroded and depleted. In natural gravel the binding fines, or clay materials, lose their cohesive properties through moisture loss in dry weather. They are then easily drawn out of the surfacing material by the action of pneumatic tyres. The losses are substantial in countries with long dry seasons. Intense rain also washes out the fines. Rates of gravel loss have been studied in a number of countries and empirical relationships have been established with regard to the various influencing factors.

CONCERNS REGARDING USE OF GRAVEL

There are five very serious concerns to the national governments, development agencies and rural communities regarding the use of gravel road surfaces.

financial and economic cost

Firstly there is the financial and economic cost of the provision and on-going replacement of this gravel surface material. Gravel is a 'wasting' surface. Typically an initial gravel layer of 200mm will be laid as a road surfacing. A residual gravel thickness of about 80-100mm is required to adequately support the traffic and protect the underlying weaker/erodable in-situ soil. This leaves the top approximately 100-120 mm of the initial surface to act as a 'wearing' layer. Depending on factors of material, traffic, climate and gradient, the 100 - 120 mm wearing layer can be lost in between 1 to 10 years! Box 2 shows typical measurements taken from laterite surfaced roads in Battambang Province.

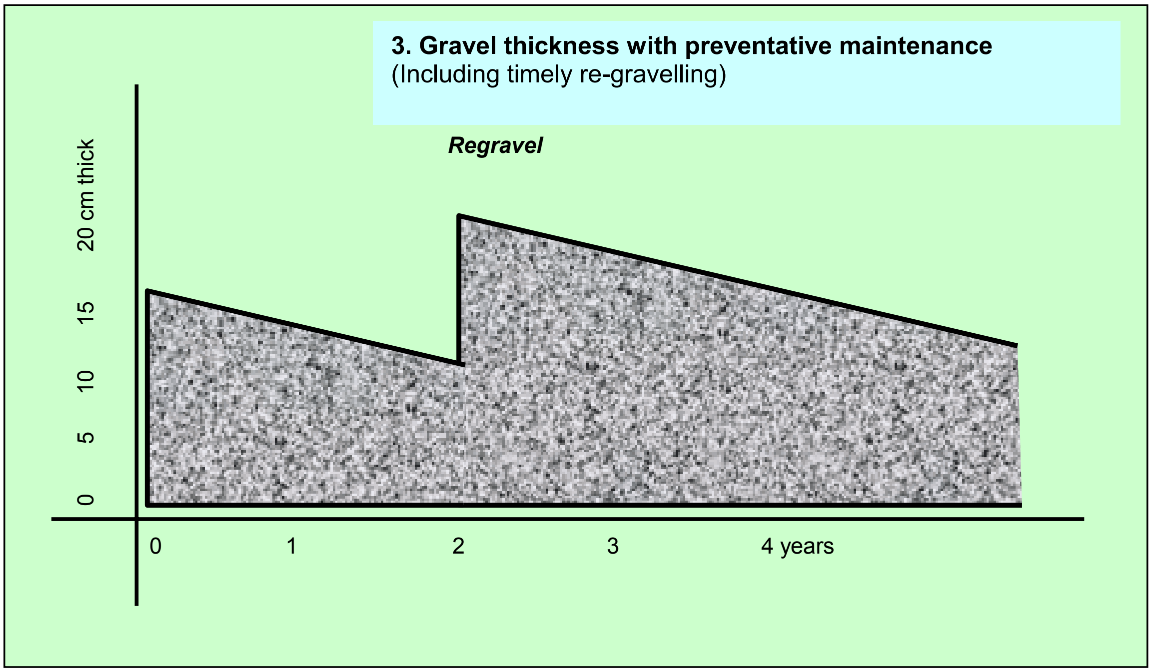
2. Residual Gravel Thickness on Roads in Battambang

Road No.	Year constructed	Residual gravel thickness (cm)	Estimated annual gravel loss (cm)
1	1998	5*	3
2	1998	5*	3
3	1999	9	3
4	2000	8	6
5	2000	10	5
6	1999	12	2
7	2000	8	7
8	1998	8	2
Estimated Average Annual Gravel Loss (cm)			**3.4**

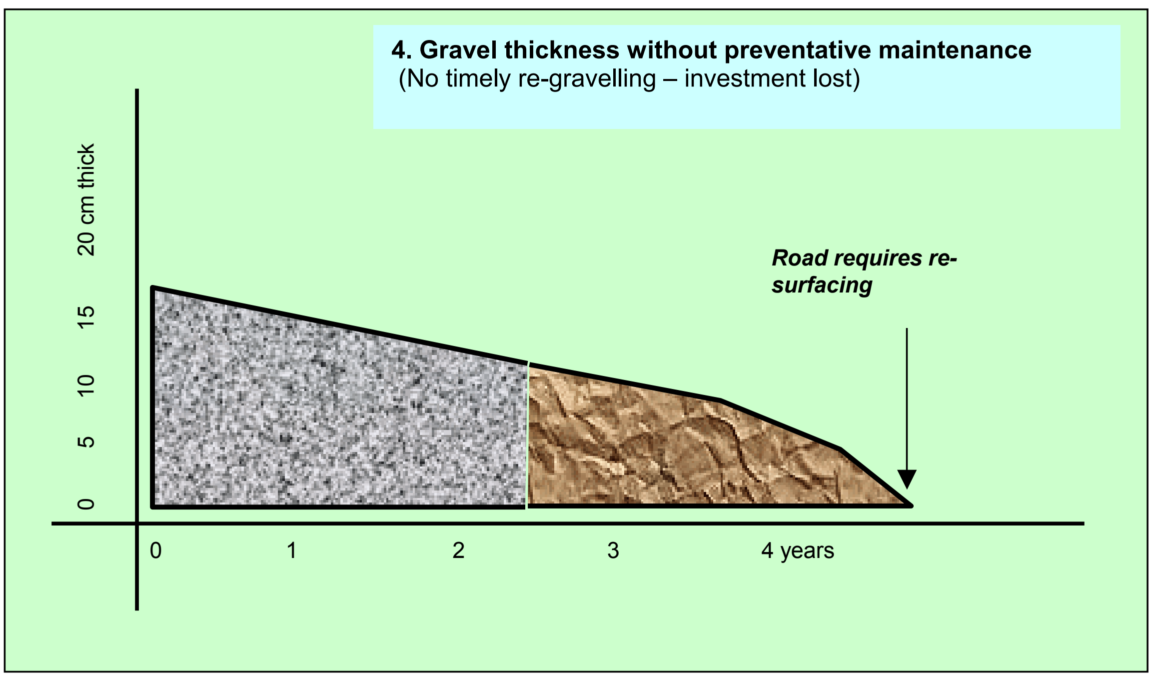
** Potholes starting to form in road surface*

The observed rates of gravel loss agree with empirical relationships that would predict a loss at up to 4 cm per year for laterite roads.

The full cost of each periodic regravelling operation depends on factors such as width and thickness of gravel layer, gravel quality, haulage distance, haul conditions, technology used, location, mineral fees, organisational arrangements, etc. This is without considering the further routine maintenance costs such as grading/reshaping, patching and off-carriageway operations. Few developing country government agencies currently have the financial resources to sustain their designated gravel road networks. Communities also find it difficult to generate and allocate such quantities of funds or resources for road maintenance. Box 3 illustrates the regular regravelling requirements due to loss of surface material in a typical situation. Box 4 shows that inability to provide timely periodic maintenance of a gravel surface will quickly lead to the total loss of investment and all-weather access.



Further costs are also involved in the periodic regravelling operations, as there is additional deterioration of other road network sections caused by the haulage of materials along them.



institutional and management problems

The second and widespread problem is the quantity of maintenance work required in routine maintenance and regravelling, and the burden on national and local road agencies and organisations. Institutional and management problems identified by the World Bank and others show deep seated, complex (and to date largely unsolved) problems of organising adequate maintenance of road networks in developing countries, particularly at the lower network levels. The physical, human and financial resources and motivating forces are simply not available to sustain the designated or desirable gravel road networks of most developing countries.

Despite strong economic and management arguments for asset preservation through good maintenance, there are anyway usually considerable political, commercial and social pressures to focus the limited available resources on the further development of the road network. For a road user or politician it may be difficult to accept that scarce resources should be allocated to re-gravel a visually good gravel surface nearing its critical residual thickness, which would prevent its deterioration to a condition requiring very expensive rehabilitation.

inappropriate technology and sustainable employment

The third serious problem is that of inappropriate technology. This is related to the fourth problem of lack of sustainable employment opportunities and the way this constrains poverty alleviation initiatives. Regravelling is usually carried out using imported, heavy equipment methods. This requires considerable financial investment in a high-cost finance environment There are also very serious problems of ownership and operation of this sophisticated equipment in developing countries (see Box 5) and common lack of appreciation of the real costs involved. Furthermore, the local communities, small enterprises and the poor have no stake in this technology, which primarily benefits manufacturers and large contractors. Even gravelling by tractors and trailers has a high equipment provision and operation cost component.

5. Problems often associated with sophisticated imported heavy equipment for roadworks in developing countries

- Dedicated function (can only be used for one operation)
- Inter-dependence (e.g. bulldozer, loader, trucks, motor-grader, bowser, roller all required for gravelling - what happens when ONE link in the chain breaks down?)
- All equipment and spares imported - consuming scarce foreign exchange
- Long spares supply lines and delivery times
- Limited local market for equipment sales of each model
- Few dealers able to provide the necessary close support
- High capital and finance costs
- High costs of stocking and provision of spares
- High pressure hydraulic systems
- Sophisticated mechanisms
- Specialist repair and maintenance skills, tools and facilities required (often only available in the capital or major cities)
- Frequent model “improvements" causing spares stocking and procurement problems and “planned" obsolescence
- Disposable components; difficult to repair or refurbish
- Lack of continuity of workload for plant items of dedicated function

RESULT - low availability and high overall costs!

It is desirable to provide low initial cost, essential basic access to all rural and urban communities. This should be achieved using affordable and sustainable technologies (both in provision and maintenance). There will be a greater chance of sustainability if local resources (materials, labour and simple equipment), management, enterprises and communities can be involved in an effective way.

environment The fifth equally important concern is with regard to the environment. There are three main issues in this respect. Firstly, gravel and laterite deposits are particularly limited and they are a non-replaceable resource. In many areas the local deposits are non-existent, not accessible because they are under farmland or worked out, leading to extremely expensive hauls of up to 50 km and more.

Secondly, is the impact that the dry weather dust pollution has on road users and the people who are living adjacent to the road. This can lead to cleanliness and health problems, as well as damage to crops and property, and increased wear on vehicles.

Thirdly, dust emissions can cause a severe visibility related safety hazard for road users, particularly for overtaking movements, and for pedestrians and animals on the road.

conclusions The foregoing problems combine to make gravel an inappropriate surfacing for many road locations in developing countries and the lack of approved appropriate and affordable alternative road surface is a serious impediment to ALL development activities, particularly in the rural areas. The poor and disadvantaged groups in society are particularly affected.

AVAILABLE ALTERNATIVE SURFACING

Fortunately there is a range of alternative low-cost surfacing which are already used in various locations around the world. However, the alternative surfacing techniques are not properly documented and accessible; thus decision-makers are usually not aware of the options, potential, requirements, cost and benefits.

need for authoritative guidelines Authoritative guidelines are required to enable road authorities and other interested groups in developing countries to understand the technology, issues and features of these low-cost, appropriate surfaces and enable them to be more widely adopted.

range of options Improvement options range from very low cost ‘hardening’ of access suitable for non motorised transport or motorcycles, up to paving suitable for very heavy truck axle loads. All of these techniques can be implemented using labour and simple equipment. Basic access can be provided and maintained in many situations for annualised funding or equivalent resources of much less than US$1,000 per km per year equivalent, principally using resources available within the community. The labour orientated road base and surfacing techniques on which the LCS project is focusing are summarised in Box 6 and listed and described in detail in Box 8.

6. Basic road surfacing options

1. Gravelled (unbound) roads

2. Paved roads:

Rigid pavements (concrete)

Flexible pavements:

xxxii. Bituminous

- Paving blocks (stone and concrete)

problem sections There is also considerable potential to use the alternative surfacing on short particular problem sections such as through villages, weak sub-grades and hill sections; effectively a 'spot improvement' or basic access approach for when resources are particularly constrained. Gravel is anyway not recommended for gradients of more than 6% due to severe erosion in heavy rainfall.

benefits These methods can use labour-based approaches, typically generating more than 1,500 worker-days per km during construction. The local communities (particularly the poor and otherwise unemployed) would benefit considerably from their adoption in terms of productive work creation, empowerment of groups that currently are severely disadvantaged, and local enterprise creation. These advantages are in addition to the economic benefits to the poor communities through provision of improved infrastructure that would otherwise not be provided, and tackling poverty through creation of increased social and economic opportunities in the communities. Appropriate use of the various surfacing options would depend on local circumstances.

equal opportunities The labour-based techniques can create equal opportunities for female employment where properly managed and social traditions are approached sensitively with suitable consultation. The alternative surfacing are often low maintenance so that they would considerably ease the financial and (intractable) institutional burdens on road authorities and communities. Organisations, enterprises and community groupings with limited resources and skills could use them. The alternative surfacing would also provide considerable environmental benefits. They should be more sustainable.

SCOPE OF THE LCS REVIEW

The LCS project is carrying out a review of the experiences with labour-based alternative road surfaces in developing countries, particularly in Africa and Asia. The countries of India, Bangladesh, Nepal and China are of particular interest due to their wider experiences with these forms of road pavement. It is intended to review experiences in Southern and Eastern Africa, Arabia, the Americas and other regions where these techniques are identified. The project is also reviewing the experiences of pavements in Holland (brick paving) and France (stone paving) where they are still widely used despite the significantly higher wage costs now prevailing.

The institutional, technical and socio-economic issues that are being investigated on a national/regional basis will include:

institutional issues being

- Stage of local development (pilot/demonstration, isolated or

investigated

'mainstreamed')

- National standards, codes of practice and specifications
- Applicability/limitations of the technique (terrain, traffic, climate, materials etc.)
- Planning and policy issues
- Affordable and sustainable standards relating to local transport needs.

technical issues

- Documentation on construction methods and techniques
- Methods of quality control and testing, ensuring essential technical inputs
- Resource requirements:
- *Human resources requirements - unskilled and skilled labour components*
- *Requirements for handtools and intermediate equipment*
- *Materials requirements*
- Productivity norms
- Typical construction and supervision costs, sample Bill of Quantities
- Maintenance requirements, arrangements, techniques and costs.

socio-economic issues

- Safety issues (workers and road users)
- Labour and employment issues
- Environmental Issues
- Socio-economic issues
- Scope for (or constraints to) local contracting/consultancy application, and contracting issues
- Lessons for 'mainstreaming' (if appropriate), with respect to demonstration, awareness creation and training etc.

future investigations

After these issues have been investigated, the LCS project will prepare draft guidelines as a basis for peer review and limited trials to refine technical, management, socio-economic, gender, environmental, cost, resource poverty alleviation and sustainability issues. The resulting experiences will allow the guidelines to be further developed and finalised for possible dissemination through PIARC (World Road Association) which is a global, authoritative organisation representing the interests of national road authorities and other stakeholders in the road sector. PIARC has a declared policy of targeting the needs of developing countries, particularly through the work of its Appropriate Development Committee.

dissemination and liaison

Other dissemination paths include a network of universities and organisations active in the appropriate technology roadworks sector. These include ITC, Chieng Mai University (Thailand), the University of Witwatersrand (South Africa) and other interested academic institutions.

The LCS project is also liasing closely with the UK Transport Research Laboratory (TRL). This organisation is currently carrying out and preparing a number of research programmes that are of important and complementary relevance to the LCS project. These include research into bitumen alternative road pavements including the use of labour-based technology (Environmentally Optimised Design), Minimising the cost of sustainable rural road access and the Labour based Engineering Standards programme.

FURTHER READING

The student should refer to the following documents:

1 **Bentall, P., A. Beusch and J. de Veen,** (1999). *Employment Intensive Infrastructure Programmes: Capacity Building for Contracting in the Construction Sector.* ILO, Geneva.

2 **Heggie, I.** (1995). *Management and Financing of Roads, An Agenda for Reform*. World Bank Technical Paper Number 275, World Bank, Washington D.C.

3 **Larcher P. and R. Petts,** (1997). *Selective Experience of Training, Contracting and the Use of Intermediate Equipment for Labour-based Roadworks*. MART Working Paper No 2, University of Loughborough, UK.

4 **Malmberg Calvo, C.** (1998). *Options for Managing and Financing Rural Transport Infrastructure.* World Bank Technical Paper No 411, World Bank, Washington D.C.

5 **Millard, R. S.** (1993). *Road Building in the Tropics.* TRL, UK.

6 **Petts, R.,** (2001). *Rationale for The Compilation of International Guidelines on Low-Cost, Labour-Based, Alternative and Sustainable Road Surfacings.* LCS Working Paper No. 1, Intech Associates, UK.

7 **TRL,** (1993). *Overseas Road Note 31 (4th Edition): A Guide to the Structural Design of Bitumen Surfaced Roads in Tropical and Sub-Tropical Countries,* Transport Research Laboratory, Crowthorne, Berkshire, UK.

7. Questions for students:

- *Why is it necessary to consider alternative surfacing materials?*
- *If there is no road maintenance what happens to the residual/bottom layer of gravel?*
- *What are the sorts of problems associated with the use of heavy equipment?*
- *What are some typical examples of alternative surface options?*
- *What types of technical issues is the LCS project reviewing?*
- *Is it possible to use recycled materials for road construction?*

8. Schedule of alternative road surface improvements

	Road Surface Improvement Options	Description
C1	Dragging Road Surface	Smoothing out minor defects on an earth or gravel road surface and redistributing loose material on the surface, using tyre or blade drag.
C2	Light Grading/Reshaping of Surface	Minor reshaping of an earth or gravel surface to restore correct camber using labour or light/heavy grading equipment.
C3	Construct Natural Gravel Surface	A layer of compacted natural gravel wearing course (typically 15 – 20cm thick)
C4	Lime Stabilisation of Existing Surface	Addition of and mixing of quicklime or hydrated lime to a soil or surface material, watering and compaction to increase its strength and reduce its susceptibility to the weakening effect of increasing moisture content. This is achieved by chemical reaction of the lime with the clay particles. Mixing and compaction by light or heavy equipment.
C5	Stone Chippings Surface	A layer of single sized (typically 20mm) crushed stone chippings.
C6	Construct Hand Packed Stone Surface	A layer (typically 20 – 30cm thick) of large broken stone pieces, tightly packed and wedged in place with stone chips rammed by hand into joints, with remaining voids filled with sand. The Hand Packed Stone is normally bedded on a thin layer of sand/gravel.
C7	Construct Dressed Stone Surface	A layer (typically 15 – 20cm thick) of stone blocks cut (dressed) to a cubic shape by hand, laid by hand. Joints mortared/sealed or tightly packed and wedged with stone chips rammed into place with remaining voids filled with sand. The Dressed Stone is normally bedded on a thin layer of sand/gravel.
C8	Construct Stone Sett Surface (Pavé)	As dressed stone, however stone blocks are smaller; typically about 10cm x 10cm x 10cm with mortared joints.
C9	Construct Concrete Block Surface	A layer of concrete blocks (typically each 10cm x 20cm and 7 – 10cm thick) laid by hand on a thin (3 – 5cm) sand bed with joints also filled with sand and lightly compacted.
C10	Construct Clay Brick Surface	A layer of high quality clay bricks (typically each 10cm x 20cm and 7 – 10cm thick) laid by hand on a thin sand bed with joints also filled with sand and lightly compacted.
C11	Construct Bamboo Reinforced Concrete Surface	Jointed slabs of structural quality concrete reinforced with a split bamboo rod grid. Joints with steel weight transfer dowels and bitumen seal.
C12	Construct Steel Reinforced Concrete Surface	Jointed slabs of structural quality concrete reinforced with a mild steel rod grid. Joints with steel weight transfer dowels and bitumen seal.
C13	Construct Bituminous/Tar Sand Seal Surface	A seal consisting of a hand or machine applied film of bitumen (straight run, cutback or emulsion) or road tar followed by the application of excess angular sand or fine crushed stone, lightly rolled into the bitumen/tar.
C14	Construct Ottaseal Surface	A layer consisting of a hand or machine applied film of relatively soft bitumen (usually straight run or cutback) followed by the application of graded natural gravel or crushed stone aggregate (typically 16mm downwards), rolled into the bitumen using heavy pneumatic tyred rollers.
C15	Construct Bitumen/Tar Surface Dressing Surface	A seal consisting of a hand or machine applied film of bitumen (straight run, cutback or emulsion) or road tar followed by the application of a single layer of single sized (6 – 20mm) stone chippings, lightly rolled into the bitumen/tar.
C16	Construct Bitumen Slurry Seal Surface (and "Cape" Seals)	A seal consisting of fine graded aggregates (typically 10mm downwards), water, bitumen emulsion, cement, and sometimes an additive, mixed in a concrete mixer or other machine and spread on the road surface by hand or machine. Cape seals are combinations of Surface Dressing and Slurry Seal.
C17	Construct Bituminous Premix Macadam Surface	Graded crushed stone material (typically 28mm downwards) usually derived from fresh sound quarried rock, boulders or granular material and mixed with a bituminous binder (straight run, cutback or emulsion) and laid and compacted. Material may be hand or machine mixed and laid. Compaction by light or heavy equipment.

C18	Construct Penetration Macadam Surface	Two or three layers of single size crushed stone (of decreasing nominal aggregate size, e.g. 63 mm downwards) each compacted and with bitumen (straight run, cutback or emulsion) or road tar sprayed between each stone application.
C19	Construct Water Bound Macadam Roadbase	A layer of nominal single sized (typically up to 50mm) crushed stone compacted and fully blinded with well-graded fine aggregate, which is watered into the voids and compacted to produce a dense stable material. Layer thickness up to twice the nominal stone size. Material may be hand or machine crushed and laid.
C20	Construct Dry Bound Macadam Roadbase	A layer of nominal single sized (typically up to 50mm) crushed stone compacted and fully blinded with angular sand or fine crushed stone material, which is then vibro-compacted to produce a dense stable material. Layer thickness up to twice the nominal stone size. Material may be hand or machine crushed and laid. Suitable in areas short of water.
C21	Construct Slurry Bound Macadam Roadbase	A layer (about m thick) of single size aggregate (typically 50mm) blinded with smaller aggregate (typically 25mm), plate compacted and grouted with bitumen emulsion slurry before final compaction
C22	Construct Crushed Stone Roadbase	A layer (usually up to 20cm thick) of graded crushed stone material (typically 50mm downwards) usually derived from fresh sound quarried rock, boulders or granular material. The angular material derives its strength primarily from mechanical interlock. Material may be hand or machine crushed.
C23	Construct Mechanically Stabilised Roadbase	Addition and mixing of granular material such as crushed stone or sand to a material to increase its strength and achieve the properties required of a roadbase.
C24	• Construct Chemical or Emulsion Stabilised Roadbase	Addition and mixing of a stabiliser such as lime, cement, or ion exchange chemicals, to a material to increase its strength and achieve the properties required of a roadbase. Mixing and compaction by light or heavy equipment.
C25	• Improvement using Recycled Materials	Use of recycled road pavement materials, brick kiln waste, broken brick, demolition materials, industrial slags, etc.

Source: Intech Associates

14: CASE STUDY ON LABOUR-BASED STONE PAVED ROADS

Contents

1. Issues covered in this lecture

- Reasons for using stone road construction
- Pavement design and materials
- Community involvement
- Construction methods
- Impact of the trial
- Cost comparison of stone pavement with laterite
- Conclusions and recommendations from the trial

REASONS FOR USING STONE ROAD CONSTRUCTION

As has been emphasised in a number of the previous lectures the use of laterite to surface roads in Cambodia is becoming questionable. Although this surface has a relatively low initial cost, ongoing periodic maintenance requirements are considerable and it causes dust problems. Another important consideration is that supplies of laterite are limited and non-renewable. This lecture describes a case study of a 1.5 kilometre long stone pavement trial that examined the potential technical and employment benefits, utilisation of local resources, environmental effects and benefits to the local community of this method. The ILO initiated the study, which was implemented in Kampong Cham province in collaboration with MRD and the Kreditanstalt fur Wiederaufbau funded Tertiary Road Improvement Programme.

Stone roads are still found in many countries because of their appearance, durability, ease of maintenance and the fact that can be recycled for the same or other purposes should the need arise at the end of the pavement life. Stone pavement can also improve traffic safety by limiting vehicle speed.

PAVEMENT DESIGN

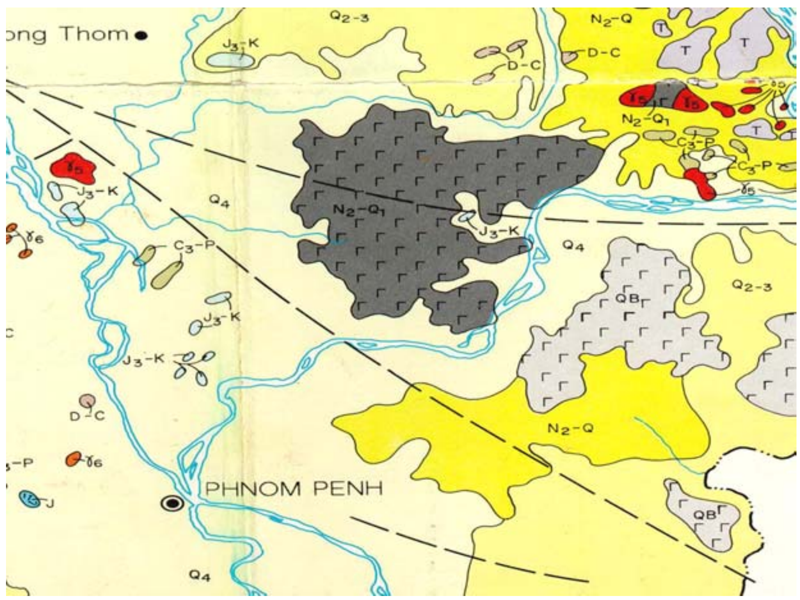
The basic design requirements for the trial was to construct a long lasting all-weather tertiary road that made maximum use of local resources and used labour based construction and maintenance methods. The basic road design was for a carriageway width of 3 metres, with 500mm shoulders, a carriageway cross-fall of 3%, shoulder cross-fall of 5% and embankment slope of 1:2 (vertical to horizontal). The pavements consisted of an earth embankment, sub-grade layer, sub-base layer and road base. The stone pavement was the base layer. Three options were chosen for the trial:

2. Trial options

- Stone packing with 200mm stone blocks (818-metre length);
- Stone packing with 150mm stone blocks 488.5-metre length); and
- Dressed stone pavement (190-metre length).

stone used in the trials The desired stones needed to be unweathered, not cracked and have strength greater than 30 Mpa. Basalt fulfils these criteria and is a basic volcanic rock found commonly in some areas of Cambodia, including Kampong Cham. It is fine grained; glassy textured, compact, hard and heavy. Good quality basalt breaks cleanly but is hard to work. Basalt is generally suitable for road metal, paving work, concrete aggregate, rubble masonry and sometimes for carving. Its availability, durability and low maintenance requirements could make it a better and cheaper alternative to laterite. The bedrock of Kampong Cham province is mainly basalt (see below). The basalt occurs as boulders either on the surface or at a shallow depth. The stone is crushed by mechanical crushers or by hand and used as aggregate. In the north of the province, villagers sell stone blocks (dressed stones). This demonstrated the villager's ability to work this type of stone.

3. Geological map of Kampong Cham Province



selection of a quarry More than one source of stone was found close to the trial site. The main stone source (2-3km from the site) was chosen to minimise haulage, good access, availability of stones, security and stone quality. Access was via an oxcart track, relatively easy to traverse in the dry season, but impassable during wet conditions. With the permission of the owner, a temporary access road, parallel to the oxcart road, was made through a rice field.

quarrying Basalt in Kampong Cham occurs as boulders, ranging from 200 to 600mm in diameter. Quarrying, channelling and cutting were needed to prepare the blocks. Handtools were purchased from the market for stone breaking but were only used for a few hours. The tools bent and deformed after a few strikes. After consultation with the villagers, parts from old vehicles, like axle shafts, were purchased and sent to a local blacksmith to fabricate more appropriate tools. Hand tools used for quarrying, breaking and shaping were a sledgehammer, club hammer, crowbar and chisel.

handling and transporting blocks Two methods were used to transport basalt blocks from the quarry to the road site. The first method used locally made Etean trucks, but these were unsuitable for the regular transport of heavy loads and frequently broke down. Later, oxcarts were hired to transport the basalt blocks. Oxcarts could carry 20-30 blocks per trip and make two trips a day. This method proved more effective, as they could operate in wet conditions more efficiently than trucks.

stone shaping Blocks were unloaded along both sides of the site. As the stones had been roughly shaped at the quarry, only minor shaping was carried out at the road site. A club hammer, template and sledgehammer were used to shape the blocks. The work norm for reshaping the blocks was set at 100 blocks per person per day. Once reshaping was completed, the top face was marked. This helped masons to lay the stones with the best face upwards. Both women and old men were willing to do this work.

stone dressing In stone dressing, the stone blocks must be roughly smoothed on all sides. A club hammer and a chisel were used for this. Each worker produced around 50 dressed blocks each day. Women mostly applied for the task of stone dressing.

COMMUNITY INVOLVEMENT

The project benefited from the full support of the local community. The Village Development Committee helped to identify the trial site and locate basalt deposits. The Committee was particularly active in locating and mobilising local labour sources, arranging the appropriate transport of stone blocks; deciding on transport routes and helping the project team secure alternative tools when those bought from the market failed. The VDC guarded the site and tools. To protect the workers and equipment the district authority provided two armed guards at the quarry site.

labour force Labour was easy to locate and people were willing to work. The exception was selecting labourers for stone breaking, which only attracted young men, due to the hard work involved. No women or older men applied for this task. Breaking. Although many people in the area break stones to make aggregate for construction, shaping stones for road paving was a new concept. In the beginning, a norm of 25 blocks per workday was set. When the number of workers fell below target, this norm was revised to 17 blocks per workday. A very strong worker could produce 100 blocks per workday. The project hired a disabled worker in the later stages of the trial. This man was an amputee who was hired to smooth initial road sections where the packing blocks were irregular. He worked on completed road sections and chipped off uneven surfaces with a hammer and chisel.

appropriate tools In labour-based stone paved road construction and maintenance, labour operated hand tools are used to produce the same results as heavy equipment in capital-intensive works. To achieve this, the selection of appropriate tools is important. The condition of hand tools greatly affects the productivity of labourers. If labourers use unsuitable or worn tools, they cannot produce as much as with tools in good condition.

CONSTRUCTION METHODS

The road selected for the trial was rehabilitated and surfaced with laterite by the TRIP Programme at the beginning of 1998.

surveying and setting out Thus, the embankment was already fixed and the existing grade and centreline of the road were followed. Depending on the condition of the existing road, the new design level varied 50-100mm from the original level. Spot levels were taken at 10m intervals using profile boards. Pegs and lines were placed every 5m both longitudinally and within the cross section.

box cutting Cutting a box within the existing embankment was needed to obtain a restraining edge for the sand cushion and stone blocks. The box edges were preserved as damaged edges can cause movement of the blocks, particularly during vibrating and compacting operations. Box depth varied from 150 to 200mm depending on the condition and level of the existing road. The camber of the box was 3%, to allow sufficient slope for drainage.

The surface soil was watered prior to compaction, with a plate compactor. Compaction was checked using a Dynamic Cone Penetrometer (DCP). Based on the DCP results, compaction was repeated until the desired result was achieved. Sub-grade soil could also be changed in case of very weak material, shown by the DCP results. To ensure a solid edge in the case of the stone dressing trial or when using kerbstones, the sides of the box were cut 100 mm deeper than the main box.

filter drains The filter drains take water from the sand cushion to the side drain to avoid water damage to the subgrade. The filter drains were rectangular, 100mm deep and 250mm wide and constructed at 5m intervals, under the side edges of the subgrade and road shoulders. The drains were 1-1.5m long depending on the shoulder width.

The drains were excavated to a depth of 200-300mm under the subgrade, with the filter shoulders reaching the side of the embankment a little above the side drains. The filter drains were filled with a 100mm layer of broken stone and sand to reach the level of the subgrade.

sand cushion Inside the box, a 50mm layer of coarse sand was spread over the subgrade, to drain water coming from the voids between the stone blocks to the filter drains before damaging the subgrade and to provide a cushion on which the stone blocks could settle evenly. The sand cushion had the same 3% crossfall as the box subgrade.

placing and packing stones Two depths of stone were chosen for the stone packing - 200mm and 150mm. For the stone dressing option, 150mm stones were used. The stone blocks were shaped before packing as this layer serves as a wearing course. Stones were placed from the edges of the road to the centre-line and laid so that each block settled on the sand cushion without any support from the blocks nearby and with a desired average space of 10-15 mm between blocks. A skilled mason could lay stones to an acceptable standard at $6.5m^2$ per day. This rate increased over time, as workers became more skilled and a smoother, better quality surface was produced towards the end of the trial.

A similar procedure was followed for the stone dressing option, with two differences. The first was laying the kerbstones at the edges of the box and the second was the final shaping of the surface. Kerbstones restrain the stone blocks of the carriageway and prevent undesired side movement or damage to the shoulders. The kerbstones were laid first, followed by the rest of the carriageway to achieve this restraining effect.

4. Filling the voids

filling the voids To avoid movement of the stone blocks, the voids between the blocks were filled. After packing the gaps with broken stones, sand was washed and brushed into the voids. A thin layer of sand was spread over the surface and washed into the voids using water. A residual coarse-grained material was found nearby that was 2.5 times cheaper than fine sand and this local material was substituted. A skilled labourer averaged 30m^2 per workday.

compaction A plate compactor was used for compaction, the vibration helping to move the fill material into the voids between the stone blocks. Compacting was carried out from the edge to the centreline of the road to avoid extra stress on the shoulders. Two passes were sufficient to vibrate the stone blocks and further compress the fill material. A skilled labourer could cover 30m^2 per workday.

road shoulders To further strengthen the road shoulders a 100mm-depth laterite layer was used to construct the hard shoulders. These work with the box to prevent movement of the stone blocks. The shoulder also serves as a driveway for bicycles and motorbikes as the stone pavement is relatively rough for this mode of transport.

IMPACT OF THE TRIAL

The total road length of the trial was 1,496.5m, with a total surface area of stone pavement of approximately 4,490m^2.

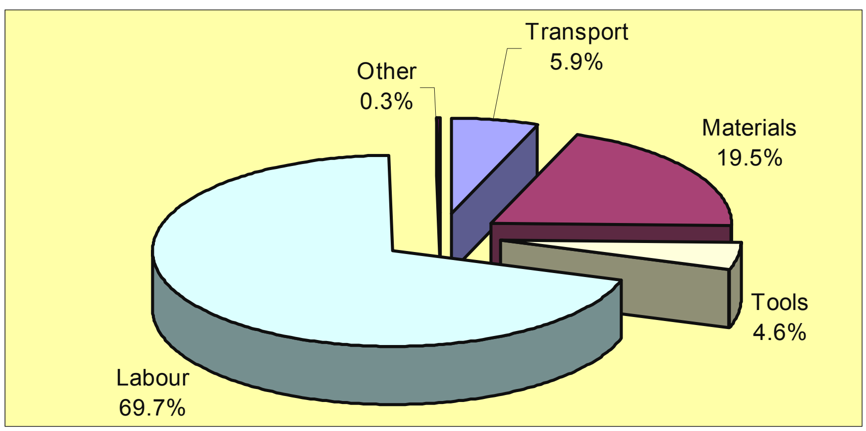
The direct impact of the trial was the creation of total 7,552 workdays of employment and income generation as follows:

5. Details of the work activities

Activity	Workdays
Stone breaking	3,393
Stone packing	620
Stone shaping and dressing	933
Box cutting	575
Repairing shoulder, compacting, filling	1,344
Loading	583
Other	104
Total	7,552

labour component Labour costs were 69.7% of the total trial costs. Materials were 19.5% of costs, tools 4.6% and miscellaneous activities 0.3%. The amount that went to the local community was 75.9% of the total cost - the sum of labour, transport and other costs. In addition, a major part of the tool cost was paid to local blacksmiths. Forty seven percent of the material cost (9.2% of the total cost) went to purchase stones to speed construction. This increased the material cost and could have been added to the labour cost by using more labour for stone breaking instead of purchasing the stones. This would have increased the labour portion of the cost to 78.9% and decreased material costs to 10.3% of the total.

6. Cost analysis of the stone pavement



dust reduction Villagers near the trial appreciated environmental improvements achieved by reduced dust levels. This is a common problem with gravel surfaced roads. The dust raised has an acute environmental impact on villages along the road and for those travelling in open vehicles. Dust is a safety hazard for drivers as it impairs visibility.

traffic pattern Surface smoothness improved steadily as the work progressed. However, this meant a rough surface at the beginning of the trial. For this stretch, motorbikes and bicycles drive on the shoulders and use the stone paved carriageway when it becomes smoother.

after one rainy season

The trial was followed-up after construction. Despite no form of maintenance, not even routine maintenance, being carried out on the stone road the road was open to traffic even during the flood period that damaged many roads in the area of Kampong Cham.

COST COMPARISON OF STONE PAVEMENT WITH LATERITE

The costs were the same for stone packing with 200mm or 150mm stones at US$6,866 per kilometre including shoulders. For dressed stone the price was US$7,582 per kilometre. The cost for one kilometre of laterite road was US$6,127. Stone packed roads were found to be particularly cost effective in the long term with a 20 year cost projection revealing substantial savings due to decreased maintenance costs.

Stone packed roads were found to be more economically feasible than laterite roads. The opportunities for local income generation were also higher. If constructed to specification, stone packed roads are longer lasting, cheaper alternatives to laterite for rural road construction in Cambodia.

CONCLUSIONS AND RECOMMENDATIONS FROM THE TRIAL

The study found the following advantages of stone paved roads – long life span, minimal maintenance, labour intensive construction and maintenance, maximum use of local resources, suitability for upgrading, dust free. The disadvantages were – relatively rough surface, slower construction, higher initial investment than unpaved roads and the requirement for well-maintained shoulders. These factors are summarised below:

7. Advantages and disadvantages of stone pavement

Advantages	Disadvantages
• Strong and durable surface, i.e. long life span • Minimal maintenance required. Easy maintenance activities	• Relatively rough surface for motorcycles and bicycles
• The majority of costs are for labour, i.e. income for villages nearby. Labour intensive construction and maintenance	• Relatively slow construction progress compared to unpaved roads - depending on the availability of stone breakers
• Maximum use of local resources	• Higher initial investment than unpaved roads
• Suitable for upgrading and staged construction in case of increased traffic • Dust free	• Requires well maintained shoulders in case of not using kerbstones

recommendation 1

Using 150mm deep stone blocks, the subgrade layer material should be carefully selected to achieve high strength. Generally, expansive soils are not recommended for this type of pavement due to the large decrease in strength when soaked with water. Although excess rainwater will decrease with time due to the sealing of the voids between the blocks, some rainwater will penetrate to the subgrade. This water may not drain quickly enough and can damage the subgrade in heavy traffic conditions. Another problem is the capillary effect in cases of flood.

recommendation 2 When using 200mm deep stone blocks, it is important to maintain a suitable minimum spacing between each block. The need for a strong subgrade layer is less, but will increase with greater traffic weight and volume. Furthermore, ensuring the proper thickness of the sand cushion is strongly recommended as it plays a major role in preventing subgrade damage. The use of 200mm thick stone blocks is recommended in case of no major increase in the cost. Special care should be taken in having a strong sub-grade coarse when using the 150mm thick stone blocks. It is also recommended to always use kerbstones.

recommendation 3 Although the cost of the pavement did not include the price of stone (which was free), stone pavement is still more economically feasible than laterite surfaced roads. This is true even if stone boulders cost up to US\$11m^3. Therefore, stone pavement can still be used in other provinces of Cambodia even at higher cost. It should also be noted that the price of laterite is much higher in other provinces than in Kampong Cham. This would increase the economic advantages of stone pavement.

FURTHER READING

The student should refer to the following documents:

1 **Al-Fayadh, S.** (2001). *Labour-Based Stone Paved Roads, Kampong Cham Province.* Upstream Project, International Labour Organisation, Phnom Penh.

2 **Dennis, R.** (undated), *Handtools for Labour Based Roadwork, Guideline for selection and procurement*. Mart Publication, University of Loughborough, UK

3 **ILO** (1991). *Stone Masonry.* Training Element. ILO, Geneva.

4 **ILO** (1992). *Stone Paving-Blocks: Quarrying, Cutting and Dressing.* Training Element and Technical Guide for SPWP Workers, Booklet No.8, ILO, Geneva.

5 **Petts, R. C. et al** (1997). *Low Cost Road Construction in Indonesia. Labour Based Road Projects in Manggarai District*. Interoperation, Offsetdruck OD, Switzerland.

6 **Shadmon, A.** (1996). *Stone: An introduction.* Intermediate Technology Publications, London.

7 **TRL Overseas Unit** (1982) *Overseas Road Note 3: A guide to surface dressing in tropical and sub-tropical countries*. Transport Research Laboratory, Crowthorne, Berkshire, UK.

8. Questions for students:

- *What are some of the reasons and advantages that make stone-based pavements still popular?*
- *What are some of the physical qualities of basalt?*
- *Why was community involvement important in implementing the pilot project?*
- *What is the purpose of installing filter drains? Where are they installed?*
- *What was the compaction method used and what was its purpose?*
- *What was the major item of labour involved in the construction process?*
- *Why is the sub-grade construction important?*

15: TECHNICAL PLANNING AND SURVEYING FOR DEVELOPMENT ENGINEERING

Contents

1. Issues covered in this lecture

- Approach to technical planning and surveying
- Stages in project surveying
- Reconnaissance surveys used in development engineering

APPROACH TO TECHNICAL PLANNING AND SURVEYING

This lecture on technical planning and surveys is particularly targeted at the types of information required for the design of rural roads, bridges and other drainage works. Similar information is used in the design of irrigation and soil conservation works, but much of the data for building design tends to be specific to the function of the building (i.e. a market, a school, etc.).

All engineering design is highly dependent on adopting the right approach to the technical planning and survey of a project. This is truer in development engineering than conventional engineering design, as the choice of technology in development engineering is mostly determined by the availability and cost of local resources and by the specific site conditions.

STAGES IN PROJECT SURVEYING

The survey of these factors, therefore, is critical before design work can begin. There are broadly three levels of survey:

2. Types of surveys

xxxiii. **Site inspection or reconnaissance survey:** a rapid but thorough survey of the terrain and characteristics of an area or strip of land;

xxxiv. **Preliminary or semi-detailed survey:** a survey generally using survey equipment, but only collecting sufficient detail to allow preliminary design choices to be made and approximate quantities to be estimated (for small projects this level is often omitted); and

xxxv. **Detailed survey:** also using survey equipment to allow precise designs to be made, to provide a basis for land acquisition and to be used for accurately estimating construction quantities.

The techniques used in detailed geodetic and topographic land surveying are not dealt with in this lecture, nor the participatory methods, social assessments and socio-economic justifications of projects. These subjects are covered in other lecture series.

site inspection or reconnaissance survey

The most important step in design for the project engineer (and in bidding for the contractor) is the site inspection or reconnaissance survey. Information obtained from others sources may be helpful, but this is not a substitute for a thorough site inspection. Thus, the main purpose of the present lecture is to provide basic “rules of thumb” and checklists for undertaking these simple surveys.

> **KEY POINT**
>
> *A careful site inspection or reconnaissance is the ONLY way you can find out what you need to know about the site conditions.*

No engineer should prepare designs or contractor submit a tender without a clear understanding of the practical difficulties that will have to be faced in carrying out the work. A good engineer and contractor is a risk measurer and a risk manager - not a gambler. All projects spring unpleasant surprises from time to time. The purpose of the site inspection is to identify as many of them as possible. All these surprises are hiding somewhere on the site. If the engineer fails to find them it is likely to have financial consequences or to cause delays in project implementation.

information to be collected during reconnaissance survey

The purpose of collecting information is to provide technical planning data for new construction, such as a new road alignment or bridge, or to prepare a road condition inventory as the basis for a routine or periodic maintenance plan. The sorts of technical and contractual problems that the engineer will need to identify during a reconnaissance survey for roads are:

- Horizontal and vertical alignment and condition of the road;
- Drainage conditions;
- Existing structures and new structures needed;
- Sources of supply of materials and water; and
- General site, contractual and cost conditions.

Information on basic engineering design parameters will also need to be collected, such as climatic data, physical properties of soils, average daily traffic data and population levels.

As most new rural roads follow existing alignments the data for new roads is similar to that needed for maintenance planning – although with greater emphasis on the vertical and horizontal alignments and on the sourcing potential construction materials.

The information collected during the reconnaissance survey is identical if the works are to be implemented by labour-based methods or machine-based. However, with labour-based works more emphasis needs to be placed on minimising the longitudinal haulage of earthworks and in the avoidance of constructing roads on weak soils or rocky formations.

conducting a site inspection

The basic equipment that it is needed to undertake a site inspection or reconnaissance survey are:

3. Basic survey equipment requirements

xxxvi. a long tape or chain, at least 100 metres (for measuring length);
xxxvii. a short tape, say 2-10 metres (for measuring heights and off-sets);

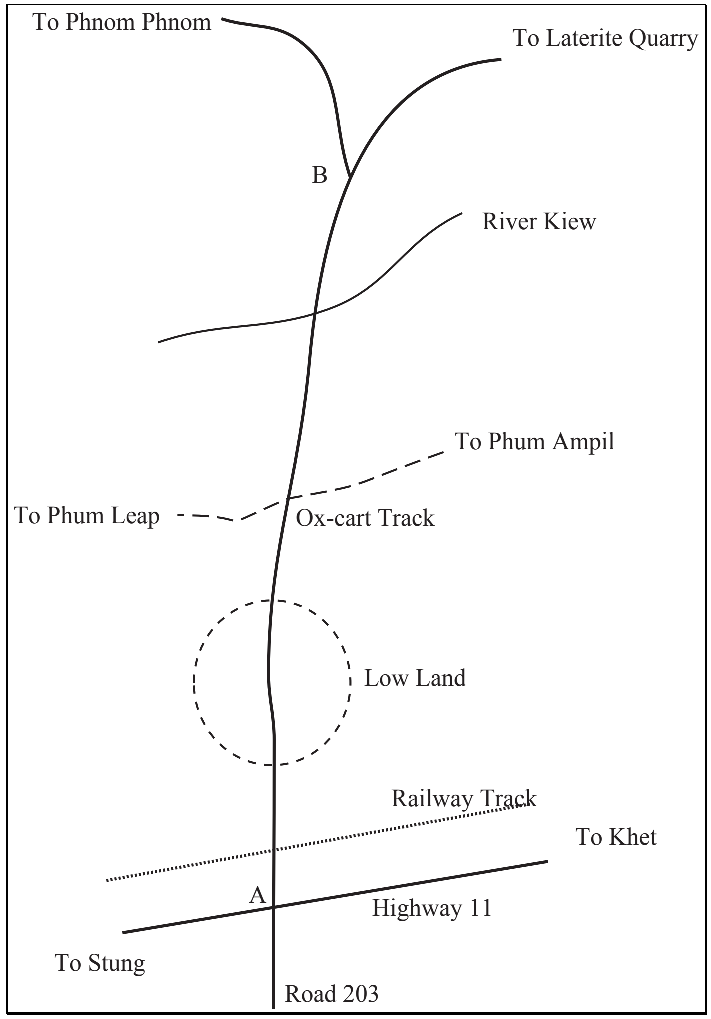
xxxviii. a builder's line;
xxxix. timber or metal pegs;
xl. a set of ranging poles;
xli. a line level;
xlii. a pencil, an eraser and a ruler;
xliii. a hard backing (clip-board) for the survey forms and base maps;
xliv. a notebook and a pen;
xlv. a pick and shovel (or hoe) to dig trial holes (if necessary and if permitted by the land owner); and
xlvi. a bush knife to cut vegetation.

using survey checklists and base maps

When making a site inspection, it is always best to have a checklist of all the points that have to be noted. It is essential to use standard forms so that all the information needed is systematically checked-off and to prepare "strip maps" which locate the information.

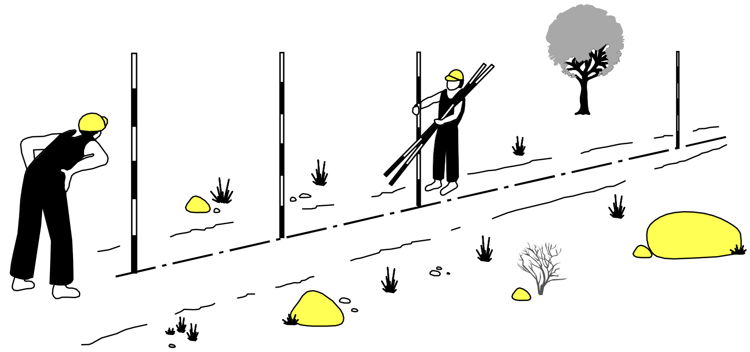
Where accurate base maps at an appropriate scale (1:5,000-10,000) already exist this is the best basis for mapping – either plotting the information directly on the base map or using a tracing paper overlay. Alternatively, aerial photos if available can be used – marking the site features with a china-graph pencil on clear plastic overlays. However, in many cases in rural areas no mapping is available at a scale of less than 1:50,000 and it will be necessary to construct a base map. Distances can be measured using a pedometer (or a vehicle's odometer) and the main features (such as cross roads, village centres and stream crossings) located with a GPS. A typical example of a simple base map is as follows:

4. Example of a simple strip map



details on base maps

All the major physical features should be inspected during the site visit. In addition to the strip map of the road, sketches need to be made of important details. This will include taking all relevant measurements, like the existing cross-section of the roads, the camber and ditch sizes. Information about landmines and UXOs, weather conditions, soils, labour availability and other features that might influence the work can be collected by asking local people. The strip map and notes will be vital when starting to prepare the initial (budget) cost estimate. To ensure that the notes are clear and easy to read and understand, they should be made neatly, in ink. The map can be made in pencil, but it should also be clear, particularly the figures indicating measurements and distances.



RECONNAISSANCE SURVEYS USED IN DEVELOPMENT ENGINEERING

The following notes provide some checklists of information that needs to be collected to prepare a road condition or design survey and gives guidance on some of the simple techniques that can be used during reconnaissance surveys. It is important to remember that the information collected will also be used to prepare the specification. A checklist of the various specification items that have to be considered to carry out road construction is shown in an Attachment at the end of the lecture.

pavement and subgrade characteristics

The assessment of the road should start with plotting the main characteristics of the road itself. The key features to note are the alignment of the road (noting any sharp bends or other defects), the soil conditions and the state of the road pavement.

soils

Sometimes detailed geo-technical reports or soils maps (using a terrain classification) may be available to guide the engineer, giving an indication of the expected California Bearing Ratio (CBRs) of the sub-soil conditions. Alternatively, if equipment is available for undertaking standard penetration tests, an in-situ assessment can be made, which can be correlated with CBRs.

testing soils

However, to assess the soil type and stability, the simplest solution is to dig a trial hole at carefully chosen locations, after getting permission from the landowners. From the trial holes the water-table level can be determined and the thickness and types of soil strata can be observed. If there is some doubt about the suitability of the soils samples from the trail holes should be taken (put in labelled airtight jars) and sent to a laboratory for testing.

state of the road running surface

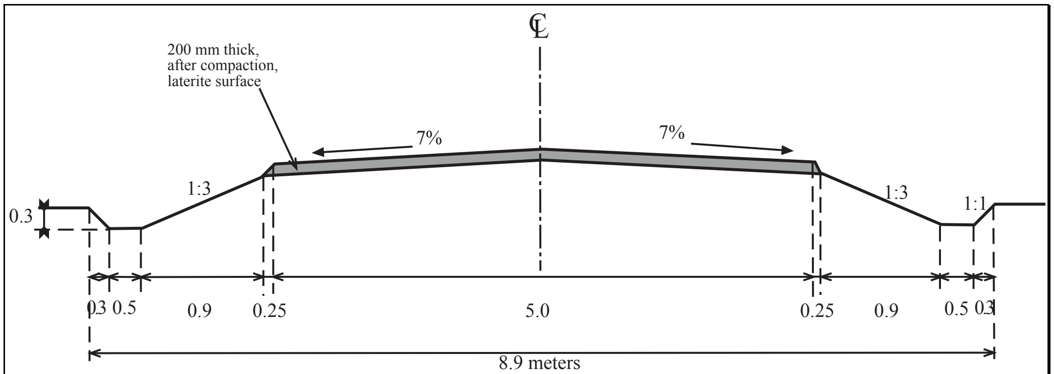
The road pavement should be examined carefully, recording on the strip map and schedules the following characteristics:

8. running surface surveys

Condition:	*Indicator*
Cross-fall	Condition of cross-fall: slope gradient (˚)
Pavement	Road affected by potholes/ruts: length (m/km)
	Road affected by corrugations: length (m/km)
	Gravel layer: thickness (cm/mm)
	Condition of gravel layer: good, moderate, poor, etc.

To assess the gravel layer a series of small holes should be made in the pavement and the residual thickness measured. The MRD has a technical standard for tertiary roads, which has a cross section (shown below) that should be compared to the existing conditions:

10. Standard cross-section of tertiary road



Standard Cambodian Road Cross Section, without Embankment

Note: 1/ In mountainous terrain, it may not be possible to adhere to the drain specifications as described above.
2/ In clayey soils, it is possible to increase the gradient of the side and back slopes.

drainage conditions

The drainage conditions of the road should then be recorded on the strip maps and scheduled (including the side drainage, culverts, drifts/fords, mitre drains, catch water drains and cut-off drains) using the following indicators:

9. Drainage surveys

Item	*Indicator*
Culvert/drifts	Extent of silting/blockage: blocked, half-silted etc.
	Correctness of dimensions: checked against design
Side/mitre drains	Extent of silting/blockage: blocked, half-silted etc.
	Extent of erosion: eroded or not
Catch-water and	Extent of silting/blockage: blocked, half-silted etc.
Cut-off drains	Extent of erosion: eroded or not
	Functioning length: metres operational

structural surveying of bridges and culverts

The condition of existing structures, such as bridges, drifts/fords and culverts, needs to be mapped and assessed by type, size and location (chainage). Factors to consider are as follows:

11. Types of structural defects

foundations	Cracks	Erosion along and underneath	
head & wing walls	Cracks	Erosion behind wing walls	Blocked seepage holes
abutments & piers	Cracks	Erosion behind abutment	Blocked drainage
culverts	Cracks	Blocked or silted-up	Uneven settlement
decking	Cracks/deflect -ion	Cleanliness	Drainage
approaches	Visibility	Drainage	Uneven settlement
beams	Cracks/bends	Corroded steel beams or exposed reinforcement)	Rotting timber beams
waterway	Vegetation growth	Deposits of sand, silt or organic debris	Eroded banks
road furniture	Damaged	Missing	Faded or peeled paintwork
hand/guard - rails	Damaged	Missing	

identifying and testing construction resource

It will be necessary to visit the potential borrow sites and quarries for earth fill and laterite in order to assess the quality and variability of material. Record the haulage distances, the owner's name and address, and the unit cost. For sand and laterite check that there are no organic impurities and make simple tests to establish whether the fine grain component is not too high (maximum 3%). For sand, the simplest test is to half fill a bottle with water and sand, shake vigorously and leave to settle for 2 hours. The sedimentation should be less than 3% of the height of the mixture and the water should be clear or only lightly cloudy.

exploiting the quarries

Prepare an outline programme for exploiting the quarry, including an outline sketch of the quarry with all the important features (e.g. where to place overburden, where to stockpile gravel, etc.,) and estimate the volume of material to be excavated and hauled. Examine the environmental implications; such as whether there could be any soil erosion caused by the work and/or would the quarry need to be filled with overburden at the end of the job. Examine the condition of the haul road and its maintenance and rehabilitation requirements.

water supply

Water for road compaction, sand washing and for mixing concrete is a key component of low-cost roadworks and its availability needs to be investigated. In some cases clean water is not easily available and it is necessary to install wells or pumped supply as part of the road construction programme.

7. Water supply factors to be surveyed

xlvii. Clean water available nearby for concrete mixing
xlviii. Possible to get permission to use water
xlix. Water suitable for drinking for labour
l. Necessary to pump the water
li. Necessary to cart the water by barrel or bowser

climatic data The main climatic data that the engineer needs to obtain are peak and average rainfall records, particularly if the project is likely to need hydraulic design of drainage and structures, such as bridges. Data for the site will probably not be available, but records may be obtained from the rain gauges operated by local airfields and agricultural research stations. Records for 20 years are desirable, but a 5-year run is acceptable. For the design of small-scale irrigation schemes much more detailed information will be needed, including data on temperature, humidity, evaporation and the daily number of sunshine hours.

flooding Data on local flooding is always useful, both for the design of structures (determining free-board levels for bridges and slab levels for fords) and in order to determine the road embankment height. Local knowledge on recent floods will give some indication. The best way to obtain this is to interview local people and get them to explain the height to which the flood came up to and whether this was a typical or exceptional condition.

traffic levels - moving observer counts The annual daily traffic (ADT) levels are needed for two main reasons. First, as the basis for the pavement design. Second, as a baseline for assessing the impact of the road improvements. At the reconnaissance stage it is not usually possible to undertake detailed manual traffic counts (usually a 12-hour count during daylight hours, expanded to 24 hours by multiplying by 1.33). An alternative method for roughly estimating traffic flows is to make a "moving observer count" whilst travelling in the survey vehicle for at least one hour. The observer should count:

lii. Vehicles travelling in the opposite direction (x);

liii. Vehicles overtaking the observer (y); and

liv. Vehicles overtaken by the observer (z).

The hourly traffic (HT) in both directions will be:

HT = (x + y - z)/survey time in hours

To convert the hourly flow into an approximate daily flow (DF):

DF = 16 x HT

types of transport It is usual to collect the traffic data classified by the type of vehicle (car, motorbike, truck, etc.). Non-motorised forms of transport, such as bicycle and carts should also be counted, as although these are not used in pavement or bridge loading calculations, they are considered in looking at the impact of road improvements.

population and other data Even if a detailed socio-economic assessment is not going to be undertaken it is still very useful to collect some basic background information about the project area - that can be used for preparing a report about the project. The most essential information is the potential number of people served by project. Other significant data to be mapped is the presence of villages, markets, local industry, tourism, health, education and administrative facilities.

organising the works At the end of the survey it will be necessary to think how the construction works might be organised. The sort of issues that need to be investigated are:

5. Site organisation factors to be surveyed

- Identify possible locations for site camp(s)
- Confirm use of the client(s) existing facilities is possible
- Identify any adjacent buildings that need special consideration
- Identify if electricity supply is available on, or near, the site
- Identify if petrol and diesel is available on, or near, the site
- Locate availability of garage or mechanic's workshop nearby
- Check if road alignment/borrow pits is free from mines and UXOs
- Identify whether access roads could get flooded
- Identify if any demolition is required
- Identify available sites for disposal of debris and surplus material
- Determine if the site is secure without special measures
- Identify if it is possible to recruit casual labour locally

cost implications Some of these issues (see later lectures) may have implications on the indirect cost of the contact (such as on the preliminaries or a need for special contingencies) and on the direct costs (such as increased unit rates for labour or equipment). In order that a realistic assessment can be made the following needs to analysed:

6. Cost factors to be surveyed

- Extent of vegetation cover and need for clearance
- Presence of tree roots under foundation trenches of structures
- Presence of streams that may cause flooding if blocked
- Potential costs for renting land to establish a contractor’s camp
- Conditions present, such as tolls, that may affect transport costs
- Payment needed for access or haul roads over private land
- Lack of local equipment for hire
- Long haulage distance for earthworks and laterite
- Level of unskilled wage levels and seasonal availability

postscript Site inspections take time and cost money, so it is essential to ensure that all information is obtained during the inspection. Thus, after completing the sketch plan and detailed notes, the site should be looked at again to make sure that nothing has been missed.

FURTHER READING

The student should refer to the following documents:

1 **Davidson, D**. (1980). *Soils and Land Use Planning*. Longman, London.

2 **Johannessen, B.** (undated): *Labour-based Road Construction and Maintenance Technology: Module 2 – Technical Planning.* Prepared by ILO for the National Polytechnic Institute, School of Communication and Transport, Lao Democratic Republic.

3 **Krähenbühl, J. and A. Wagner** (1983). *Survey, Design and Construction of Trail Suspension Bridges for Remote Areas*. Prepared for Helvetas, Zurich. SKAT, St. Gallen, Switzerland.

4 **Lebo, J. and D. Schelling** (2001): *Design and Appraisal of Rural Transport Infrastructure – Ensuring Basic Access for Rural Communities.* World Bank Technical Paper No. 496, World Bank. Washington D.C.

5 **Spence, R. and D. Cook** (1983): *Building Materials in Developing Countries.* John Wiley & Son, Chichester and New York.

6 **Stern. P.** (1980): *Small Scale Irrigation: A Manual of Low-cost Water Technology.* Intermediate Technology Publications Ltd. London.

7 **Stern. P.** (1985). *Field Engineering - An Introduction to Development Works and Construction Rural Areas.* Intermediate Technology Publications Ltd. London.

8 **Upstream Project** (2000): *Contract Management Manual.* ILO Upstream Project/Ministry of Rural Development, Phnom Penh.

12. Questions for students:

- *What are the main stages in surveying of roads?*
- *How would you go about preparing a strip map of the road?*
- *What are the methods used for assessing soil conditions?*
- *What are the types of information that should be recorded in assessing drainage conditions?*
- *Why is it important to review the availability of water supplies?*
- *How would you estimate the existing traffic levels on a road?*
- *What are some of the general factors that might influence the organisation and cost of a road contract?*

ATTACHMENT - CHECK LIST OF SPECIFICATION ITEMS

SECTION	SPECIFICATION ITEMS
a) General Items	• Setting out the works • Access for the public • Site safety (general) • Security and lighting • Site cleanliness and disposal of rubbish • Attendance on the Superintendent (if any) • Maintenance of offices (if any) • Works on private property
b) Road Formation (Reserve Width)	• Site clearance of trees, shrubs, bush, stumps • Grubbing of topsoil, roots, vegetation • Clearing obstructions, demolition of broken structures, old and damaged concrete • Disposal of debris
c) Earthworks	• Quarrying and borrow pits, transport of material • Excavation by hand according to drawings • Removal and re-use/disposal of top soil • Construction of embankments in layers • Need to shed water during construction • Compaction, watering, testing of earth works • Measures taken when testing is not available • Filling of holes and depressions • Treatment of soft areas and unsuitable material • Excavated material and surplus soil disposal • Use of construction aids, string line, pegs, camber board • Access for traffic during construction • Final finish to formation before subsequent layer(s) • Trimming slopes and grassing/turfing
d) Drainage	• Ditch excavation to lines, levels and dimensions on drawings • Suitable excavated material to be placed on the road formation • Disposal of surplus and unsuitable material • Widening of ditches for additional material • Construction of mitre drains, cut off drains • Use of construction aids, boning rods, templates
e) Road Pavement	• Approval of the finished formation • Materials to be used, no oversize stone: PI range • Delivery and off-loading of pavement material to avoid damaging the formation • Spreading of pavement materials in layers • Watering and compaction, final proof rolling • Use of camber board and straightedge • Tolerance of surface finish

f) Culvert Works and Small Bridges	• Position to be fixed by the engineer • Setting out to be approved • Excavation, foundations, excavation to be kept dry • Construction of culverts: blinding, base, pipes, surround, abutments, slabs, boxes • Backfilling and compaction of backfill • Formwork: timber, mortar tight and rigid • Cement quality • Concrete placement and curing • Reinforcement: bent, fixed • Structural concrete to be tested, taking cubes • Timber quality for bridges to be included if necessary

16: APPROACHES TO IMPLEMENTING LABOUR-BASED TECHNOLOGY

Contents

1. Issues covered in this lecture

- Assessing prospects for labour-based works
- Role of the private sector
- Development of small-scale LBAT contractor capacity
- Creating an enabling environment for labour-based construction

ASSESSING PROSPECTS FOR LABOUR-BASED WORKS

Methods for assessing the prospects for labour-based operations have evolved in an effort to limit the risk of implementing unsuccessful projects. In 1979 the World Bank argued that in countries where the unskilled wage rate was less than US$ 4 per day, labour-based techniques should be seriously considered. With wages slightly above US$ 4 per day, an appropriate mix of labour and equipment might still tend towards the use of labour-intensive methods under certain circumstances (this could be situations involving relatively small quantities of work in remote areas, such as rural roads). Since then, equipment and transport prices have more than doubled in US$ terms for most developing countries, while labour wages have generally decreased. This implies that the wage level thresholds can be significantly increased, making labour-based approaches a potentially viable option.

appraisal techniques and indicators of viability

In the early 1980s the ILO developed the idea of "indicators of viability" for labour-based operations in recognition that prospects could not be accurately assessed on the basis of wage levels alone. Factors considered were GNP per capita, as a readily available proxy for wage levels; population density; annual growth rate of the labour force; minimum daily wage rate in agriculture; road density; maintenance expenditure as % of GNP; and maintenance expenditure per kilometre.

Recently more detailed methods of assessment have been used. Typically such appraisals use "key factors" such as the attitude of government, labour supply and the possibilities of paying work incentives, tools and equipment availability and quality, organisation and administration, training resources and experience, and existing maintenance arrangements.

previous experience with labour-based technology

A main difficulty in deciding whether to adopt a labour-based is that conditions vary so much from country to country. Implementation could be entirely by force account operation, or in efforts may be made to involve the private sector, or in others cases a mixture of these approaches might be considered. Moreover there are relatively few countries where some form of employment-intensive civil works has not been attempted. This experience has its advantages and disadvantages.

The positive side is that basic information may be available about labour conditions, government regulations, tools and equipment, etc. The experience may also have negative aspects because of "make work" schemes or the failure of pilot projects to obtain support for larger-scale programmes could have left a legacy of prejudice that will need to be overcome.

In developing new labour-based approaches from there are a number of possibilities as follows:

2. Developing new labour-based approaches

Reviving previous labour-based activities, correcting past mistakes.

Expansion of pilot project activities to national scale operations.

A transition from labour-extensive to labour-intensive - from an inefficient to efficient use of labour.

Changes in the character of labour-based operations:

- Force account to private sector.
- Minor to higher classes of road.
- Rural to urban operations.
- Continuous to spot improvements.
- Introduction of incentive schemes, such as piecework.

assessment methods

Methods for the assessment of prospects for labour-based rural road works are still evolving. Early studies, which were mostly for road construction, used full cost-benefit techniques. However, application of these methods is now rare because of their complexity and the increased importance of issues such as maintenance and sustainability. Currently there is also increased interest in spot improvement methods, which introduces a further element of uncertainty into the assessment of benefits and lowers the value of individual investments.

However since current concerns are mostly with the rehabilitation and maintenance of *existing roads* more pragmatic assessments of the prospects for labour-based methods are usually used. If it can be shown, as is usually the case, that labour-based methods are as cheap as, or cheaper than, equivalent equipment-intensive methods, then that is taken as evidence of economic viability. There is also now a wealth of experience to draw on from countries displaying a wide range of economic, social, climatic and terrain conditions. This considerably reduces the 'risk' element inherent in any technological innovation.

key factors to consider The use of a *checklist* of key factors is the best way of making a rapid initial assessment of the prospects for labour-based operations. Among the key factors in an appraisal are:

3. Checklist of key factors

• Sustainability and replication;	• Economic efficiency;
• Labour supply and recruitment:	• Organisation;
- remuneration	• Training;
- Women's participation	• Administration;
- Community participation	• Cost and financial control;
- Poverty targeting	• Maintenance strategy;
- Work incentives	• Detailed work programme;
• Tools and equipment;	• Improvement cost estimates;
• Project identification techniques;	• Project resource requirements;
• Technical feasibility;	• Environmental protection;

sustainability Sustainability, poverty alleviation and environmental issues have recently become important issues to addressed, particularly since these aspects are among the most significant advantages of the labour-based approach. However, for a labour-based approach to road works to be sustainable and replicable it is required, first, that the central government is committed to the approach and has taken the necessary actions to facilitate its adoption. This commitment has to be assessed from documents or verbally and should, at best, include clear indications of:

central government commitment

- The adoption of appropriate policies for project selection and the choice of technology which favour labour-intensive methods (or at least are not biased against these methods);
- The creation of an economic environment which favours private sector development; and
- Agreement to develop the necessary institutional capacity through appropriate organisational arrangements and training of staff in the public and private sectors.

local resource approach Since their financial support will be required for a long time, it is also important that aid agencies show commitment towards the local resource approach by avoiding funding conditions or conditions which directly or indirectly are biased against labour-based methods.

attitude of government

The government's attitude is crucial because to firmly establish labour-based techniques usually requires far-reaching and fundamental changes in procedures, systems, job descriptions and career progression arrangements, procurement regulations, etc. Without strong government commitment to the changes bureaucratic inertia is likely to triumph and defeat the proposals. In principle preference should be given to the strengthening of existing institutions over the creation of new ones. On the other hand, existing bureaucratic structures may be difficult to reform and make efficient due to staff constraints, government procedures and practices.

4. Key concept: government attitude

The attitude of the government and the degree of willingness to make necessary changes in institutional structures and procedures is without doubt the single most important requirement for the launch of any labour-based activity, whether at the pilot or a more adventurous scale.

Although the initial blessing of a government is an essential first step, this may not be enough to guarantee success in launching labour-based methods where they have not previously been in use. Too frequently initial promises have been frustrated by engineers who either do not believe in labour-based methods and are not prepared to give them a fair trial, or feel threatened by the new developments and so obstruct them. It is necessary to try to ensure commitment to the venture from *all* concerned.

ROLE OF THE PRIVATE SECTOR

Considerable emphasis is now placed on the involvement of the private sector in labour-based operations. Underlying these efforts is the belief that in the long-term this is likely to lead to a more sustainable technology. It also introduces another major actor into the lobbying process and reduces the influence of the government as both the demander and supplier of infrastructure provision. At the initial appraisal stage the main priority would be to examine the structure and capability of the contracting industry.

profitability of labour-based methods

For private sector contractors the only issue of real importance is whether their operations are profitable. Therefore, to introduce labour-based technologies into the private sector with any chance of success, it is necessary to demonstrate the cost-effectiveness of these methods. The emphasis on small contractors was based on the idea that they had limited amount of plant and could adapt easily to the use of labour-based techniques. There was a tendency to ignore the fact that small contractors are generally in need of training in proper financial management. One thing, however, is certain: there is no real future for the use of labour-based techniques if they are not adopted by the private sector.

The positive and negative impacts of using contractors for labour-based works are not very different from those of using contractors in general. The advantages of using contractors for labour-based works will be:

advantages of using contractors for LBAT

- Flexibility of contracts (ability to introduce incentive schemes, control of labour force, etc.);
- Less bureaucratic procedures;
- Government released of *direct* management responsibility;
- Contractual commitment of maintenance funds (difficult to divert funds to other purposes);
- Political support for a well-defined activity;
- Development of skills for local contractors.

However, using contractors also has some disadvantages:

disadvantages of using contractors for LBAT

- It requires high-level skills on the part of Government to administer, monitor and control projects.
- It raises the issue of what will happen to redundant government staff.
- There is a risk of monopolies, price fixing and corruption.
- There is also a risk that contractors are incapable from a technical, managerial or financial point of view, or even that they are not available.
- In case of emergencies, working through contracts is less flexible.

To ensure that these problems do not emerge with private sector contractors the following conditions need to be followed:

5. Conditions for using the private sector

- Contractors need initially to be guided on procedures and technical aspects to point them in the right direction.
- Monitoring and controlling the works is needed in order to safeguard the required quality. This implies that there is a need to establish a small, but competent, body for setting engineering standards, tendering and supervision. If such a control is not established, there is a big danger of collusion, high cost and low quality works.
- Competition needs to be maintained both between firms by keeping an efficient force account maintenance capacity.

DEVELOPMENT OF SMALL-SCALE LBAT CONTRACTOR CAPACITY

Small-scale contractors face a variety of constraints in their activities. These relate to problems of obtaining credit, of keeping an effective cash flow, and of being paid on time. These problems remain the same whatever the technology. However, contractors using labour-based technology will more easily run into problems, as labour-based methods can be more vulnerable to such difficulties. Assisting them to solve these problems poses a big challenge for any agency attempting to develop this sector. Two inter-related issues must be addressed.

training contractors

First, there is the requirement to develop an ability to utilise local manpower and materials effectively in order to produce good quality results within a set cost and time frame. This means that a demonstration training period will be necessary to transfer the required organisational and management skills. In addition, contractors need to be trained in cost accounting, estimating and bidding, and the comprehension of contract documentation such as design specifications, drawings and payment procedures.

modifying procedures

Second, it is essential to modify the working environment of the small contractors in such a way that the major constraints to their effective performance are removed. Key areas here include:

- Development of appropriate contract procedures;
- Provision of a certain amount of assistance in the establishment period, in terms of procurement, the provision of back-up in the contractor's relations with the banking system and a degree of guarantee concerning contract-assignments; and
- Ensuring an adequate and timely cash flow during the implementation period.

CREATING AN ENABLING ENVIRONMENT FOR LABOUR-BASED COMNSTRUCTION

Development of small-scale contractors poses particular challenges. Thus the next lectures examine in more detail how to assist small contractors in Cambodia in being able to implement labour-based civil construction and maintenance works effectively. The following notes apply to the creation of an enabling environment for small-scale contractors in general (whether labour-based or not).

development of appropriate contract procedures

Contract procedures for civil works are generally biased towards the execution of relatively large-sized projects by using equipment. For example, to be able to tender for roadworks, contractors are usually required to be registered as road constructors. In order to qualify for this category, the contractor is usually required to possess a minimum number of equipment items. For small labour-based contracts, a proven management experience or training certificates could be substituted as a pre-qualification requirement.

design specifications

The design specifications in contract documents for roadworks are generally rigid in terms of compaction standards, thickness of base and sub-base and quality of materials. A less rigid approach - where, for example, it would be permitted to use thicker layers of lesser quality material compacted to slightly lower compaction rates - could allow local contractors to compete effectively for such works. In such cases, hauling distances could be minimised and different compaction methods applied. Also, the very size of contracts may prevent local contractors from participating. If a contract can be broken down into a number of smaller sized packages or elements, the work would be more accessible.

simple contract documentation If the small firm is to participate effectively in estimating and tendering for small jobs, the contract documentation needs to be simple and straightforward. On the other hand, Bills of Quantities and work descriptions need to be sufficiently detailed to guide the small contractors in their estimating.

decentralised authority Finally, governments need to decentralise part of its authority in awarding, monitoring and paying contracts. Centralised procedures for small-scale contracts do not make a great deal of sense and lead to unnecessary administrative delays that, in turn, jeopardise the successful establishment of this approach.

assistance in contractor development The general working environment is not always conducive to private sector work. This applies particularly to small upcoming contractors who wish to establish their firms. A major issue is the procedures for awarding contracts. The contract documentation, if it is too complex on the one hand (legal protection of the employer) and not detailed enough on the other (guidance to the contractor), is often another major constraint.

bank collateral Other problems exist, however, for the emerging firm. Banks will insist on collateral before any loan is awarded. Terms of debt repayment are generally very unfavourable. Foreign exchange is difficult or impossible to obtain, making the procurement of essential items and materials a difficult exercise, and transport a hazardous undertaking. Developing a private sector capacity in such situations must take account of these difficulties. This means that government in fostering a small contractor capacity for roadworks must be prepared to back up contractors in their relations with banks, if necessary, by providing support to ease initial procurement and transport problems.

cash flow problems Labour-based works are very sensitive to cash flow problems. Timely payment is a essential in order to retain workers' confidence in the employer, whether it be the government or a contractor. However, the contractor’s work will be seriously and directly affected if payment is not forthcoming at the right time. It is evident also that small contractors cannot easily advance large sums for labour wages, which represent the largest single item of their payment obligations. It is crucial, therefore, that the disbursement and payment procedures of the employers are streamlined in such a way that the contractor is able to meet his obligations to the work force.

advance payments In some situations the making of advance payments may be feasible, otherwise regular payments of monthly certificates should be introduced as a minimum. Yet another, although costlier, approach may be to introduce a system where work certificates could serve as bank guarantees for overdraft facilities.

In any case, the contract documentation should clearly describe payment procedures and timing, and indicate the contractor's rights when payments are delayed for reasons beyond his control. Such rights should preferably be a financial penalisation of the employer in the form of interest charges at commercial rates payable to the contractor over the period that payment is delayed. On the employer's side, it is advisable to ensure that funds of sufficient size are available to cover at least two months of contract operations in order to minimise cash flow problems.

changing roles In many countries the role of government is being redefined. Thus the actual execution of public works is increasingly left to the private sector and works on force account are becoming less common. The role of government is gradually being reduced to policy formulation and the creation of an overall legal and administrative market economy framework within which the private sector can develop. This equally applies to the role of aid agencies, who need to look closer at how private sector development might be assisted

consultants The implementation of labour-based contract works through well-defined programmes also offers opportunities to involve and develop local consulting firms. Many tasks can still be given to the consulting firms: preparing bills of quantities, quality control, checking and valuing completed works, and preparing payment certificates can be done effectively with the support of local consultants. Consulting firms may represent a good opportunity for redundant Government staff. They need, however, on starting up to go through a somewhat similar process to the contractors. Projects should include components for training consultants in the development of appropriate documentation, terms of reference, defining job responsibilities, etc.

FURTHER READING

The student should refer to the following documents:

1 **Coukis, B.** (1983): *Labor-Based Construction Programs: A practical Guide for Planning and Management*, Published for the World Bank, Washington, D.C. (Oxford University Press).

2 **Edmonds, G. and J. de Veen** (1991): *Technology choice for the construction and maintenance of roads in developing countries: developments and guidelines*, Geneva, ILO, World Employment Programme CTP 128.

3 **Edmonds, G. and O. Ruud** (1984): *Labour-based construction and maintenance: some indicators of viability*, Geneva, ILO, World Employment Programme CTP 39.

4 **McCleary, W.A.** (1976): *Equipment versus employment: a social cost-benefit analysis of alternative techniques of feeder road construction in Thailand*. Geneva, (International Labour Office).

6. Questions for students:

- *What approaches might be investigated for new labour-based programmes?*
- *What are some of the key factors that need to be checked before initiating a new programme?*
- *Why is the attitude of governments critical?*
- *What are the advantages of adopting a private sector approach to construction?*
- *What are some of the problems that contractors may have in starting or expanding a business?*
- *Is the contractor's cash flow an important issue to consider? Why?*

17: BACKGROUND TO DEVELOPMENT ENGINEERING CONTRACTING

Contents

1. Issues covered in this lecture

- Agents involved with labour-based small scale contracting
- 'Force account' and 'private sector' approaches compared
- Costs of different contracting systems
- Engineering, management and socio-economic factors

AGENTS INVOLVED WITH LABOUR-BASED SMALL SCALE CONTRACTING

Construction is a process comprising of a wide variety of activities and products. In all construction activities there are a number of parties or "agents" involved. This is equally true with labour-based small scale contracting for infrastructure construction and maintenance works.

construction industry: its agents and potential for job creation

The agents involved, range from those responsible for funding, design, procurement and supervision to those carrying out the work. In the road sector - when works are contracted out - the principal agents include government agencies, banks and other credit agencies, suppliers of goods, services and materials, consultant and contractors. The latter group is widely diversified, ranging from multi-national firms to micro contractors. Sometimes it is limited to one person such as the road maintenance "length-person" responsible for the routine maintenance of a stretch of road.

In order to increase production and quality employment in the construction sector in developing countries, imaginative and alternative approaches can be applied with different roles and responsibilities for all these actors. In particular the civil works sector - roads, irrigation, water supply and soil conservation - offers a huge potential for job creation through employment-oriented investment policies and strategies

potential for realising socio-economic objectives through construction projects

There is a definite relationship between employment opportunities, available skills, entrepreneurship and the use of small-scale enterprises in the creation and maintenance of assets. The construction strategies that are adopted can be used to address social and economic needs and concerns. Also, depending upon how they are structured, such strategies can facilitate the economic empowerment of marginalised groups, e.g. community organisations, micro and small enterprises in a focussed manner. Thus, the process of constructing assets can be just as important as the provision of the assets themselves.

'FORCE ACCOUNT' AND 'PRIVATE SECTOR' APPROACHES COMPARED

In the road sector, there are two basic approaches to organising construction and maintenance works:

- Force Account
- Contracting

The basic differences between the two approaches are as follows:

force account With this arrangement the road authority employs personnel permanently to carry out their works. The planning, managing resources, supervision, monitoring and auditing of the works are carried out 'in-house' – this is a 'one party' system.

contracting This a 'multi-party system' involving a number of parties:

2. Parties involved in private contracting

- ***Client or Employer:*** The person or organisation for which the works are carried out, such as a road authority.
- ***Contractor:*** The person or organisation who contracts to carry out the complete works according to agreed time, price and quality criteria.
- ***Sub-contractor:*** The person or organisation who contracts with the Contractor to carry out part of the complete works - often a specialist supplier of labour, skills or equipment.
- ***Engineer:*** A person appointed by the Client to ensure that the works are completed according to the contract and with equitable treatment of the Client's and Contractor's interests.
- ***Arbitrator or Adjudicator:*** An independent person brought in to settle serious disputes.

linkages in the construction industry The relationship between the construction industry parties is supported by a complex pattern of inter-linkages. These include banks, professional and trade organisations, government departments and agencies, equipment and material suppliers, universities and training bodies. Each linkage has a contribution to make to the benefit of the industry.

Unfortunately in developing countries many of these organisations and linkages may not be well developed. These constraints need to be recognised in developing the small scale contracting sub-sector, promoting initiatives where necessary to support an 'enabling environment'

advantages and disadvantages in approaches There are advantages and disadvantages in using either the force account and contracting approaches. It is clear that neither offers a 'painless' solution. The prerequisites for success are important issues to consider.

The force account method is typically used for both roadworks construction and maintenance. For that purpose it has the following advantages:

3. Advantages of force account roadworks

- Direct response to needs (operational/emergency)
- Rapid mobilisation when funds are available
- Retain existing skills and experience, which are familiar with the process and able to apply standards, etc.
- Direct control of personnel
- Pride of 'ownership'
- Security and continuity of employment, with career progression
- Disputes with outside parties minimised
- Provides benchmark for contractor performance and costs

However, there are also a substantial number of disadvantages:

4. Disadvantages of force account roadworks

- Remuneration packages usually inadequate to motivate sufficiently
- Slow equipment procurement and lowest cost policy prevents standardisation
- Bureaucratic procedures and slow progress, performance not encouraged, poor incentives, poor discipline
- Poor quality/assurance systems
- Effective financial and performance audit rarely in place
- Poor cost-awareness
- Low efficiency and poor management/use of available resources
- Political interference
- Little pressure to try new methods/technologies

force account- prerequisites for success

For a force account process to be successful there needs to be sufficient funding and cash flow for at least basic level of works, with an adequate remuneration and motivation system for the personnel, which responds to their work performance. This needs to be supported by good planning, budgeting, disbursement and cost monitoring. Other factors that need to be considered are:

- Policy formulation and political support
- Trained and skilled management
- Effective financial and performance audit
- Minimise political interference

advantages and disadvantages of private sector roadworks implementation

In the circumstances of Cambodia it is likely that the private sector approach offers an easier and more rapid path to a workable and sustainable system. It is also clear that considerable effort is required to develop a healthy construction sector. The advantages of the private sector approach is as follows:

5. Advantages of private sector roadworks

- Government released from direct organisational responsibilities
- Equipment funding, procurement and management transferred to contractors
- Manpower recruitment & management delegated to private sector
- Flexibility to hire/fire and motivate personnel
- Able to respond to changing sector circumstances
- Market forces can bring competition, efficiency, high utilisation of assets, and lower costs.
- Possible to gain political support for well defined activity
- Better accountability possible
- Easier to resist political interference once contracts are let
- Greater chance of innovation to reduce costs

There are of course also disadvantages, but theses are generally less serious than those that are found with force account works:

6. Disadvantages of private sector roadworks

- Duplication of supervision
- Duplication of equipment between contractors unless active hire market
- Long lead times in registration/classification, tendering, evaluation and award of contracts
- Civil service redundancies in move from force account to private sector, client authority restructuring
- Government employees require retraining and restructuring for new roles
- Higher cost of borrowing (for contractor)
- Changes in legislation, and procedures may be required

local contracting-prerequisites for success

For a contracting approach to be successful there needs to be adequate funding and cash flow to support an effective and competitive market. This is helped by the existence of a reasonably stable sector workload, by rational policy formulation and political support.

COSTS OF DIFFERENT CONTRACTING SYSTEMS

The full costs of force account and contracting approaches must be appreciated to make a realistic comparison of the two options. A common point of view is that contracting is far more expensive than force account works. This view is usually not rationally founded and not based on a fair assessment of all of the cost components involved. Most accounting systems are set up to control expenditure (and minimise malpractice) or comply with taxation and shareholder requirements. They are certainly not set up to enable fair evaluation of technology or implementation options.

Many of the true costs of Force Account systems are often ignored or 'lost'. Equipment costs can represent a substantial part of the total costs of both labour-based and equipment based systems. All equipment cost components should be included in any comparative assessment. The equipment cost components to be considered are:

7. Items often omitted in costing equipment

- Finance/Opportunity cost of capital
- Depreciation/Replacement/Amortisation
- Fuel and lubricants
- Spares and consumables
- Workshop costs
- Operators' payments, allowances & on-costs
- Overheads
- Risk (e.g. late payment)
- Profit

The various cost components for equipment normally make up a substantial share of the costs of any construction sector system (typically 20-50%+). Unfortunately many construction and maintenance managers do not have access to all of the cost data, often only fuel, lubricants and spares costs are apparent. These components can actually comprise less than 25% of the true overall cost of owning and operating equipment.

The two often neglected or underestimated cost components are:

- 'Finance' which is either the cost of borrowing the capital or 'opportunity cost of capital' (if the capital was invested for another purpose), and
- 'Replacement' of the equipment as it is 'used-up' - expressed by its depreciation and amortisation. When a piece of equipment is new, it may have an economic life potential of 5,000-20,000 hours but even with inflation, the residual value of the piece of equipment will tend towards zero!

In a developing country situation with scarcity of capital, high interest rates and problems of owning, operating and supporting heavy equipment, these two components together can comprise almost half of the true overall cost of owning and operating equipment. A detailed description of equipment costing is given in the next lectures.

ENGINEERING, MANAGEMENT AND SOCIO-ECONOMIC FACTORS

The choice of technology issue discussed in earlier lectures is of course also influenced by the choice of contracting method. Attached to the end of the lecture is a framework for making an initial assessment of the engineering, management and socio-economic advantages and disadvantages of the various technology options for infrastructure activities:

- Labour methods – using handtools.
- Intermediate equipment, such as tractor-based plant and light trucks.
- Heavy equipment, such as bulldozers, graders and specialist trucks.

These matrices (9 and 10) are useful as a means of highlighting the benefits and disbenefits of the various technology approaches. The management and engineering factors are of essential importance to the construction and maintenance sector engineers and managers. The socio-economic issues should be of importance to economists, politicians and social experts, as well as the conscience of the engineer!

FURTHER READING

The student should refer to the following documents:

1 **Andersson, C.A., A. Beusch and D. Miles** (1996). *Road maintenance and gravelling (ROMAR) using labour-based methods - Handbook.* Intermediate Technology Publications, UK.

2 **Bentall, P., A. Beusch and J. de Veen** (1999). *Employment-Intensive Infrastructure Programmes: Capacity Building for Contracting in the Construction Sector.* ILO, Geneva.

3 **Larcher P.** (1996). *Private Sector Development and Institution Building. A Select Bibliography and Literature Review*. MART Working Paper No. 6. , University of Loughborough

4 **Larcher P. and R. Petts** (1996/7). *Selective Experience of Training, Contracting and use of Intermediate Equipment for Labour-based Roadworks.* MART Working Paper No. 2, University of Loughborough (in association with ILO).

5 **Miles, D.** editor (1996). *Towards Guidelines for Labour-based Contracting. A Framework Document*. MART Working Paper No. 1., University of Loughborough (in association with ILO).

6 **PIARC** (1994). *International Road maintenance Handbook, Volumes I-IV.* Revised by R. C. Petts of Intech Associates under assignment to the Transport Road Research Laboratory, UK.

8. Questions for students:

- *Who are the parties involved with private contracting?*
- *Are there any disadvantages in using force accounts methods for road maintenance?*
- *What sorts of factors need to be in place for private sector roadworks to succeed?*
- *What are the main items frequently missed in costing equipment?*
- *What are the engineering and management disadvantages of intermediate scale equipment?*

9. CHOICE OF TECHNOLOGY FOR RURAL ROAD WORKS – ENGINEERING AND MANAGEMENT CONSIDERATIONS

LABOUR METHODS-USING HANDTOOLS	INTERMEDIATE EQUIPMENT E.G. LIGHT TRUCKS, TRACTORS	HEAVY EQUIPMENT E.G. DOZERS. MOTOR GRADERS, SPECIALIST TRUCKS OR TRUCKS > 10 tone
ADVANTAGES • CHEAPER IN A LOW WAGE ENVIRONMENT • QUALITY MATCHES OTHER OPTIONS IF WELL MANAGED • LOW CAPITAL REQUIREMENTS • CASHFLOW BENEFITS (PAY AFTER WORK DELIVERED) • FLEXIBILITY OF LABOUR FOR DIFFERENT OPERATIONS • SUITABLE FOR LOCAL CONTRACTORS AND SMALL ENTERPRISES • REQUIRED SKILLS ARE LIMITED AND EASY TO DEVELOP	***ADVANTAGES*** • SPEED OF OUTPUT PER PRODUCTIVE UNIT • REQUIRES LITTLE SITE SUPERVISION • REQUIRES LESS CAPITAL, FOREX AND OPERATING FINANCE THAN HEAVY EQUIPMENT • LOWER SKILLS REQUIREMENTS THAN HEAVY EQUIPMENT • APPLICATIONS ALREADY ESTABLISHED IN THE RURAL AREAS • EASIER TO SUPPORT THAN HEAVY EQUIPMENT • MULTI-ROLE AND MULTI-SECTOR APPLICATIONS LEADS TO HIGHER UTILISATION • LOCAL MANUFACTURING POSSIBILITIES • SUITABLE FOR LOCAL CONTRACTORS / SMALL ENTERPRISES	***ADVANTAGES*** • SPEED OF OUTPUT PER PRODUCTIVE UNIT • REQUIRE LITTLE SITE SUPERVISION • EASIER TO ACHIEVE CONSISTENT QUALITY • CONVENIENT TO USE • USE USUALLY UNDERSTOOD BY ENGINEERS AND SUPERVISORS
DISADVANTAGES • REQUIRE MORE MANAGEMENT AND SUPERVISION • REQUIRES SPECIFIC TRAINING • POSSIBLE LABOUR SHORTAGES AT HARVEST TIME • SPEED OF OUPUT PER PRODUCTIVE UNIT MAY BE LIMITED • ENGINEERS OFTEN NOT TRAINED FOR THESE METHODS • GOOD QUALITY HANDTOOLS SOMETIMES NOT AVAILABLE • REQUIRES GOOD PAYMENT SYSTEMS • REQUIRES GOOD MONITORING ARRANGEMENTS • POOR PERFORMANCE CAN OCCUR ON COMPACTION AND HAULAGE	***DISADVANTAGES*** • LOCAL BUILT QUALITY CAN BE VARIABLE • LACK OF AWARENESS OF POTENTIAL USES • MARKET AVAILABILITY OF INTERMEDIATE EQUIPMENT • ENGINEERS OFTEN NOT TRAINED FOR THESE METHODS	***DISADVANTAGES*** • DESIGNED FOR HIGH-WAGE, LOW-FINANCE-COST ECONOMIES • HIGH CAPITAL AND FINANCE COST (FINANCE DIFFICULT AND INTEREST RATES ARE USUALLY HIGH) LONG INVESTMENT HORIZON • CONSIDERABLE FOREX REQUIREMENTS FOR INITIAL PURCHASE AND SPARES (USUALLY MORE EXPENSIVE THAN INITIAL COSTS) • DEDICATE FUNCTION - INFLEXIBLE • INTERDEPENDENCE FOR MANY OPERATION • REQUIRES WELL TRAINED MANAGERS, OPERATORS AND MECHANICS, GOOD WORKSHOPS, GOOD SPARE SUPPLY • REQUIRES HIGH WORKLOAD FOR COST EFFECTIVENESS (UTILISATION TYPICALY > 1,000 HOURS PER YEAR) • SMALL LOCAL EQUIPMENT MARKET, SPARES STOCKING PROBLEMS, HIGH COSTS AND LONG SUPPLY LINES MAKE EQUIPMENT MAINTENANCE PROBLEMATIC AND COSTLY • TRANSPORT LONGISTICS FOR REMOTE WORKING

		(LOW LOADER REQUIRED) • NOT COST EFFECTIVE FOR SMALL-SCALE WORKS

10. CHOICE OF TECHNOLOGY FOR RURAL ROAD WORKS – SOCIO – ECONOMIC CONSIDERATIONS

LABOUR METHODS-USING HANDTOOLS	INTERMEDIATE EQUIPMENT E.G. LIGHT TRUCKS, TRACTORS	HEAVY EQUIPMENT E.G. DOZERS, MOTOR GRADERS, SPECIALIST TRUCKS OR TRUCKS > 10
ADVANTAGES • BETTER USE OF LOCAL RESOURCES • EMPLOYMENT CREATION (PARTICULARLY IN RURAL AREAS) • REQUIRES LITTLE FOREIGN EXCHANGE • DEVELOPS RANGE OF LOCAL SKILLS • INJECTS CASH INTO LOCAL ECONOMIES • CAN SUPPLEMENT SUBSISTENCE INCOME • LABOUR FLEXIBILITY TO WORK IN DIFFERENT ROLES AND SECTORS • ENCOURAGES SELF RELIANCE	***ADVANTAGES*** • POTENTIAL FOR LOCAL MANUFACTURING SKILLS AND JOBS • POTENTIAL FOR MULTI-SECTOR RURAL CONTRACTORS • INTERMEDIATE EQUIPMENT BASED ON USE OF LOCAL CONTRACTORS COULD MEET MANY OF THE RURAL INFRASTRUCTURE CONSTRUCTION AND MAINTENANCE NEEDS	***ADVANTAGES*** NONE
DISADVANTAGES • POSSIBLE POLITICAL AND SOCIAL NON-ACCEPTABILITY WITHOUT AWARENESS CREATION • POSSIBLE NON-ACCEPTABILITY BY ENGINEERS WITH NO PREVIOUS EXPERIENCE	***DISADVANTAGES*** • POSSIBLE NON-ACCEPTABILITY BY ENGINEERS WITH NO PREVIOUS EXPERIENCE	***DISADVANTAGES*** • CREATES LITTLE EMPLOYMENT • LITTLE CONTRIBUTION TO THE LOCAL ECONOMY • MOST COSTS AND PROFITS ARE FOREIGN • EXPENSIVE

SOURCE: INTECH ASSOCIATES

18: SMALL SCALE LABOUR-BASED CONTRACTING FOR ROADWORKS

Contents

1. Issues covered in this lecture

- Small scale labour-based contracting approach
- Promoting small-scale contractors
- Experience of capacity building in Cambodia
- Contract documentation and management procedures
- Labour standards for small-scale contracting

SMALL SCALE LABOUR-BASED CONTRACTING APPROACH

This lecture develops in more detail the points made in the previous lectures on promoting small-scale contractors for labour-based works. The following box highlights the advantages of using a local small scale contracting approach to infrastructure works, in contrast to employing foreign large scale contractors. The essential engineering and management issues are differentiated from the socio-economic considerations.

2. Advantages of small-scale contracting

- More efficient and cheaper for small works through competition
- Small firms more likely to use LBAT methods
- *Small firms create more employment*
- Lower overheads and mobilisation costs
- Lower capital requirements of intermediate equipment - less borrowing required
- Market and enterprise flexibility
- *Inter-sector flexibility & potential*
- *Reduced heavy equipment imports (foreign exchange savings)*
- Less risk *and better local resource utilisation*
- *Good entry point for local entrepreneurs*
- *Economic empowerment (for disadvantaged communities) and better able to serve disadvantaged rural areas*
- More opportunity for innovation and good management
- *Can be a target for aid agencies*

(Note: Expected government policy areas identified interests in italics)

PROMOTING SMALL-SCALE CONTRACTORS

Previous lectures have stressed the need to create an enabling environment for small-scale contractors. Any assessment of the working environment for small-scale enterprises in a developing country will identify a range of constraints that impede the success and even survival of the enterprises. It is important to identify these constraints and promote initiatives to overcome them or reduce their impact

core financial issues

Regular payments to contractors by the client are crucial for labour-based programmes. Because of the large numbers of temporary workers on their payroll, labour-based contractors are particularly vulnerable to payment delays. Executing contracts requires the successful performance of the contractor, the contracting agency (or “client”) and the client's agent. The core financial problem for the small-scale contractors are:

- The tendency of clients to award contracts without ensuring that the required funds will be available.
- Weak managerial and administrative capability of client.
- The difficulty in obtaining commitment and support from financial institutions.

flow of funding

An enabling environment, therefore, includes ensuring a regular flow of funding for work, streamlining disbursement and administrative procedures, access to credit facilities and equipment by contractors, a reasonably steady workload and the client's strong capability to mange contracts.

contract documentation

The client should also ensure appropriate contract documentation and streamlined (and where possible decentralised) procedures for contract award, certification and payment. Contractor associations have an important role to play in representing individual contractors, in negotiating on their behalf and in capacity building.

working environment for small-scale enterprises

Any assessment of the working environment for small-scale enterprises in a developing country will need to identify the constraints that hinder the success and even survival of the enterprises. It is important to identify these constraints and promote initiatives to overcome them or reduce their impact. Some of the most important constraints identified from various investigations of the sector are as follows:

3. Contractor's most common problem

Ranked by frequency of occurrence in over 20 reports

- Bank finance is difficult to obtain (1=)
- Long delays in receiving payment (1=)
- Contract documents over complex and unsuitable for the work (3)
- No work continuity (4=)
- Poorly managed/no classification or pre-qualification system (4=)
- Tenders/estimates and bids are poorly assembled and difficult to follow (6=)
- Lack of skilled labour/staff at all levels (6=)
- There is little or no on-site supervision/quality control (8=)
- There is no provision for price fluctuations/estimated badly (8=)
- Specifications over-complex & impractical - usually foreign codes (10=)
- Insufficient meetings between client, consultant & contractor (10=)
- There is lack of equipment for hire (10=)
- Bank interest charges are very high (13=)
- Contract documents are biased against the contractor (13=)
- Difficulty in obtaining performance bonds/guarantees and cost (13=)
- Contracts awarded to lowest tenderers who bid too low (16=)
- Delays and shortage of supply of materials (16=)
- Lack of expertise in planning and programming (16=)

(Source: MART Working Paper No 14)

The range of factors which contribute to an 'enabling environment' for the development and sustainability of small scale labour-based contractors are summarised below:

4. Enabling environment for LBAT contractors - key concerns

- Government commitment and policy framework
- Government legislation on key issues
- Fiscal regime (Government Revenue)
- Client's financial administration
- Appropriate management framework
- Procurement policies & procedures
- Donor policy
- Funding mechanisms - raising and disbursement
- Capacity building

All contributing to CONFIDENCE and an EFFECTIVE & SUSTAINABLE MARKET for delivering cost-effective Works

These factors are detailed in the attachment to this lecture.

EXPERIENCE OF CAPACITY BUILDING IN CAMBODIA

In Cambodia, the MRD (under the ILO supported Upstream Project) has adopted a new approach to the government's role in facilitating capacity building for small-scale infrastructure contractor development:

5. Small contractors in Cambodia

In Cambodia a programme for training small contractors in labour-based techniques has been started. During the training process, the contractors are given training in both technical and contractual aspects of the work. The basic tender documents have been modified to make them appropriate to the new techniques. At the successful completion of the training the contractors are able to bid for labour-based projects and are told that there would be a flow of such projects.

The basic approach taken to promote this sector in Cambodia has been to provide a range of initiatives. These have the objectives of strengthening the capacity within provincial authorities to plan, design, implement and maintain infrastructure (roads, structures, water supply and minor irrigation) works using the most cost-effective contraction techniques. The technology adopted has been to use labour-based methods, primarily based on the use of locally available resources, and with the participation of the private construction industry.

The outputs of the approach have been as follows:

Cambodia: Systems and procedures development

- Preparation of technical manuals for the construction of rural roads and drainage structures using labour-based methods to the maximum extent possible.
- A maintenance management system based on decentralised organisation using small contractors recruited from villages in the vicinity of the works to be maintained.
- Guidelines and procedures for planning, estimating, budgeting, personnel recruitment and employment conditions.
- A comprehensive reporting and monitoring system to ensure feedback of correct and comparable information from field projects that can be used as an effective management tool.
- Complete training packages developed and tested, targeted at:
- Provincial ministry staff in the management of labour-based rural infrastructure projects, and
- Small contractors in the technical aspects of labour-based infrastructure works, as well as in business management.
- Provincial engineers and technicians trained in selection, planning, design, implementation and management of contracts for infrastructure rehabilitation and maintenance by local small-scale contractors.

CONTRACT DOCUMENTATION AND MANAGEMENT PROCEDURES

To successfully promote small-scale contractors adjustments are needed to contract documentation and some of the management procedures. The following box sets out the steps in the preparation and tendering of a contract up to signature by the parties involved. Each step needs to be carefully planned and carried out to achieve a workable and 'transparent' system that gains the confidence of the parties involved.

6. Steps involved in letting a contract

lv. Works planned and approved?

lvi. Ensure funds are available

lvii. Appoint contract supervisor

lviii. Prepare contract documentation including conditions of contract, specifications, designs, method of measurement, arrangements for payments/inflation, bills of quantities and quality control method.

lix. Appoint contract adjudicator or arbitrator (where required).

lx. Contractors categorised according to experience, capability and training? Alternatively pre-qualify.

lxi. Select shortlist of contractors.

lxii. Invite selected contractors to tender.

lxiii. Respond to tenderer's queries and requests for clarification.

lxiv. Check compliance and evaluate tenders.

lxv. Approve selected tenderer.

lxvi. Check that funds are still available.

lxvii. Sign contract documents.

lxviii. Mobilise any training, instructors, equipment hire or special credit arrangements

limitations of FIDIC - 4th edition 1987

The traditional FIDIC (international) form of contract was designed for large construction projects. It has 145 clauses and 200 sub-clauses.

It is inappropriate for small-scale works. FIDIC needs to be modified and simplified to take account of the lower complexity of LBAT works and the lower risks and consequential costs for client. LBAT methods need to be encouraged by modifying construction/maintenance specifications. Changes need to be made to the contractor's equipment ownership requirements and whether somebody with LBAT experience needs to be permanently on site. Other factors to modify are the basis of measurement and payment, including the arrangements for payments, the payment period and late payment arrangements. The specific conditions that need to be considered are:

7. Adaptations to FIDIC needed for LBAT works

lxix. Inflation arrangements?

lxx. Handtools - safety and performance of workers.

lxxi. Worker health & safety.

lxxii. Safeguards against worker exploitation

lxxiii. Restrictions on contractors working elsewhere if client arranges particular assistance (e.g. training, finance, plant)

lxxiv. Simple language.

lxxv. Claims, complaints and disputes procedures (recognise client's dominant position?).

lxxvi. Testing obligations.

lxxvii. Insurance requirements.

lxxviii. Legal standing of documentation.

alternative standard contract documents

Fortunately a number of alternative and more appropriate standard contract documents are available. The alternatives include the contracts of the Institute of Civil Engineers (ICE): Minor Works 2nd Edition (1995), which is rather UK orientated; Short Contract for Small Scale Works (international) (1999); and Agreement for Consulting Work in Respect of Domestic or Small Works (1997). The World Bank has a contract for Procurement of Works, Smaller Contracts (1995), but this is appropriate only for international competitive bidding. FIDIC now has a Short Form of Contract (Test Edition) (1998). This has only 15 clauses and 55 sub-clauses. Alternatively, Tailor-made contract documentation can be developed directly related to LBAT needs and to the legal context.

change from force account

The change from a force account to a contracting approach for LBAT has far reaching implications for the client organisation and its management structure. With force account only a single organisation was involved, with contracting many. The main issues for a client organisation to consider in the change are who will now be responsible for the various contract administration stages:

8. Force account to private contracting – new participants

- Contract documentation and tendering procedures: legal departments, tender committees and professionals (engineers and quantity surveyors)
- Contract award: ministerial, provincial and local tender committees
- Monitoring of the works: supervisors and local consultants
- Certification of the works: engineers and laboratory staff
- Payment: certifying officers and accountants

Lesotho: capacity development for contract management

For example, after 20 years as a successful force account organisation after its establishment in 1977, the Labour Construction Unit in Lesotho revised its organisational structure to develop capacity for contract management. The objective was to gradually transform itself into a contracting agency with responsibility for contracts, including the capacity to plan and design contracts, issue tenders, award contracts. The shortage of local human resources meant that several of these tasks had to be carried out by expatriate technical assistance. The need for investment in the development in the development of systems and procedures, as well as for capacity building through training and experience, was generally underestimated.

There are a number of key issues essential for the survival of a small-scale contractor:

9. Issues essential to survival of emerging LBAT contractor

- Timely inspection of work
- Preparation of certificates of work
- Timely payment
- Assistance for cash-flow
- Appropriate contract size
- Continuity of work
- Diversity of work

New responsibilities and skills are required which will necessitate a capacity building programme. Both contractors and supervising organisations require appropriate planning and reporting systems to manage the works effectively and to minimise problems before they get out of control. Particularly important in improving the engineer and contractor performance will be to provide training in co-ordinated planning and reporting systems:

10. General planning and reporting systems

Frequency of reporting	*Contractor's internal system*	***Contracting agency's system***
Daily	• Resource use - muster roll - equipment • Materials • Tasks • Planned & actual outputs • problems on site	**Daily site diary** Daily site record of works
Weekly	• Resource use: - equipment - materials • Planned & actual outputs • Costs • Problems on site • Forecasts	**Record of site instructions** **Weekly works measurements** Inspection reports
Monthly	• Resource use: - equipment - materials • Planned & actual outputs • Costs • Problems on site • Forecasts	**From site to management** • progress • statistics • financial • problems • forecasts Summary to senior management
Quarterly/year		**Summary progress report from management to government departments and e funding agencies:** • Financial report • Plan of operations • Reviews /evaluations/studies

LABOUR STANDARDS FOR SMALL-SCALE CONTRACTING

There are a number of labour employment issues for which internationally agreed standards have been set. The employing and contracting organisations should comply with these.

- Equality
- Freedom from forced labour
- Freedom of association
- Minimum age limits
- Minimum wages
- Protection of wages
- Safety and health

Cambodia: Labour standards in practice

Cambodia has taken initiatives to comply with these standards. Thus, in some of the labour-based rural infrastructure projects in Cambodia, the application of relevant labour standards has been incorporated into counterpart staff training and can be observed in these projects' daily activities. They have served to introduce new concepts of labour practice and employment standards that are differed from the customary norms of employment in Cambodia. The dissemination of these new practices has gone beyond the project workers and reached wider sections of the rural communities. Among other things, the projects have developed visual aids such as posters on the themes of child labour, forced labour and on equal opportunities to men and women. These have been translated into Khmer and distributed to local commune offices. Special training modules (appropriate to local conditions) have been developed to help project staff in getting the message across to rural leader and workers, starting from the recruitment stage throughout until the completion of the works.

FURTHER READING

The student should refer to the following documents:

1 **Andersson, C.A., D. Miles, R. Neale and J. Ward** (1994). *Improve Your Construction Business: IYCB 1 - Pricing and Bidding; IYCB 2 – Site Management.* ILO, Geneva.

2 **Austen, A. and D. Miles, editors** (1987). *Guidelines for the Development of Small-scale Construction Enterprises.* ILO, Geneva.

3 **Bentall, P, A. Beusch and J. de Veen** (1999). *Employment Intensive Infrastructure Programmes: Capacity Building for Contracting in the Construction Sector*. ILO, Geneva.

4 **FIDIC (**1998). *Short Form of Contract.* Test Edition. FDIC.

5 **ICE** (1999). *Engineering and Construction Short Contract.* Institute of Civil Engineers, London.

6 **Larcher, P**. (1999). *A Model for A Contractor Support Agency.* MART Working Paper No 14, University of Loughborough, UK.

7 **Stiedl, D.** (1997*). A note on the draft ICE Short Contract and its. application to developing countries*. Mart Working Paper No. 11, University of Loughborough, UK.

11. Questions for students:

- *What are some of the advantages of using small-scale contractors?*
- *What are the types of problems experienced by small-scale contractors?*
- *How has capacity building for small-scale contractors been assisted in Cambodia?*
- *What are the basic steps involved in letting a LBAT contract?*
- *Why would a standard FIDIC contract need to be modified to use it for LBAT works?*
- *What are the key issues to resolve to ensure survival of small-scale contractors?*

ATTACHMENT – ENABLING ENVIRONMENT FOR LBAT CONTRACTORS

OBJECTIVE

This attachment details the factors that should be considered to obtain an enabling environment for small-scale LBAT contractors.

KEY POINTS – PRE-REQUISTES FOR SUCCESS

The key points involved with ensuring that there is an enabling environment to promote LBAT are:

lxxix. Competent contractors available, with adequate resources

lxxx. A reasonable balance between contractor capacity and market size for LBAT works.

lxxxi. Client's personnel capable of managing and supervising contracts.

lxxxii. Adequate registration/pre-qualification, selection and award procedures for contractors.

lxxxiii. Appropriate contract documentation.

lxxxiv. Contractor's access to affordable credit.

lxxxv. Efficient payment procedures.

To allow this to happen changes are needed over a wide range of institutions:

GOVERNMENT COMMITMENT AND POLICY FRAMEWORK

- Role as an agent for change
- Enabling environment for each category of contractor
- Adapting client role and attitudinal change
- Local resource utilisation, labour, skills etc.
- Decentralisation
- Educational and professional development
- Community involvement
- Inter-sectoral planning and co-ordination

GOVERNMENT LEGISLATION ON KEY ISSUES

- Contractors associations
- Anti-cartel measures
- Labour issues, standards and role of unions
- Community contracts and by-laws
- Equipment lease and hire-purchase
- Local consultant sector
- Fiscal, financial audit and procurement

FISCAL REGIME (GOVERNMENT REVENUE)

- Taxes and duties
- Subsidies, and levies

CLIENT'S FINANCIAL ADMINISTRATION

- Secure Funding
- Acceptable cashflow
- Dedicated road fund? Board? Stakeholder representation?
- Financial planning and management
- Timely and correct payment
- Effective financial audit

APPROPRIATE MANAGEMENT FRAMEWORK

- Autonomous Road Authority?
- Performance contracts
- NGOs and Communities
- Effective manpower development & training
- Realistic remuneration and career development
- Competent and motivated staff
- Competent specialist consultants
- Continuity in personnel and funding
- Internal co-ordination & collaboration

PROCUREMENT POLICIES & PROCEDURES

- Practices
- Decentralisation
- Contract Packaging
- Contractor classification
- (Local) capacity building
- Development of standards/specifications involving stakeholders
- Local supply of appropriate tools & equipment

DONOR POLICY

- Practices and experience
- Sector related co-ordination by government
- Collaboration
- Technical assistance (if required)
- Continuity

FUNDING MECHANISMS - RAISING AND DISBURSEMENT

- Adequate?
- Timely?
- Equipment?

CAPACITY BUILDING

- Clients
- Contractors
- Sub-contractors
- Supervisors and skilled personnel
- Communities
- Stakeholders

19: COSTING DEVELOPMENT WORKS – PRINCIPLES AND METHODS

Contents

1. Issues covered in this lecture

- Purpose of costing
- Economics and development engineering
- Principles of construction costing
- Direct Costs
- Indirect Project Costs

PURPOSE OF COSTING

Effective development engineering practice is highly dependent on the correct costing of the proposals. The prime reason for estimating costs is to ensure that the estimate (often called the "engineer's estimate") comes within a specific budget and to act as a guide for tendering. However, as the main reasons for using a development engineering approach is to obtain small-scale, inexpensive infrastructure appropriate for low-income rural areas the costs frequently need to be compared with construction using different methods. In addition, the costs often also have to be used in a financial and economic analysis of a project.

ECONOMICS AND DEVELOPMENT ENGINEERING

Before such analysis can be undertaken it will be necessary to assemble together all the information that has been collected and prepared in designing the project. The economic evaluation of any project will depend on the flow of development costs and revenues. There are broadly of two categories of cost:

- Initial investment (capital) costs; and
- Recurrent costs i.e. periodic and routine maintenance of infrastructure, and operating cost of plant and equipment. .

design trade-offs One of the commonest problems in engineering design is making trade-offs between different solutions. This can be between:

- Alternative design approaches, such as choosing between different road alignments or in deciding whether to build a single or two-storey building.
- Alternative work methods resulting in problems in the supply of materials or labour and different contract lengths.
- Alternative technologies, comparing capital intensive versus labour-based technologies.
- Alternative construction methods, such as making a trade-off between road pavement thickness and subgrade strength.
- Alternative materials, such as using locally made bricks with lime mortar, against imported concrete blocks and cement mortar (both requiring high energy and foreign exchange).
- Trading-off quality against quantity, such as a longer length of earth road instead of a short length of paved road.
- Alternative design standards, such as variations in road design speeds or design loads of bridges.
- Trading-off initial capital cost against maintenance cost, such as the costs of stone paved roads (with very low maintenance) against using laterite surfacing, with a lower initial cost but frequent maintenance needs.

life cycle cost planning

Life cycle costing is a useful concept in development engineering as it enables such trade-offs to be evaluated. This is done by quantifying the initial and recurrent costs as "costs-in-use" (also called "whole-life cost"). The basic method is as follows:

3. Life cycle costing (LCC)

$$LCC = Ic + (Mc + Ec + Cc + Oc) + (Vc) - Rv$$

Where:

- Ic = Initial cost
- Mc = Maintenance costs (annual and periodic)
- Ec = Energy cost (for buildings)
- Cc = Cleaning costs
- Oc = Overheads and management costs
- Vc = Utilisation costs
- Rv = Resale or scrap value

discounting costs

These costs occur at different times, so all costs need to be reduced (called "discounting") to a common time basis. This is to either allow a single value to be calculated ("net present value" or worth at one time) or a flow of money per time period (an "annual equivalent" sum). Present value can be obtained from standard tables, by using the formulas in cash flows entered into computer spreadsheets or be calculated from the following formula:

Net present value (NPV) of US$ 1 = 1 ÷ (1 + *i*)^n

Net present value: *The sum of the discounted costs and benefits. The higher the NPV the greater the project benefits.*

Where: i = rate of interest ÷ 100 and n = number of years

The annual equivalent method is similar to the NPV, but it is often simpler to understand as it produces an average annual outgoing. However, it is more appropriate as a way of evaluating building proposals (with rather uniform annual outgoings) rather than civil engineering construction.

shadow (economic) pricing and accounting ratio

The costs described above are financial costs and do not necessarily reflect their value to society. Thus resources should be priced according to their value to society – normally called "shadow pricing". This means adjusting for the "opportunity cost" of using the resources, which is their value if used for another purpose. For example, some scarce resources may be undervalued because of price subsidies or fixed foreign exchange rates. Unskilled labour may be over-valued if there are no alternative forms of employment. Calculating these shadow prices is a fairly complex process, but standard figures prepared by economists are sometimes available. The ratio between the financial price is called the "accounting ratio" and gives an indication of the over and under-pricing of resources. The following table (from Spence and Cook, 1983) gives some examples from India in 1975 for common construction materials:

4. Shadow pricing and accounting ratios (Rupees)

	Unit	*Financial price*	*Shadow price*	*Accounting ratio*
Cement	tonne	291.0	428.0	1: 1.47
Steel	tonne	2,510.0	5,780.0	1: 2.30
Timber	m^3	596.0	512.0	0.85
Stone	m^3	40.7	15.9	0.39
Sand	m^3	16.7	9.0	0.61

PRINCIPLES OF CONSTRUCTION COSTING

Detailed budget estimates of capital works will need to be prepared by the engineer. Preparation of costs should be undertaken as carefully as possible, since time spent at this stage is a small proportion of the total investment cost, and the value-for-money return on ensuring good and economic design is substantial.

types of cost estimates Cost estimates are required throughout the whole construction process, ranging from simple estimates at the initial identification and design stages, to more detailed costs prior to tendering:

lxxxvi. At preliminary stage it is usual to make budget estimates for each of the major elements using a simple unit cost basis such as kilometre length basis for roads, hectare developed for irrigation or m^2 for buildings or bridge decks. These costs, although very rough, need to be used cautiously as the whole economics of a project are often based upon them.

lxxxvii. During the design process, cost estimates are prepared based on approximate quantities, but using realistic unit rates, preferably derived from previous comparable projects. This type of costing is useful to check whether preliminary cost estimates were realistic.

lxxxviii. At the detailed design stage, costing is based upon an accurate bill of quantities. Preferably, each element should be priced in detail using unit rates reflecting local conditions and derived from recent contracts of a similar scale or, if applicable, using quotations obtained from manufacturers or suppliers (e.g. for vehicles or equipment).

cost elements The costs need to be carefully identified as they can be significantly affected by the methods of project procurement, i.e. whether it is by a conventional, targeted or force-account contract. A summary of typical cost elements are shown below:

5. Typical construction cost elements

- Pre-development costs, including site survey, planning fees, official permit fees and financing costs paid to banks and other lending institutions;
- Land acquisition costs, including legal fees and taxes;
- Direct construction costs, for labour, tools, equipment, materials, including:
  - Site preparation and clearance;
  - Infrastructure (civil works), usually broken down into sub-elements;
  - Structures -, culverts, bridges and buildings; and
  - Environmental impact mitigation measures.
- Indirect contract costs (non-constructional elements such as preliminaries).
- Design and supervision costs (for planning consultants and engineers).

The rest of this lecture is concerned with how the engineer or contractor goes about estimating contract costs. The description is based on the assumption that quantities are available for costing.

planning the work Before pricing each activity it is necessary for the engineer (or contractor) to "plan" the work to be carried out:

- Decide an overall strategy to organise and carry out the work.
- List activities in the order including preparatory and support activities (e.g. transport, establishment of site camp, etc.)
- For each activity estimate the resources required and calculate the time necessary to complete the task.
- Decide on the organisation arrangements (e.g. number of supervisors, work gangs, responsibilities, support, etc.)
- Draw up a preliminary work programme.
- Prepare a schedule of manpower, equipment and materials requirements matching the work programme.
- Check availability of manpower, equipment and materials from other companies, organisations or suppliers (hire or purchase).
- Check procurement period for new equipment.
- Check work plan against the available of resources and correct it if necessary
- Identify critical activities, events or potential delays that may need alternative plans or management decisions.

To make sure all costs are taken into account a system needs to be followed when pricing, by dividing cost into two main groups:

lxxxix. Direct costs (linked directly to the activities of the job); and

xc. Indirect costs (other costs a contractor needs to recover.

DIRECT COSTS

Direct project costs are materials, labour, plant and transportation. These costs are usually based on comparable unit rates from records of previous projects.

things to remember

- When calculating plant and labour costs, based on actual working time, no allowance is made for when labourers are not working, but are still being paid, or when plant is standing idle.
- If materials are already in stock, they should be costed at their replacement value because that is the value they have now.
- Task rates for individual activities are based on averages for several projects. A major issue during the site inspection is to determine operating conditions affecting expected task rates.

example of direct costs

An example of building up direct costs is shown in Attachment 1 at the end of this lecture. The first four columns are taken directly from the bill of quantities and provide basic information for the calculation. The next five columns contain the four cost elements for each item, plus the total for that item.

INDIRECT PROJECT COST

Indirect project costs are costs that are not linked to a specific project activity but are necessary to complete a project.

recovery of costs Some indirect costs can be recovered over a series of separate contracts. Temporary buildings, such as offices, are dismantled and re-used many times before they come to the end of their useful life, but they will lose some of their value each time they are re-used and each job should help to pay for their replacement. Other costs will have to be recovered in full on the project on which they are used. If many major indirect costs are forgotten it can easily turn an anticipated profit into a loss. There are broadly three types of indirect costs: preliminaries, risk and company costs.

Preliminaries

Preliminaries are additional costs that are related to carrying out the project but are not directly linked to any specific project activity (item in the bill of quantities). A calculation of preliminary costs on a project is shown in Attachment 2. The example is based on the same contract used when calculating Direct Project costs. The preliminary costs are presented under the following headings:

supervision Site supervision is a combination of the cost of employing any or all of the following: site manager; general supervisors/foremen; trades foremen; site clerk; storekeepers; engineers and surveyors. On many contracts site supervision is listed as a separate item in the bill.

site camp facilities Before site work can start a site camp has to be established. The size of the camp depends on the kind of work and how many people need to be housed in the field. Typical requirements for a construction site field camp are: hut for the site supervisor; site office; store, toilet and bathroom; housing for plant operators during gravelling, and separate store for fuel, oil and lubricants.

water supply A supply of clean water is essential both to supply the staff with drinking water and to ensure that concrete mixed on site is of adequate quality and that soils are compacted to an optimal moisture content. There can be considerable costs for access to clean water and to transport it to site and/or site camp.

transport Transportation includes transport of site personnel and the cost of setting up facilities on site. Transport costs, like transport of materials needed for construction can be allowed for in three separate ways: as an item under preliminaries; in the unit price of materials; and as a proportion of the direct project cost.

road safety measures Roadwork contractors are directly responsible for the safety of workers and road users. Many roadwork activities are potentially dangerous and to minimise the risks, temporary traffic signs, barriers and other protections need to be provided and correctly located on site for the duration of the works. The signs, barriers can of course be used on several projects if properly taken care of.

safety These costs include provision of protective clothing, safety helmets, protective glasses, safety shoes, first-aid boxes, etc. Apart from legal considerations it is false economy to cut down on these costs, as it would reduce the productivity and goodwill of the workforce, and hence reduce the overall profit on a project.

security It may be necessary to provide protection in the form of watchmen, alarms watch dogs. In Cambodia, road construction projects and site camps may require demining before setting out and construction commences.

site clearance An allowance has to be made for clearing up the site and the camp, so that it is clean and tidy when handed over to the client.

insurance Insurance cover is required by national law, some as a condition of contract and some are voluntary. The common types of insurance are: vehicle insurance; employers' liability insurance; public liability; plant insurance; and workers compensation. These are sometimes covered by a contractor's all-risks policy.

bonds Performance bonds are a form of insurance cover, taken out to cover the risks to the owner of non-performance by the contractor. Non-performance can include bankruptcy or liquidation of the contractors business, failure to complete work on time resulting in the need to appoint another contractor to complete the work. The contractor pays for the bond but the benefit goes to the client, so the cost of the bond must be fully reflected in the contractor's price. Small contractors often find it very difficult to obtain bonds.

Risk allowance

The main risks in construction are: inaccurate estimating; rising prices on fixed price contracts; delays due to bad weather; work needing to be redone; carelessness by employees, unexpected technical problems and clients defaulting on their debts. By signing a contract, the client ensures that the cost of the project is known, and the risk is passed on to the contractor in return for the margin of profit allowed. Whatever precautions are taken, the contractor will never be able to eliminate all the risks but it is possible, by proper planning and forecasting, to find ways to reduce the risks. Some risks are covered by an appropriate insurance policy and included in preliminaries. Extra precautions to cover special contract risks that are not covered elsewhere should be included in the risk allowance.

calculating the risk allowance There are two different ways of calculating risk allowances. It can be added to individual work items and shared according to the amount of risk connected with various items. For example, a 10% allowance could be added to works that can be seriously affected by bad weather, but only 2% to other works that are relatively free of risk. Alternatively, on smaller contracts. it can be added as a percentage of total direct project costs:

Assume that the total direct project cost has been calculated at $11,858.61. The bidder has decided to make an overall risk allowance of 5%. The risk allowance @ 5% of $11,858 = $593

Construction company costs

Every year, contractors must meet a certain amount of company costs, representing the basic costs of being in the business. Each contract must therefore cover part of the company costs. As a general principle, the bigger the contract, the larger the proportion of the company cost it has to cover. The main company costs are: staff salaries; property; vehicles and loan interest.

staff salaries Staff salaries cover all costs of employing full time staff, including the contractor's salary (and partners, if any), site mangers and permanent foremen, secretaries, accountancy staff and watchmen. Foremen and supervisors hired for a specific job can also directly charged to a project in the preliminaries. Additional cost to basic salaries and wages include taxes and any benefits paid for by the company, such as housing allowances.

property: Property costs are the expenses connected with the company's office or storage facilities. If rented, the costs are simply the rent paid plus any related direct costs. If a property is on a long lease, then the cost of buying the lease would be spread over a number of years. In addition, allowance must be made for related charges such as maintenance costs and electricity, water and telephone charges. These can usually be estimated on the basis of past records, plus an allowance for future inflation.

vehicles The cost of running company vehicles includes buying their vehicles, maintenance, spare parts, insurance and fuel. The cost of buying the vehicles is a one-time investment every 5-10 years, depending on the type of vehicle and how much it is used. This should be allowed for by depreciating the cost over the number of years it is expected to last (described in the next lectures).

loan interest The contractor normally has to take short-term loans, which have a high rate of interest. A cash flow forecast tells him how much cash he will need to be able to run a project but also when it starts to give him a net income i.e. when a loan can be paid back.

calculating company costs The following is an example of annual company running costs:

6. Typical types of construction company costs

Item No	*Description*	*Cost ($)*
C1	Director's salary (contractor) @ $300 per month	3,600.00
C2	Secretary/Typist @ $60 per month	720.00
C3	Office cleaner @ $30 per month	360.00
C4	Book-keeper/Auditor (Accounts) @ $70 per month	840.00
C5	Office rent and running cost @ $40 per month	480.00
C6	Lease of director's vehicle	600.00
C7	Interest on bank loan	150.00
	Total Company Cost	6,750.00
	Monthly average cost	562.50

distributing company costs The next step is to distribute the company cost fairly over different projects. One way of doing this is as a percentage of the overall turnover, estimated on the basis of past performance or future workload. For example, if the estimated turnover of the company is $100,000 and the company cost is $15,000, a 15% charge on all projects should be sufficient to recover all company costs.

Summarising indirect costs

Sometimes "preliminaries" are included in a bill of quantities, in which case they can be priced directly. However, bill items rarely cover the other indirect project costs, either as a separate lump sum or as a percentage addition to all the items in the bill of quantities.

lump sums - qualified bids

Although a single lump sum is easier to calculate, it has certain disadvantages. The most important of these is that there will be no specific item in the bill of quantities to cover it, so the bid will effectively be altered from the form proposed by the consultant and become "qualified". Such qualified bids create extra work for the client and the consultant since they make it more difficult to compare one bid with another. Sometimes qualified bids are automatically disqualified. Explicit mention of "risk allowance" and "company costs" can make the client suspicious that the contractor is overcharging and can lead to arguments when certificates are submitted.

percentage additions to bill items

So the second alternative is usually best, letting each item bear a fair share of the overall costs of carrying out the work. The advantages are in the avoidance of a controversial lump sum provision and in the possibility of varying percentage additions to take account of the risk and/or to obtain quicker recovery by increasing percentage on early items and reducing it on work undertaken later.

total indirect costs

An example of the make up indirect costs is shown below:

7. Summary of indirect costs

Item No.	*Description*	*Cost ($)*
A.	Preliminaries	2,147.00
B.	Risk Allowance	593.00
C.	Company Costs	1,687.00
Total indirect costs		4,427.00

In the example shown, based on figures in Attachments 1 and 2, total indirect project cost represents an addition of approximately 37% onto the direct project cost (100 x 4,427/11,856 = 37.3%). This could either presented as a lump sum or as 37% added to the individual unit rates.

Contingency sums on budget estimates

It is usual to add a physical contingency sum of between 10-20% to allow for uncertainties. If the cost estimate is very broad (i.e. no suitable unit rates are available) or the works is uncertain, such as site preparation where sub-soil conditions are unknown, then a higher percentage should be used. An allowance for professional fees should also be included if the works are of sufficient complexity to require the employment of outside consultants.

FURTHER READING

The student should refer to the following documents:

1 **Andersson C-A.** et al (1994): *Pricing and Bidding - Improve Your Construction Business – I*. ILO, Geneva.

2 **Allal. M. and G. Edmunds** (1977). *Manual on the planning of labour-intensive road construction*. ILO, Geneva.

3 **Davis Langdon and Everest, editors** (1997): *Spon's Civil Engineering & Highway Works Price Book.* E. & F.N. Spon, Chapman and Hall, London.

4 **Lee, R. (1987).** *Building Maintenance Management.* William Collins Sons & Co. Ltd., London.

5 **Spain, B. (1994).** *Spon's Budget Estimating Handbook.* E. & F.N. Spon, Chapman and Hall, London.

6 **Spence, R. and D. Cook** (1983). *Building Materials in Developing Countries.* John Wiley & Son, Chichester and New York.

8. Questions for students:

- *What are some examples of trade-offs that may have to be made in project design?*
- *Why is using net present values a useful method of evaluating trade-offs?*
- *What types of cost estimates are usually undertaken during project design?*
- *What is the difference between direct and indirect costs?*
- *What are some of the main items included in the preliminaries?*
- *How would you go about calculating the cost of project risks?*
- *How is the cost of vehicles taken into account in assessing construction company costs?*

ATTACHMENT 1: DIRECT PROJECT COSTS FOR ROAD PROJECT

Example of a list of quantities and unit costs (taken from a priced bill of quantities)

Item No	*Description*	*Unit*	*Quantities*	*Unit cost (US$)*				*Total (US$)*
				Labour	*Plant and Tools*	*Materials*	*Transport*	
1.1	(Re) establishment of road alignment	m	5,000	277.50	59.63	8.47	-	345.60
1.2	Clearing and grubbing	m^2	11,180	138.75	10.47	-	-	149.22
1.3	Construction/maintenance of access roads	m	1,000	250.00	6.96	-	-	256.96
1.4	Excavation of overburden including loading, hauling and stocking	m^3	15	185.00	12.71	-	-	197.71
2.1.1	Reform to 8% camber	m^2	18,000	277.50	21.62	-	-	299.12
2.1.2	Haul fill	m^3	10	14.80	9.88	-	-	24.68
2.1.3	Water reshaped roadway and compact	m^2	18,000	157.94	816.28	-	-	974.22
2.2.1	Collect stones & rebuild retaining walls	m^3	3.375	7.40	14.37	-	-	21.77
3.1.1	Re-excavate/clean drains and dispose of materials	m^3	40.300	14.91	3.05	-	-	17.96
3.2.1	Desilt all culverts and dispose of silt	m^3	0.420	1.85	0.35	-	-	2.20
4.1.1	Excavate, stockpile and load gravel	m^3	3,438	4,452.21	157.85	-	-	4,610.06
4.1.2	Remove boulders and stockpile	m^3	50	46.25	13.76	-	-	60.01
4.2	Haulage by tripper or tractor and trailer:							
4.2.2.1	(distance 0-2,000m)	m^3	206.25	-	-	-	92.87	92.87
4.2.2.2	(distance 2,001 – 4,000m)	m^3	1,375	-	-	-	812.52	812.52
4.2.2.3	(distance 4,001 – 6,000m)	m^3	1,375	-	-	-	1,124.52	1,124.52
4.2.2.4	(distance over 6,000m)	m^3	481.25	-	-	-	468.04	468.04
4.3.1	Spread gravel to 8% camber/cross-fall.	m^3	3,438	530.95	273.98	-	-	8,493
4.4.1	Water & compact gravel	m^2	25,000	462.50	1,133.72	-	-	1,596.22
	Final Total of Direct Project Cost							**$ 11,858.61**

ATTACHMENT 2: ESTIMATING COSTS OF PRELIMINARIES FOR ROAD PROJECT

Example of a list of quantities and unit costs (taken from a priced bill of quantities)

Item No	*Description*	*Unit*	*Quantities*	*Unit rate US$*	*Element cost US$*	***Total cost (US$)***
P1	***Supervision:***					
	supervisors	month	2	$130.00	$780.00	
	site clerk/storekeeper	month	1	$100.00	$300,00	
	night watchman	month	1	$50.00	$150.00	
	Sub-total, supervision					**$1,230.00**
P2	***Office, Shed and Storage:***					
	Site huts	number	2	$95.00	$190.00	
	Camp fencing materials	Lump sum	1	$40.00	$40.00	
	Sub-total, office, shed and storage					**$230.00**
P3	***Utility Services:*** Water payment	month	3	$10.00		**$30.00**
P4	***Plant and Tools:*** Provisional sum for any special tools required	Provisional sum	1	$50.00		**$50.00**
P5	***Transport:***					
	Supervision vehicle	number	3	$120.00	$360.00	
	Transport of tools, and camp materials	Lump sum	1	$60.00	$60.00	
	Sub-total, transport					**$420.00**
P6	***Insurance:*** Contractor's fully comprehensive insurance	Lump sum	1	$85.00		**$85.00**
P7	***Bonds:*** Performance bond	Lump sum	1	$102.00		**$102.00**
	TOTAL PRELIMINARIES COST					**$ 2,147.00**

Note on preliminaries:

P1 The contractor should have two headmen/supervisors who should be trained to assist the contractor in the quarry and on reshaping and gravel spreading. The contractor would have to carefully select and train on-the-job the headmen/supervisors to maintain and execute his contracts.

A storekeeper is always necessary on a construction site for record keeping and control of tools and materials.

For a small-scale contractor a day watchman may not be necessary since the storekeeper would be full time in the camp. However, the contractor is at liberty to provide for one.

P2 It is assumed that the site staff would be recruited from two villages and therefore would come from their homes to work. A toilet is not provided but for arrangement has been made with a landlord next to the camp for the use of his facility for a fee.

P3 Arrangement has also been made with the owner of the borehole at Kilometre 1+350.

P4 A provision is made for any special tools which may be required on the site. For example pliers, files, spanners, brushes, etc., which are not charged to a specific activity on site.

P5 Cost of transporting tools and camp materials is for both ways, to and from the site.

P6 Cost covers both the contractors' all risks policy and labourers compensation policy.

P7 Cost of acquiring a performance bond should be fully catered for.

20: EQUIPMENT COSTING – PRINCIPLES AND METHODS

Contents

1. Issues covered in this lecture

- Purpose of costing equipment
- Equipment cost components
- Financing and opportunity costs
- Depreciation and replacement
- Equipment costing issues in Cambodia

PURPOSE OF COSTING EQUIPMENT

The following notes review the general principles of costing equipment and the application of these principles in a cost model is explained in the next lecture.

true costs of ownership and operation

The purpose of costing equipment accurately is to reflect the true costs of ownership and operation. This is needed so that the true cost of the equipment is recovered over its working life and to provide an incentive so that equipment is only used for those operations for which it is appropriate and economical.

necessity to cost equipment properly

With the trend towards contractor implementation of road works (and possibly intermediate equipment hire) it becomes essential that contractors, client's representatives and other users become aware of the true costs of equipment ownership and operation. Where different cost components are managed in separate departments/accounts (e.g. investment, replacement, workshop support and operation) it is particularly important to appreciate the cost implications for each component.

practical difficulties

However, there are difficulties in equipment costing due to a range of problems, which include:

2. Difficulties with equipment costing

- Lack of awareness and consideration of all cost components.
- Lack of recorded data on actual costs, use and performance.
- Uncertainties regarding future market, costs, economic life and utilisation of the equipment.
- Insufficient commercial pressures on decision making
- Artificial market conditions including temporary availability of untaxed second-hand low-price equipment.

EQUIPMENT COST COMPONENTS

When costing the equipment component of a piece of work there are two stages to the process:

xci. **Stage 1.** Determining the cost of provision of the equipment (to make it *available*).

xcii. **Stage 2.** Determining the output or productivity of operating the piece of equipment (the *utilisation of the equipment*)

availability Apart from the purchase cost of the equipment, whether new or second-hand, the Stage 1 cost estimate needs to take into account the cost of financing the capital (or its opportunity cost) and the depreciation of the equipment, requiring it to be replaced in the future. These terms are explained a little later in this lecture.

utilisation The utilisation of the equipment obviously depends on the extent to which a contractor is able to fully use the piece of equipment. In the UK for example it is not unusual for an item of plant to be used for 2,100 hours in a working year. This means that 'it is not usually economical for contractors to own plant unless they can ensure at least a 75-80% utilisation factor, based on the contractor's normal working hours'. The basic question on utilisation, therefore, is the number of equipment work hours in a year and the number of years it will be used. To cost the utilisation of the equipment it is necessary to look at all the components that directly relate to its use. These components include:

3. Utilisation cost components

- Fuel and lubricants
- Spares and consumables
- Mechanical workshop costs
- Operators' payments, allowances and expenses
- Overheads
- Risk (e.g. late payment)
- Profit

A more detailed checklist of the components to consider is given in the attachment to this lecture. How these components are estimated is described in the next lecture.

FINANCING AND OPPORTUNITY COSTS

The financing of equipment is either the *cost of borrowing* the capital to invest in the equipment or its value as an *"opportunity cost"*. Thus, if you already have the funds or the equipment the *opportunity cost* is the 'return' you could obtain if you invested the money elsewhere. The financing is usually expressed as an annual interest rate (e.g. 15 %).

the price of money The cost of borrowing from banks in developed countries is comparatively low (currently less than 5% in the USA and UK, less than 25 in Switzerland and virtually zero in Japan). In contrast, developing country rates are typically around 20% (Indonesia, Nepal, Laos and Lesotho in 1999) and can be as high as 50% (Ghana, Madagascar and Mozambique, also in 1999). In these circumstances it may be extremely difficult for contractors to borrow from banks and they may have to rely on family sources, or in extreme circumstances, moneylenders.

opportunity cost of an equipment fleet

As mentioned before, the alternative way of looking at the price of money is to view it as an opportunity cost. For example, for gravelling capability alone (using new equipment) the following fleet of plant and equipment might be needed:

4. Equipment fleet costs

Item	Value (US$)
1 x Tracked Loading Shovel (953)	215,000
5 x 7t Tippers	275,000
1 x Motorgrader (140)	250,000
1 x Self Propelled Roller	85,000
1 x Fuel Bowser Truck	60,000
1 x Water Bowser Truck	55,000
1 x Service Truck	60,000
1 x Supervision Pick-up	20,000
TOTAL	1,020,000

These costs will obviously vary according to country involved – the local taxes, duties and dealer's margins. At an annual opportunity cost of 10% the fleet cost represents US$ 100,000 per year or about US$ 500 per working day. At a 20% opportunity cost interest rate it equals US$ 1,000 a day!

equipment replacement and depreciation costs

When a piece of equipment is new, it *may* have an economic life potential of 5,000-20,000 hours. At the end of this period, the equipment will need to be replaced. Depreciation, therefore, is the *cost for 'using up' the potential life in the piece of equipment.* Even with inflation, the residual value of the piece of equipment will tend towards zero! You will not know the **actual** depreciation costs of a piece of equipment until the day you sell or scrap it. However, it is still important to try to make an estimate of the annual cost of owning the item of plant. The key parameters involved in making this estimate are:

factors influencing costs and output of equipment

- The cost at acquisition - a known fact.
- The residual value at disposal or as scrap - a prediction, up to 15 years ahead!
- The useful or "economic" life of the equipment in years. Again a prediction but guided to some extent by the manufacturer's data on the expected number of engine hours that the equipment should be capable of providing.
- The annual utilisation, a prediction of the number of hours in a year the equipment is likely to be used.
- Obsolescence – whether it will still remain the most appropriate piece of plant to do the job.

methods of estimating depreciation

The purpose of the estimate is to convert all these factors into a common format, so the equipment cost per hour or day can be compiled. There are a number of standard methods for estimating the annual level of depreciation:

- Straight line (equal amount per year).
- Declining balance (certain percentage per year) e.g. 26%
- Sum of digits: 10+9+8+7+6+5+4+3+2+1=55 (1st year = 10/55)
- Free depreciation (in the overheads)
- Current replacement cost ÷ expected life

EQUIPMENT COSTING ISSUES IN CAMBODIA

The types of problems experienced with equipment in Cambodia are typical of many countries in the region. The construction season is short, there is little continuity of workload, a small market and relatively few clients. This means there is limited scope for contractors to expand and a low utilisation of equipment. Other issues are shortage of funds to replace old or obsolete equipment, because of the high cost and limited availability of finance, and cashflow problems due to late payment by clients.

improving the use of equipment

Contractors need to keep an eye on what the market wants. The essential point is that if any investment is made in plant it should be working nearly every day How is it possible to improve the use of equipment and to help contractors price competitively? This can be achieved by the following means:

5. Improving use of equipment

- Raising equipment utilisation
- Adequate equipment maintenance
- Careful operation
- Reducing overheads

raising equipment utilisation

The finance and depreciation cost components are a considerable proportion of the total costs and to raise utilisation requires the equipment use to be spread over a greater number of paid working hours and to keep the equipment fully occupied. This can also mean that the contractor might hire the equipment out (using their own reliable and trained operator) if they do not have work for the equipment to be fully utilised.

adequate equipment maintenance

It is essential to make sure that equipment is well maintained and will have a long operational life. The equipment should be regularly checked and maintained and mechanics should be competent, trained and motivated. The correct spares should be available and used. This means that contractors should buy only robust, reliable, flexible equipment with good spares back-up (this my be a major problem if second-hand equipment is purchased)

careful operation The contractor needs to make sure that the equipment is carefully operated by ensuring that the operator is competent, trained and motivated.

reducing overheads It is essential to keep overheads low by knowing all the costs, by eliminating waste, by not employing non-productive people or equipment and by ensuring all personnel work efficiently. Hiring-in equipment is a possible solution if the contractor expects low utilisation. By hiring, the equipment is only used when needed and the contractor does not bear the costs when it is standing idle.

initiatives to assist small-scale contractors There are a number of possible initiatives to support small-scale contractors with respect to equipment ownership and operation in Cambodia that may help contractors to overcome these problems:

6. Assistance to small-scale contractors

- Involve small-scale contractors associations.
- Promote commercial hire organisation providing a full range of intermediate equipment (and spares), run by the private sector, contractor's association, equipment suppliers or government run organisation (problematic).
- Provide a realistic and transparent equipment costing service and database – this would need to be updated regularly. The main problem to solve is who manages it and how is paid for.
- Improve access to loan finance.
- Improve payment procedures and contract terms.
- Ensure continuity of workload to the sector.
- Provide training in managing and operating equipment.

FURTHER READING

The student should refer to the following documents:

1 **Coukis, B**. (I983): *Labour-based construction programs: a practical guide for planning and management;* World Bank Publication. London (Oxford University Press).

2 **Davis Langdon and Everest, editors** (1997): *Spon's Civil Engineering & Highway Works Price Book.* E. & F.N. Spon, Chapman and Hall, London.

3 **ILO** (1981): *Guide to tools and equipment for labour based road construction* and maintenance. ILO, Geneva.

4 **Larcher, P. and R. C. Petts** (undated): *Selective Experience of Training, Contracting and Use of Intermediate Equipment for Labour-based Roadworks.* MART Working Paper No. 2, MART-ILO, Loughborough University, England.

5 **McCleary, W., M. Allal. and B. Nilsson** (1976). *Equipment versus employment*. ILO, Geneva.

6 **Petts R. C.** (1999): *Handbook of Intermediate Equipment for Roadworks in Developing Countries*, MART, Loughborough University, England.

7. Questions for students:

- *Why is it necessary to cost equipment properly and what are some of the difficulties in doing it?*
- *How will utilisation of equipment vary between developed and developing countries?*
- *What is an opportunity cost?*
- *What are the factors influencing the costs and output of equipment?*
- *How can the use of equipment be improved?*
- *How is it possible to help small-scale contractors with equipment ownership and operation?*

ATTACHMENT: SUMMARY OF FACTORS TO CONSIDER IN COSTING EQUIPMENT

The following are a summary of the factors that will affect the cost of ownership and operation of equipment, and its profitability:

Input Costs	***Output/Productivity***
• Economic Life	• Standing time (breakdowns, awaiting spares/fuel, etc.)
• Depreciation: Capital Investment /Replacement	• Unproductive time (awaiting instructions, travel to/from/between work sites etc.)
• Obsolescence	• Productive time per year
• Salvage value/demand for used equipment	• Type & size of machine (appropriate? flexible?)
• Interest: Investment Costs	• Ground conditions
• Spare Parts and Consumables	• Climate
• Workshop (inc. mechanics, equipment, tools, manuals, stores, etc.)	• Nature of the work
• Mobile mechanical & logistical support	• Skill/motivation of operator/assistant(s)
• Workshop Management	• Condition of Machine
• Skill/motivation of mechanical support	• Work Planning and Organisation
• Mobilisation (Low loader)	• Adjustments from manufacturer's guidelines
• Manufacturer's local agent support	
• Insurance's and taxes	
• Fuels, lubricants and greases (& their quality)	
• Operator and assistant(s)	
• Accommodation/transport/payroll costs	
• Training (initial and ongoing)	
• Environmental (e.g. dusty air)	
• Standardisation (effects on spares/skills/training)	
• Foreign exchange premium	
• Risks and cashflow in long term	
• Investment	
• Contractor cashflow: time lag between incurring costs and payment	

21: EQUIPMENT COSTING: USING A COST MODEL

Contents

1. Issues covered in this lecture

- BACKGROUND TO THE MODEL
- USING THE MODEL
- Depreciation and financing
- Ownership costs
- Operating costs
- Daily allowances for overheads
- Profit margin
- Total cost to be charged

BACKGROUND TO THE MODEL

This lecture goes through a procedure for costing equipment. It is based on the use of a simple model (developed by Intech Associates for MART, Institute of Development Engineering, Loughborough University, UK.).

approach to costing equipment using a model

To use the model assumptions have to be made regarding the *utilisation* of the equipment and prediction of how much work it will actually produce. This stage of the costing calculation is comparatively simple, but requires local data to be collected on actual field experiences as productivity. This will vary depending on factors such as local traditions, operator skill and motivation, site characteristics, logistics, material and weather conditions, seasonal factors etc. Indicative values for the life and utilisation of heavy plant in the UK is shown in the following table:

2. Economical ownership periods for heavy plant in the UK

Plant item	*Economic life - years*	*Usage - hours/year*
Large hydraulic excavators	9	1,575
Dozers/scrapers/graders	10	1,680
Loaders/shovels	9	1,680
Tipper trucks	6	1,890
Rollers/compaction	6	1,680
Diesel road vehicles	6-7	1,890
Petrol road vehicles	5-6	1,890

Source: Spon's Civil Engineering & Highway Works Price Book, London, 1997

importance of record keeping

The model allows assumptions to be made about the many factors affecting the cost of a piece of equipment. However, the *actual* overall costs will not be known until the day the piece of equipment is finally sold or scrapped (assuming adequate records have been kept throughout the equipment ownership). Costing, therefore, depends on good record keeping and a realistic appreciation and assessment of a range of important historical, current and future factors.

cost of finance The model can be used to highlight the real costs of financing and ownership which are neglected in equipment management systems, and which can dwarf operating costs in a high-cost-finance environment; thus possibly adversely affecting management decisions on choice of technology or equipment. Whereas finance may be obtainable at about 10% (or less) per annum in economically developed countries, they may be many times higher in developing economies (typically 15-50% per annum).

high cost of sophisticated plant. Failure to take sufficient account of and provision for financing and ownership costs will ultimately lead to severe problems when it becomes necessary to replace the equipment. Costs are also particularly sensitive to annual utilisation (as show in the Tables A and B in the Cost Model). Whereas many equipment items are designed to achieve annual utilisation of 1,000 to 2,000 hours of work for economic ownership, significantly lower utilisation can be extremely expensive and uneconomic. The model can be used to demonstrate that for most roadworks in developing countries the operating environment is particularly unfavourable to the use of sophisticated plant.

USING THE MODEL

The cost model provides a means to calculate the various cost components and the overall costs of *provision* of a piece of equipment. The model includes all cost components relating to the ownership, operation and overheads components. The model may be used for any type of intermediate or heavy equipment. It comprises three "sheets" (1, 2 and 3), which is all that is required to carry out the costing of a piece of equipment. The costing system should allow engineers and contractors to quickly assess the affects of various assumptions or scenarios and how this will affect a project's income, outgoings and profits. The detailed sheets are given in an attachment at the end of the lecture.

Depreciation and financing

The first step in using the model is to determine the hourly cost of depreciation/replacement (Sheet 1) and finance (from Sheet 2). These cost figures to be inserted on Sheet 3 in boxes C1 *and* C2 respectively using the method described below. The initial figures used are based on an assumed cost of US$ 10,000, which is adjusted later against the actual cost. The following conservative "rule-of-thumb" assumptions can be made related to the life and utilisation of equipment:

life and utilisation of equipment

- Equipment has a minimum life of 5 years (this is often longer in developing countries, but this figure is conventionally used in the financial and economic analysis of projects). A practical maximum life is 10 years, although in many cases the life may be longer; and
- An absolute minimum utilisation of 1 day a week equivalent to 400 hours per year and a typical maximum in developing countries of 1,200 hours per year (anything greater than that would produce further financial benefits).

average utilisation

- *Estimate the average utilisation of the piece of equipment in hours/year.*

economic life

- *Predict the economic life in years of the equipment between initial purchase and expected date of disposal.* The system allows for purchase new or second-hand equipment and disposal before or at the end of its useful life.

depreciation/replacement

- *From Table A1 read off the depreciation/replacement charge in US$ per hour according to the selected utilisation and economic life.* This is the cost of using up the investment or life in the equipment. *Circle or note the selected figure for future reference. Insert this figure in Box C1 on Sheet 3*

interest rate

- *Select the interest rate (Table B1, B2* or *B3) that most closely matches the expected cost of finance (or opportunity cost) through the ownership of the equipment.* For other interest rates interpolate between figures in the tables. Extreme caution should be used, as prediction of future interest rates is extremely problematic. Interest rates should include an allowance for arrangement fees and any other special charges added to the cost of arranging or servicing a loan.

finance charge

- *From Table B1, B2* or *B3 read off the finance charge in US$ per hour according to the selected utilisation and economic life. Circle or note the selected Figure for future reference. Insert this Figure in Box C2 on Sheet 3.*

This is the cost of obtaining the funds to invest in the equipment. Alternatively if the equipment is already owned or the funds to purchase it are already available, the financing cost is the *opportunity cost* of the capital; if the money was invested elsewhere it could represent the interest or return that would be obtained by investing the capital.

Particular care should be taken in selecting the interest rate. If finance is used, the actual rate, whether in local or foreign currency should be used, as this is what the financing institution will charge. However, where currency exchange rates are expected to fluctuate, an allowance should be made for this risk.

Where an opportunity cost is used, this should represent the assessed REAL value of the capital deployed. This should be determined with reference to the market interest rates for capital and local inflation. Equipment may be provided to a road authority free-of-charge or at a subsidised loan rate, but this is not a realistic or sustainable method of costing, particularly for a national equipment fleet. Contractors *must* take account of this component to realistically cost their equipment.

Steps 1 to 5 are the most difficult in the costing process to assess as assumptions are made dependent on a prediction of future conditions and equipment performance throughout its life. Over-assessment could lead to non-competitive bids by a contractor. Under-assessment will provide inadequate funding for loans and/or replacement of equipment.

- *Insert the selected interest rate assumed for reference purposes in the box provided on sheet 3.*

Ownership costs

All the next steps are all contained on Sheet 3. The first activity should be to estimate the equipment ownership cost.

3. Ownership costs

C	ADJUSTMENT FOR ACTUAL PURCHASE COST			
	Depreciation/replacement charge for $10,000 (from Table A)	*US$ per hour*		*(C1)*
	Selected finance charge from Table B (prop-rata to get actual value)	*US$ per hour*		*(C2)*
	Actual purchase/replacement cost	*US$*		*(C3)*
	Assumed number of operating hours per day	*hours per day*		*(C4)*
	DAILY OWNERSHIP COSTS = (C1 + C2) x C4 x C3/$10,000 =	*US$ per day*		*(C)*
D	ADJUSTMENT FOR EXPECTED RESIDUAL/SCRAP VALUE (if any)			
	Assumed residual/scrap value	*US$*		*(D1)*
	Assumed economic life	*years*		*(D2)*
	Assumed utilisation	*hours per year*		*(D3)*
	ADJUSTMENT FOR RESIDUAL/SCRAP VALUE = (D1 x C4)/(D2 x D3)	*US$ per day*		*(D)*
	SUB-TOTAL FOR OWNERSHIP COSTS = (C) - (D) =	*US$ per day*		*(W)*

- *Insert in Box C 1 the depreciation/replacement charge selected as described in Step 3.*
- *Insert in Box C 2 the finance charge selected as described in Step 5.*

cost of procurement

- *Insert the actual cost of procurement or replacement of the piece of equipment in Box C3.* This will almost certainly be different from the *standard cost of US$ 10,000* used in Sheets 1 and 2, and an adjustment for this will need to be made. The cost inserted in Box C3 should be the actual current *cost new* of purchasing the equipment including all taxes, duties and charges involved. Even if the equipment was purchased new some time ago the figure inserted in the table should be the current cost new; otherwise you will undervalue the life being used up by each hour of use.

Alternatively, if the equipment will be, or was, purchased *"second-hand"* that price can be inserted, however there should also be an adjustment for the reduced economic life at time of purchase and possibly lower annual utilisation compared to a new equipment model. Again it is important to adjust purchase costs with inflation. You can do this by relating the price paid for the second-hand piece of equipment compared to the price new at that time (as a percentage) and apply the same percentage to the current price new.

daily operating hour

- *Insert the assumed number of operating hours each day in Box C4.*

daily ownership cost

- *Calculate the daily ownership cost based on the formula shown and insert the Figure in Box C.* The cost should be adjusted for the expected value of the equipment on ultimate sale, disposal or scrap.

residual/scrap value

- *Insert the assumed residual value of the equipment in Box D1. It is possible to assume this is zero or just a nominal amount for scrap.*

Second-hand and scrap values of plant are difficult to predict. The residual scrap value of an obsolete item of plant can be less than the cost of using a crane and transport for disposal. The best approach is to insert an assessment of the *current* value of scrap machines of this model. If this is not known then the most conservative assumption is to insert a zero. If it is intended to dispose of the equipment item before it reaches scrap condition, make an assessment of the disposal value which would reflect any residual life remaining. An adjustment to the economic life would be necessary in Steps 2-5 in this case.

economic life

- *Insert the economic life in years selected in Step 2 in Box D2*

utilisation

- *Insert utilisation in hours/year selected in Step 1 in Box D3.*

adjustment to scrap value

- *Calculate the adjustment for scrap (or disposal) value based on the formula shown on sheet 3 and insert the figure in Box D.*

ownership costs sub-total

- *Calculate the sub-total for ownership costs (W=C less D).* The figure is an adjusted daily rate.

Operating costs

The next stage is to estimate the operating costs, either based on information from past records or by using assumed percentages.

4. Operating costs:

E SPARES AND CONSUMABLES

Actual from records or as % new cost (usually between 2-10%)	%		(E1)
DAILY COST OF SPARES = 0.01 x C3 x C4 x E1/D3 =	US$ per day		(E)

F SERVICING AND REPAIR (WORKSHOP LABOUR COSTS)

Actual from records or % spares/consumables (usually 20-100% of E)	%		(F1)
DAILY WORKSHOP LABOUR COSTS = 0.01 x E x F1/D3 =	US$ per day		(F)

G FUEL AND LUBRICANTS

Actual fuel cost per litre (add for lubricants @ 2-5%)	US$ per litre		(G1)
Assumed fuel consumption in litres per hour	litres per hour		(G2)
DAILY COST OF FUEL = C4 x G1 x G2 =	US$ per day		(G)

H OPERATORS (DAILY COSTS)

	wages	allowances	other			
Operator						
Assistant						
Other						
Sub-totals				US$ per day		(H)
SUB-TOTAL FOR OPERATING COSTS = (E) + (F) + (G) + (H) =				US$ per day		(X)

cost of spares

- *Insert in Box E1 a percentage value for the cost of spares and consumables each year compared to the machine cost new (Box C3).* This value should ideally be obtained from actual working records. Alternatively an equipment agent should be able to offer advice on this figure. As with any advice it should be checked with alternative sources such as other users.

daily cost of spares

- *Calculate the daily cost of spares based on the formula shown and insert the figure in Box E.*

workshop labour costs

- *Insert in Box F1 a percentage value of the cost of scares and consumables each year to cover the servicing and repair workshop labour costs.*

daily workshop labour costs

- *Calculate the daily workshop labour costs based on the formula shown and insert the figure in Box F.*

cost of fuel

- *Insert in Box G1 the cost of fuel per litre (delivered), adding an allowance for the cost of lubricants and greases used between servicing.*

fuel consumption

- *Insert in Box G2 the assumed fuel consumption in litres per hour from records, manufacturer's data or reference documents based on the engine size and workload.*

daily fuel cost

- *Calculate the daily fuel cost based on the formula shown and insert the figure in Box G.*

operator's daily costs

- *Insert wages, allowances and other associated costs (such as overnight allowances, housing allowances, pensions or insurance) in the spaces provided for each category of personnel necessary for the operation of the equipment. Insert the total operator's daily costs in Box H.* It is important to take account of any personnel costs for days that the equipment is idle, for whatever reason, and the operators and assistants are still drawing wages and allowances. The best approach is to calculate the annual payroll cost and divide it by the number of expected working days (equivalent working days = *D3lC4).*

operating costs sub-total

- *Calculate sub-total for operating costs (X = E + F + G + H).*

Daily allowances for overheads

- *From records and estimates calculate appropriate daily allowances for the various overheads including risks. It is usual to base this on a business' annual accounts figures or budgets, total the figures for the complete fleet being managed and assign a proportion to each piece of equipment. Divide the annual figures by the number of days that the specific equipment item will be used (D3lC4). Enter the sum of the individual overheads (I to Q) in Box Y.*

5. Overheads:

	Predict from past records to include:			
I	Offices, workshops, tools and other facilities	*US$ per day*		
J	Supervisory, management and clerical personnel	*US$ per day*		
K	Supervision and support vehicles	*US$ per day*		
L	Stores and other stocks	*US$ per day*		
M	Insurance	*US$ per day*		
N	Banking and other finance charges not relating to the equipment item	*US$ per day*		
O	Administration, training, safety and other overhead costs	*US$ per day*		
P	Risk, late payment and other contingency items	*US$ per day*		
Q	Taxes, levies, etc.	*US$ per day*		
	SUB-TOTAL FOR OVERHEADS = (I) to (Q) =	*US$ per day*		*(Y)*

Profit margin

- *Decide the profit margin to be applied and enter this in Box Z1. This is usually estimated as a percentage of the other costs. By multiplying the margin by the total costs the total daily profit (Z) can be estimated.*

6. Profit:

Z	Profit margin as % of net costs	%		*(Z1)*
	SUB-TOTAL FOR PROFIT = (W + X + Y) x (Z1) =	*US$ per day*		*(Z)*

Total cost to be charged

- *The final step is to calculate the total cost in US$ per day to be charged by summing up all the costs (= W + X + Y + Z).*

FURTHER READING

The student should refer to the following documents:

1 **Coukis, B**. (I983): *Labour-based construction programs: a practical guide for planning and management;* World Bank Publication. London (Oxford University Press).

2 **Petts R. C.** (1999): *Handbook of Intermediate Equipment for Roadworks in Developing Countries*, MART, Loughborough University, England.

7. Questions for students:

- *What is a reasonable minimum life for most equipment?*
- *How is the cost of finance used in a cost model?*
- *How should second-hand equipment be dealt with in a cost model*
- *What is the best way of estimating the cost of spare parts?*
- *Work out an example (using sheet 3) based on the purchase of a new twin drum pedestrian roller for US$ 20,000. Assume an economic life of 10 years, a utilisation rate of 600 hours a year, a scrap value of US$ 500 and a current interest rate for bank borrowing in Cambodia.*

ATTACHMENTS - EQUIPMENT COSTING WORKSHEETS

SHEET 1: WORKING SHEET - DEPRECIATION

A. EQUIPMENT DEPRECIATION/REPLACEMENT COST IN US$ PER HOUR BASED ON $10,000 INITIAL/CAPITAL COST AND ZERO SCRAP VALUE

Economic	***Utilisation in hours/year:***									
life (years)	200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
1	$50.0	$25.0	$16.7	$12.5	$10.0	$8.3	$7.1	$6.3	$5.6	$5.0
2	$25.0	$12.5	$8.3	$6.3	$5.0	$4.2	$3.6	$3.1	$2.8	$2.5
3	$16.7	$8.3	$5.6	$4.2	$3.3	$2.8	$2.4	$2.1	$1.9	$1.7
4	$12.5	$6.3	$4.2	$3.1	$2.5	$2.1	$1.8	$1.6	$1.4	$1.3
5	$10.0	$5.0	$3.3	$2.5	$2.0	$1.7	$1.4	$1.3	$1.1	$1.0
6	$8.3	$4.2	$2.8	$2.1	$1.7	$1.4	$1.2	$1.0	$0.9	$0.8
7	$7.1	$3.6	$2.4	$1.8	$1.4	$1.2	$1.0	$0.9	$0.8	
8	$6.3	$3.1	$2.1	$1.6	$1.3	$1.0	$0.9	$0.8		
9	$5.6	$2.8	$1.9	$1.4	$1.1	$0.9	$0.8			
10	$5.0	$2.5	$1.7	$1.3	$1.0	$0.8	$0.7			
11	$4.5	$2.3	$1.5	$1.1	$0.9	$0.8				
12	$4.2	$2.1	$1.4	$1.0	$0.8	$0.7				
13	$3.8	$1.9	$1.3	$1.0	$0.8					
14	$3.6	$1.8	$1.2	$0.9	$0.7					
15	$3.3	$1.7	$1.1	$0.8	$0.7					
16	$3.1	$1.6	$1.0	$0.8	$0.6					
17	$2.9	$1.5	$1.0	$0.7						
18	$2.8	$1.4	$0.9	$0.7						
19	$2.6	$1.3	$0.9	$0.7						
20	$2.5	$1.3	$0.8	$0.6						

SHEET 2: WORKING SHEET - FINANCING

B. AVERAGE ANNUAL FINANCE OR OPPORTUNITY COST OF CAPITAL IN US$ PER HOUR

B.1: Based on 10% per annum cost of borrowing

Economic life (years)	Utilisation in hours/year: 200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
1	$5.0	$2.5	$1.7	$1.3	$1.0	$0.8	$0.7	$0.6	$0.6	$0.5
2	$3.8	$1.9	$1.3	$0.9	$0.8	$0.6	$0.5	$0.5	$0.4	$0.4
3	$3.3	$1.7	$1.1	$0.8	$0.7	$0.6	$0.5	$0.4	$0.4	$0.3
4	$3.1	$1.6	$1.0	$0.8	$0.6	$0.5	$0.4	$0.4	$0.3	$0.3
5	$3.0	$1.5	$1.0	$0.8	$0.6	$0.5	$0.4	$0.4	$0.3	$0.3
6	$2.9	$1.5	$1.0	$0.7	$0.6	$0.5	$0.4	$0.4	$0.3	$0.3
7	$2.9	$1.4	$1.0	$0.7	$0.6	$0.5	$0.4	$0.4	$0.3	
8	$2.8	$1.4	$0.9	$0.7	$0.6	$0.5	$0.4	$0.4		
9	$2.8	$1.4	$0.9	$0.7	$0.6	$0.5	$0.4			
10	$2.8	$1.4	$0.9	$0.7	$0.6	$0.5	$0.4			
11	$2.7	$1.4	$0.9	$0.7	$0.5	$0.5				
12	$2.7	$1.4	$0.9	$0.7	$0.5	$0.5				
13	$2.7	$1.3	$0.9	$0.7	$0.5					
14	$2.7	$1.3	$0.9	$0.7	$0.5					
15	$2.7	$1.3	$0.9	$0.7	$0.5					

B.2: Based on 20% per annum cost of borrowing

Economic life (years)	Utilisation in hours/year: 200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
1	$10.0	$5.0	$3.3	$2.5	$2.0	$1.7	$1.4	$1.3	$1.1	$1.0
2	$7.5	$3.8	$2.5	$1.9	$1.5	$1.3	$1.1	$0.9	$0.8	$0.8
3	$6.7	$3.3	$2.2	$1.7	$1.3	$1.1	$1.0	$0.8	$0.7	$0.7
4	$6.3	$3.1	$2.1	$1.6	$1.3	$1.0	$0.9	$0.8	$0.7	$0.6
5	$6.0	$3.0	$2.0	$1.5	$1.2	$1.0	$0.9	$0.8	$0.7	$0.6
6	$5.8	$2.9	$1.9	$1.5	$1.2	$1.0	$0.8	$0.7	$0.6	$0.6
7	$5.7	$2.9	$1.9	$1.4	$1.1	$1.0	$0.8	$0.7	$0.6	
8	$5.6	$2.8	$1.9	$1.4	$1.1	$0.9	$0.8	$0.7		
9	$5.6	$2.8	$1.9	$1.4	$1.1	$0.9	$0.8			
10	$5.5	$2.8	$1.8	$1.4	$1.1	$0.9	$0.8			
11	$5.5	$2.7	$1.8	$1.4	$1.1	$0.9				
12	$5.4	$2.7	$1.8	$1.4	$1.1	$0.9				
13	$5.4	$2.7	$1.8	$1.3	$1.1					
14	$5.4	$2.7	$1.8	$1.3	$1.1					
15	$5.3	$2.7	$1.8	$1.3	$1.1					

B.2: Based on 30% per annum cost of borrowing

Economic life (years)	Utilisation in hours/year: 200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
1	$15.0	$7.5	$5.0	$3.8	$3.0	$2.5	$2.1	$1.9	$1.7	$1.5
2	$11.3	$5.6	$3.8	$2.8	$2.3	$1.9	$1.6	$1.4	$1.3	$1.1
3	$10.0	$5.0	$3.3	$2.5	$2.0	$1.7	$1.4	$1.3	$1.1	$1.0
4	$9.4	$4.7	$3.1	$2.3	$1.9	$1.6	$1.3	$1.2	$1.0	$0.9
5	$9.0	$4.5	$3.0	$2.3	$1.8	$1.5	$1.3	$1.1	$1.0	$0.9
6	$8.8	$4.4	$2.9	$2.2	$1.8	$1.5	$1.3	$1.1	$1.0	$0.9
7	$8.6	$4.3	$2.9	$2.1	$1.7	$1.4	$1.2	$1.1	$1.0	
8	$8.4	$4.2	$2.8	$2.1	$1.7	$1.4	$1.2	$1.1		
9	$8.3	$4.2	$2.8	$2.1	$1.7	$1.4	$1.2			
10	$8.3	$4.1	$2.8	$2.1	$1.7	$1.4	$1.2			
11	$8.2	$4.1	$2.7	$2.0	$1.6	$1.4				
12	$8.1	$4.1	$2.7	$2.0	$1.6	$1.4				
13	$8.1	$4.0	$2.7	$2.0	$1.6					
14	$8.0	$4.0	$2.7	$2.0	$1.6					
15	$8.0	$4.0	$2.7	$2.0	$1.6					

Source: Intech Associates

SHEET 3: WORKING SHEET - EQUIPMENT COST CONVERSION TO DAILY CHARGE RATE

INTEREST RATE ASSUMED - from Table B *% per annum* [ ]

OWNERSHIP COSTS:				
C	ADJUSTMENT FOR ACTUAL PURCHASE COST			
	Depreciation/replacement charge for $10,000 (from Table A)	*US$ per hour*		*(C1)*
	Selected finance charge from Table B (prop-rata to get actual value)	*US$ per hour*		*(C2)*
	Actual purchase/replacement cost	*US$*		*(C3)*
	Assumed number of operating hours per day	*hours per day*		*(C4)*
	DAILY OWNERSHIP COSTS = (C1 + C2) x C4 x C3/$10,000 =	*US$ per day*		*(C)*
D	ADJUSTMENT FOR EXPECTED RESIDUAL/SCRAP VALUE (if any)			
	Assumed residual/scrap value	*US$*		*(D1)*
	Assumed economic life	*years*		*(D2)*
	Assumed utilisation	*hours per year*		*(D3)*
	ADJUSTMENT FOR RESIDUAL/SCRAP VALUE = (D1 x C4)/(D2 x D3)	*US$ per day*		*(D)*
	SUB-TOTAL FOR OWNERSHIP COSTS = (C) - (D) =	*US$ per day*		*(W)*
OPERATING COSTS:				
E	SPARES AND CONSUMABLES			
	Actual from records or as % new cost (usually between 2-10%)	%		*(E1)*
	DAILY COST OF SPARES = 0.01 x C3 x C4 x E1/D3 =	*US$ per day*		*(E)*
F	SERVICING AND REPAIR (WORKSHOP LABOUR COSTS)			
	Actual from records or % spares/consumables (usually 20-100% of E)	%		*(F1)*
	DAILY WORKSHOP LABOUR COSTS = 0.01 x E x F1/D3 =	*US$ per day*		*(F)*
G	FUEL AND LUBRICANTS			
	Actual fuel cost per litre (add for lubricants @ 2-5%)	*US$ per litre*		*(G1)*
	Assumed fuel consumption in litres per hour	*litres per hour*		*(G2)*
	DAILY COST OF FUEL = C4 x G1 x G2 =	*US$ per day*		*(G)*
H	OPERATORS (DAILY COSTS)			

	wages	allowances	other
Operator			
Assistant			
Other			
Sub-totals			

		US$ per day		*(H)*
	SUB-TOTAL FOR OPERATING COSTS = (E) + (F) + (G) + (H) =			*(X)*
OVERHEADS:				
	Predict from past records to include:			
I	Offices, workshops, tools and other facilities	*US$ per day*		
J	Supervisory, management and clerical personnel	*US$ per day*		
K	Supervision and support vehicles	*US$ per day*		
L	Stores and other stocks	*US$ per day*		
M	Insurance	*US$ per day*		
N	Banking and other finance charges not relating to the equipment item	*US$ per day*		
O	Administration, training, safety and other overhead costs	*US$ per day*		
P	Risk, late payment and other contingency items	*US$ per day*		
Q	Taxes, levies, etc.	*US$ per day*		
	SUB-TOTAL FOR OVERHEADS = (I) to (Q) =	*US$ per day*		*(Y)*
PROFIT:				
Z	Profit margin as % of net costs	%		*(Z1)*
	SUB-TOTAL FOR PROFIT = (W + X + Y) x (Z1) =	*US$ per day*		*(Z)*
	TOTAL TO BE CHARGED PER DAY = (W) + (X) + (Y) + (Z) =	*US$ per day*		

Source: Intech Associates

22: MAINTENANCE: ALTERNATIVE STRATEGIES AND METHODS

Contents

1. Issues covered in this lecture

- Introduction
- Maintenance strategies
- Choice of the maintenance technology and institutional framework
- Alternative maintenance systems

INTRODUCTION

A road network is only in a sustainable condition if the level of expenditure on maintenance is adequate to redress natural processes of deterioration, due to climatic effects *and* that due to traffic. It is clear that the majority of developing countries fall very far short of this condition. In parts of Africa and elsewhere, the road network is deteriorating at a faster rate than it is being constructed.

maintenance costs related to GNP

According to estimates made by the ILO in 1982 developing countries allocated, but rarely spent, an average of about 0.33% of their gross national product (GNP) on road maintenance annually. Industrialised countries, whose networks are generally well established, spent more, up to an average of 0.5 or 0.6% of GNP. The ILO argued that, given other development requirements, it would be unrealistic to expect developing countries to spend more than about 0.35% of GNP on road maintenance. The *rational* network based on an expenditure on maintenance of 0.35% of GNP, compared to the *feasible* network with current actual expenditures and the actual road network looks as follows:

2. Potential of maintenance in selected countries

Country	Actual size of road network (Km/1000 pop.)	Size of *rational* network based on 0.35% of GNP (Km/1000 pop.)	*Size of feasible* network based on actual expenditure (Km/1000 pop.)
ASIA			
Sri Lanka	4.5	1.5	1.0
Thailand	3.0	3.8	1.7
Philippines	3.0	3.5	2.1
India	2.0	1.2	-
Bangladesh	*1.5*	0.6	0.2
Indonesia	1.0	2.6	0.4
AFRICA			
Cameroon	6.8	3.9	4.8
Kenya	3.3	1.6	2.1
Burkina Faso	2.5	0.8	0.7
Guinea	2.4	1.4	0.8
Malawi	2.3	1.0	0.9
Senegal	2.3	2.1	0.5
Ethiopia	1.1	0.6	0.7

In African countries the rational network ranged from 33-91 per cent of the actual length of roads, averaging just 55 per cent. For middle income countries, like Thailand, it would in theory have been possible to maintain their networks if they increased maintenance expenditures to a level of 0.35 per cent of GNP. However, lower income countries, like Burkina Faso, would only have been able to maintain between 30-60 per cent of their networks. In practice for most poor countries the feasible network that can be maintained, with current levels of expenditure, is *substantially less* than the rational network. In most of Africa it is probably well less than 50 per cent of the current network.

To some extent this is an inherent problem, due to the generally scattered pattern of population settlement and low resulting population densities. While there are obvious exceptions, such as Rwanda and Burundi, Sub-Saharan Africa's mean mid-population density is 22 persons per km^2. This is in marked contrast to that of Asia (including South and East Asia and the Pacific, but excluding Central Asia) at 130 persons per km^2, although similar to that of South America at 21 persons per km^2. An immediate implication of g roads and other communication channels to rural areas. Since this region is simultaneously characterised by low average income per capita, its comparative disadvantage to other regions is really enormous

3. Key concept: sustainable condition

A road network can only be considered to be in a sustainable condition if the level of expenditure on maintenance is sufficient to combat natural deterioration due to climate and use by vehicles.

MAINTENANCE STRATEGIES

International opinion is unanimous that the road maintenance situation in many developing countries has become so critical that a number of hard choices have become inevitable, the ILO identified these choices more than a decade ago:

- Spread resources thinly over selected parts of the whole network;
- Maintain only that part of the network for which adequate resources are available;
- Increase effectiveness/productivity of existing operations;
- Develop cheaper/more effective approaches.

alternative (i)

This is occurring naturally and leads to a progressive deterioration of the whole network. As the road maintenance organisation will tend to focus its resources on that part of the network that is subject to the greatest political pressures, some parts will deteriorate faster than others will. Usually it is the rural roads which are most neglected

alternative (ii) This is a rationalisation of the real situation and is recognition that existing road systems may have become unaffordable. Although politically it will be difficult and unpopular to abandon selected parts of the network it would be preferable to develop objective criteria for this purpose rather than ignoring the situation and have the same thing happen in an uncontrolled way.

alternatives (iii) and (iv) These are not alternatives in their own right but they complement alternatives (i) and (ii) in that they represent an attempt to make available resources stretch further. Experience has shown that with imagination and the development of a proper institutional framework and backup system, there are various possibilities to involve the private sector and/or local road beneficiaries in the execution of road maintenance activities to a greater extent than is currently the case. Moreover, within the existing structure of the maintenance organisation there is also considerable scope for improvement through the selection of incentive schemes, appropriate training and improvements in the planning, programming and control systems. Both alternatives (iii) and (iv) employ the substitution of labour for equipment-based technologies on a significant scale. Experience on ILO projects has shown this to be both technically feasible and economically beneficial. Experience of the U.K. Transport and Road Research Laboratory, confirms the same thing.

further option In the last few years, a further option has emerged: change the basis for road maintenance financing. The old notion of Road Funds, which receive a dedicated proportion of all taxes on road users, has been revived in Ethiopia, Kenya, Sierra Leone and Tanzania among other countries. Experience with these experiments is limited, but they are unpopular with the general public and so face immense political implementation difficulties

opportunity to define levels of intervention A planned restructuring of resources provides an opportunity to define levels of intervention. Depending on the type and function of the road in question. For example, a comprehensive maintenance plan could indicate for each road or road section: the frequency of grading, whether or not vegetation would be controlled along the whole road; whether interventions would be limited to drainage works on selected sections; etc. In other words it would be possible to develop a 'selective maintenance' policy complementary to the 'spot improvement' policies being advocated for rehabilitation works.

4. Key concept: labour substitution

Labour-based methods can be substituted for many maintenance operations traditionally done with equipment.

increase effectiveness and productivity

The effectiveness of management can be increased in a number of ways. First, there is a lot of scope to improve planning, programming and control of the works. Maintenance managers should be made accountable for their work and their awareness of the costs of the different operations should be improved. For this, the establishment of management information systems are necessary to collect data on:

- The quantity, location, conditions and function of the different road links inventories describing maintenance requirements;
- The real cost, availability and utilisation rates of equipment; and
- The real cost, availability and productivity of labour.

These actions are essential to enable the manager to set priorities for periodic and routine maintenance interventions, to determine what levels of maintenance service should be provided to different road links and finally to make a rational *choice of technology* for the approach he will apply in the different cases.

efficiency of equipment use

In a similar way it is possible to significantly increase the efficiency of equipment use. The availability and utilisation rates for equipment are on average very low. Even when equipment is in working order, it is often not optimally utilised. The result is that in these circumstances the real hourly cost of equipment is extremely high. The main reasons for low availability and poor use of equipment are well known

- Scarcity of foreign exchange (spares. fuel),
- Cumbersome, time-consuming procurement,
- ➢ Less than optimal interaction between mechanical departments and road departments, and
- ➢ Poor motivation of maintenance staff.

The situation is aggravated by the proliferation of different makes types of equipment, which pose great difficulties for effective equipment maintenance. There are a number of options available to improve equipment usage in these circumstances:

- Standardisation to a limited number of different makes and types of equipment is essential. This requires firm policy on the part of governments, collaboration amongst donors, and co-ordination of procurement on a national basis.
- A controversial option with many implications is to reduce the size of the equipment fleet to manageable proportions, concentrating on achievement of a high-performance core fleet of equipment for which effective mechanical back-up can be provided.
- Use the private sector if feasible. If this not immediately available, one should start projects to develop private sector capacity as has been done in Ghana and elsewhere.
- Improve planning and programming control, including the development of an equipment hire system based on realistic costs.
- Install rigorous preventive equipment maintenance systems.

CHOICE OF MAINTENANCE TECHNOLOGY AND INSTITUTIONAL FRAMEWORK

In order to make choices based on costs and effectiveness it is necessary to know what to do *where.* The answers to these questions are influenced by the choice of maintenance technology and the institutional framework, which in turn necessitates a clear understanding of the local operational environment. In a schematic way this might be assessed as follows:

5. Factors affecting the choice of maintenance approach
➢ Purpose of the road (road function, traffic levels)
➢ Level of maintenance to be achieved
➢ Availability of human, material and financial resources
➢ Cost effectiveness of current road maintenance system for different categories of road
➢ Existing institutional and organisational framework
➢ Funding arrangements
➢ Feasibility and cost effectiveness of applying alternative systems for road maintenance
➢ Availability of external resources and expertise to establish cost-effective alternative systems
➢ Integration of alternative systems into existing ones (organisation, administration, management)

planning methodology

First, information is required on the purpose of the road and the type and number of road users. Does the road connect regional, district or market centres? Is its primary, function to provide access to an area for crop marketing or will there be regular through-traffic? What are the current and projected traffic levels? This information allows decisions regarding the minimum necessary levels of serviceability of the roads and hence the level of maintenance required. For example, roads carrying 1 to 5 vehicles per day and with traffic peaks in the crop-harvesting season require different maintenance interventions than roads servings as communication links between locally important centres and carrying traffic levels of 20 to 50 vehicles per day. In the former case the main purpose of the maintenance would be to keep the road open and maintenance work could be scheduled at fixed intervals during the year. The second category would require a higher level of surface smoothness and would need regular interventions throughout the year. Through a careful analysis one would be able to categorise the type and level of required maintenance interventions for a number of road types, varying with their function.

Items 3 and 4 relate to the availability of resources for road maintenance and the way these are currently being utilised. Items 5 and 6 refer to necessary information on the functioning of the existing organisation and financial systems. For example, the routing of road maintenance funds from central to site levels is important and it would be essential to know to what extent maintenance funding is controlled and monitored by road maintenance staff.

Finally, items 7 to 9 relate to the identification of the possibilities to utilise available resources in a different way. In this context, it is necessary to examine under which conditions local organisations might be involved in road maintenance and how easy or difficult it may be to reorient the existing organisational and financial arrangements towards the application of alternative approaches. From the above, it can be concluded that information is required on:

- The quantity and frequency of the road maintenance works (levels of service);
- The time cost of the producing unit(s);
- The effective output of these producing unit(s) over a specified period of time; and
- The mobilisation and overhead costs which apply to the implementation of a given approach.

After the minimum required level of road maintenance has been determined (item i) the cost and effectiveness of different approaches can be compared. In most cases, the choice between labour and machines is not an 'either/or' situation. A combination of the two is often cost-effective.

equipment costs and productivity

When a piece of equipment is the producing unit, item (ii) would normally be expressed as a cost per hour. This cost will vary with the purchase price of the machine, prevailing interest rates, maintenance and repair costs and average utilisation of the machine.

In assessing equipment productivity (item iii) it is almost always inappropriate to use the recommended 'productivity per hour estimates' provided by the manufacturer. It requires exceptionally good management and a well-paid and motivated work force to achieve high equipment productivity levels on maintenance; work is scattered and there is a lot of wasted time moving from site-to-site. For this reason the *actual* productivity, expressed as an average output per hour for a certain activity must be monitored over longer time periods (say a minimum of one year). This actual productivity will depend on the average overall availability of the machine and its effective utilisation in respect of the maintenance activity concerned.

Factors that influence machine availability and effective utilisation include the availability of fuel, lubricants and spare parts, the organisation and effectiveness of mechanical back-up services and the amount of time lost due to ineffective operation, transportation or insufficient skills of the operators. Usually the negative effect of these factors is minimised in profit-oriented private organisations, but can be quite substantial in the case of government-run organisations.

The net utilisation of the machine is primarily determined by factors such as overall management and planning, size of the network to be covered, and the motivation and skills of the operators and supervisory staff. Since these factors vary from year to year, from country to country and even from district to district, regular monitoring of the actual performance and cost is an indispensable management tool.

The mobilisation and overhead costs (item iv) will depend on the approach used. The utilisation of a heavy bulldozer in remote mountainous terrain is likely to give rise to significant mobilisation costs. On the other hand, labour-based approaches will require investments in an adequate supervision structure.

labour costs and productivity

When the producing unit is a labourer, cost will generally be expressed as a cost per person-day, and will usually be determined by the prevailing minimum wage rate in the area concerned. Productivity will be determined by the way the worker is motivated (incentive schemes), site organisation and management, availability of good quality, well designed, hand tools and implements, and finally the workers' skill in carrying out their tasks.

Moreover, organisational and administrative issues such as the ensuring of timely and regular payment have a direct and major impact of the function of a labour-based work force

6. Key concept: local communities

Alternative maintenance systems emphasise local resource use and involve local communities in the planning and execution of the works.

ALTERNATIVE MAINTENANCE SYSTEMS

Alternative maintenance systems have been developed over the past two decades. They have as their key characteristic that they emphasise the local resource environment and involve local people in the planning and execution of the maintenance works. The alternative ways of organising road improvement and maintenance activities are as follows:

7. Organisational alternatives for road improvement and maintenance

- Paid permanent staff supported by equipment
- Paid Casual workers for deferred tasks
- Direct contracts with individuals or groups (payment by results)
- Contracts through petty, medium or large scale contractors
- Agreements with communities
- Agreements with deferred village or youth organisations.
- Self-help mobilised through local administration: voluntary, non-paid work; collecting funds and hiring people or contractors; and collecting funds and using self-help with rented equipment inputs.

Line ministries responsible for road maintenance normally use a combination of approaches (i) and (ii) and their effectiveness is largely dependent on utilisation of transport and equipment. The alternative approaches (iii)-(vii) are more labour-based and are likely to require substantial technical and managerial inputs, certainly in the establishment phase. These are perhaps more sophisticated than those used for equipment-based systems.

These systems and principles need to be developed and established before they are applied on a large scale, and a pilot project of two or three years is indispensable for this purpose. Policies and procedures need to be developed in six key areas:

- Planning and programming systems;
- Disbursement and payments procedures;
- Procurement procedures;
- Management and control systems;
- Technical and organisational training;
- Establishment of organisational and administrative structures for implementing a large-scale programme.

How these organisational alterations right apply to different categories of work might be as follows:

8. A possible combination of maintenance approaches for different categories of roads

MAIN ROAD OR TRUNK ROAD – primary

- Equipment supported by labour (Emergency works, grading)
- Contracts (Periodic maintenance)
- Petty contracts or lengthmen (Routine maintenance)

REGIONAL ROAD - secondary

- Equipment supported by labour (Emergency works, grading)
- Contracts (Periodic maintenance)
- Petty contracts or lengthmen (Routine maintenance)

DISTRICT ROAD - tertiary

- Equipment supported by labour (Emergency works, grading)
- Force account (Emergency works)
- Contracts (Periodic maintenance)
- Labour-based/simple equipment (Rehabilitation works)
- Agreement with communities (Routine maintenance)
- Petty contracts or lengthmen (Routine maintenance)

ACCESS/FEEDER ROAD – sub-tertiary

- Agreement with communities (Routine maintenance)
- Self-help with supervision/material inputs (Routine maintenance)

FURTHER READING

The student should refer to the following documents:

1 **Andersson, C-A, A. Beusch and D. Miles** (1996): *Road maintenance and regravelling (ROMAR) using labour-based methods – Handbook.* Prepared for ILO. Intermediate Technology Publications, UK.

2 **Edmonds, G.A. and de Veen, J.J.** (1982): *Road Maintenance: Options for Improvement,* Geneva, ILO.

3 **Owen, W.** (1987): *Transport and Development, London (Hutchinson).*

4 **TRRL OVERSEAS UNIT** (1987): *Maintenance Management for District Engineers,* Crowthorne, Overseas Road Note 1, 2nd edition, Transport Road Research Laboratory.

9. Questions for students:

- *What is the importance of the relationship of GNP to road maintenance?*
- *What is the basic principle for achieving sustainability in road maintenance?*
- *What are the options for road maintenance strategies?*
- *How is it possible to improve equipment usage for road maintenance?*
- *What are the main factors effecting the choice of maintenance approach*
- *What organisational options are available for road improvement and maintenance?*

23: PUTTING THEORY INTO PRACTICE

Contents

1. Issues covered in this lecture

- Summary of current practice
- Design considerations in development engineering
- Factors to consider in choosing labour-based methods
- Basis of successful labour-based programmes
- Mainstreaming a national programme

SUMMARY OF CURRENT PRACTICE

Since the mid-1970's labour-intensive road construction has progressed from being a theoretical possibility to a practical reality. National programmes have been established in Botswana, Ghana, Kenya, Lesotho, Malawi and Thailand; pilot projects have also been carried out in many more countries all over the world. These projects and programmes have usually been initiated by governments as part of their policies for rural development, and have included the creation of employment opportunities, the provision of infrastructure and the promotion of agriculture.

Since early experience in countries such as Kenya, Botswana, Malawi and Lesotho, implementation priorities are now more firmly focused on road rehabilitation and maintenance. All of the case study, experience has shown the importance of giving careful consideration to design aspects so as to overcome the in-built bias inherent in traditional engineering practice which assumes the use of equipment-intensive technologies.

DESIGN CONSIDERATIONS IN DEVELOPMENT ENGINEERING

With the change of emphasis in the 1980s away from large-scale construction to smaller-sized and separated road rehabilitation and maintenance works the scope for labour-based methods has increased significantly. "Neutral" contract conditions, as described below, would be an important instrument to provide a substantial share of the market to small locally based firms or organisations.

This means that the proposed procurement and disbursement procedures and cost sharing arrangements should be carefully analysed because they tend to favour large established international firms and the use of capital-intensive methods to the detriment of the local target groups.

procurement procedures

Procurement procedures continue to be biased towards the use of equipment-based technology. Employment-intensive programmes should be designed in such a way that this bias may be eliminated from the procurement procedure. The following principles related to construction practice are particularly important in this respect:

2. Alternative design specifications

- It will frequently be necessary to prepare alternative designs adapted to construction by either labour or equipment. This usually implies that alternative specifications may be required.
- In a 'technology neutral' contract the alternative designs and specifications will be reflected in alternative items and corresponding quantities in the bill of quantities.
- The latter may also incorporate different billing methods and more detailed breakdowns of work items than is currently customary for equipment-based operations.
- The bidder will choose the method they wish to adopt and will price the appropriate bill section or item accordingly.

In addition to considering the implications for physical design as reflected in the specifications it is also necessary to review the conditions of contract:

3. Conditions of contract

- Conditions of contract should be equally applicable irrespective of the choice of technology or mixture of labour and equipment.
- Where the contract includes provision for price adjustment during the period of the contract, a method should be selected which will avoid bias within the range of alternative technologies likely to be offered.
- The changes introduced in neutral contracts may result in bids that are not directly comparable on the basis of cost. The bid evaluation process must take into account any significant differences in timing, cash flow, performance and project life, amongst others. The exact procedure will vary from project to project and it should be made clear to bidders.

use of locally available materials

The design specifications should be such that they favour to the maximum extent possible the use of locally available materials, simple equipment, locally established firms and organisations, and the development of small local firms. Also, structural designs should be adapted to maximise the use of local materials, labour and skills. For example, structures with lower concrete strengths and increased dimensions can often be acceptable and would allow the use of hand-broken lower-strength aggregates. Structures made of local materials such as treated hardwoods, masonry or brick may be acceptable alternatives to concrete and reinforced concrete structures. Masonry and carpentry skills are widely available in rural areas and should be utilised instead of "imported" steel fixing, shuttering and concreting skills.

performance standards

Equally, the quality and performance standards set by the designer should not be over specified so that they can only be achieved by heavy equipment, even when there is no need for such high quality standards. For example, the use of single sized crushed stone as a base layer combined with low surface tolerances on a low-volume road already predetermines the use of rock crushing equipment and graders, and would preclude the application of stone pitching and manual spreading techniques.

"method type" specifications

When small-scale contractors are involved it is recommended to use "method type" specifications. In this way inexperienced contractors can be guided on how to carry out the work as well as on the types of equipment, hand tools, etc., and labour to be used for the different construction activities. The application of method specifications means that the programming of project implementation should be modified to suit labour-based works.

For example, the grouping together of work items and quantities needs to be adapted if the work is to be carried out by labour. In practice this means that bill of quantity items should correspond as closely as possible with the way in which the work is carried out and paid for by the contractor. This is particularly important when the contractor is relatively inexperienced and lacking in financial resources. In this regard the work programming should take account of the fact that labour can work to much closer tolerances than equipment in excavation and that the same end-result can often be achieved with less effort. For example, excavation of gravel for pavement bases and sub-bases can be carried out selectively, making use of the best materials. Consequently pavement thickness can be varied at short intervals.

subgrade, base and pavement options

Employment-intensive base and subgrade design options include hand-pitched stone, dry-bound macadam, water-bound macadam, and (some) stabilised soils. Pavement options include laterite or gravel surfacing, pozzolanic or clay bricks, pre-cast and insitu concrete paving and bituminous seals. Other design considerations concern the material specifications as they relate to the thickness of the pavement, subgrade and base layers The routing and geometric specifications also influence the choice of construction techniques significantly. Finally, a design trade-off needs to be made when deciding on design standards between the initial (construction) costs and future (maintenance) requirements.

haulage

Of particular significance is any operation involving haulage as illustrated by the following labour-specific considerations:

4. Factors in haulage

- Longitudinal hauls along the road should be avoided to the maximum extent possible by excavating to waste and borrowing to fill;
- Earthworks should be carried out by cross movements rather in the longitudinal direction; and
- For gravelling works use can be made of smaller borrow pits located at more frequent intervals (in Cambodia these might form fishponds after the works are complete).

labour-based experience in varying conditions

Local variations have resulted in experience under climatic conditions varying from arid to tropical; terrain conditions varying from flat to mountainous. Traffic conditions varied from ten to several hundred vehicles a day and standards varied from spot-improvement to engineered gravel roads, and haulage varying from tipper truck to animal cart. Institutional frameworks have varied from a Department of Roads within a Ministry of Transport to a Roads Unit within a District Council that was semi-autonomous from a Ministry of Local Government.

force account methods versus private sector approaches

The first attempts to use efficient labour-based methods for road works were implemented entirely by force account methods i.e. labour employed directly under the control of government organisations and working to government regulations in relation to employment conditions and wages. Some of these attempts have been very successful, others less so. Currently greater emphasis is being placed on the involvement of the private sector, or of local communities themselves, with a view of trying to ensure greater programme sustainability.

need for supervisors as well as unskilled labour

In the early phases emphasis was upon the creation of employment opportunities for unskilled labour. Over time it became clear that the productivity achieved by organised labour could not be considered the result of unskilled work. Equally important is that to motivate labour to construct a sound product it is essential to train skilled supervisors who are technically and organisationally competent, and that during training as much a attention should be paid to character as competence.

FACTORS TO CONSIDER IN CHOOSING LABOUR-BASED METHODS

When deciding on the technique that will be most appropriate for a particular country, it is important to take account not only of the technical characteristics of the project but also of the socio-economic conditions in which it will have to be carried out. These conditions naturally vary from one case to another. However, there are three main sets of factors that need to be considered in project design: equipment; labour; and institutional issues.

equipment

- **What equipment is available, where else will it be needed and what state of repair is it in?**
- **What is the hire charge of the equipment, using the best estimate of the "shadow" interest rate and realistic depreciation rate?**
- What will be the utilisation rate of each piece of equipment?
- How accessible is the project site? How long will it take to bring in heavy equipment?
- Are there adequate supplies of spare parts and fuel?
- Are experienced equipment operators and drivers available?

labour issues

- Is there a readily available supply of unskilled and semi-skilled labour?
- How great is the need for employment creation?
- Are facilities available, if required, for the housing, feeding and welfare of the labour force employed on the project?
- What are the daily wages of the labour force, based not only on the going market wage rates but also on a more realistic "shadow" prices for labour?
- Are there any engineers, mechanics, supervisors and other technical personnel available and what are their qualifications?
- To what extent are management skills (as listed below) developed?
- Is on-the-job training desirable?

institutional issues

- What are likely to be the consequences of completing the project earlier or later than planned?
- Will there be follow-on projects? Are there any priorities to be taken into account?
- What are the advantages and disadvantages of greater or less participation by the local people in the project? In particular, if they play a greater part is this likely to provide motivation for subsequent upkeep of the project?

optimum balance

5. Key concept – optimum balance

Every project must be appraised separately with a view to achieving an "optimum balance". Only then will it become clear what degree of labour intensity a project should aim at from the very beginning.

project management training needs

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

- General management, including over-all understanding of technical as well as economic aspects of projects, especially cost-benefit analysis and network-planning methodology.
- Production management (civil and industrial engineering), including operational management of machines and men (large labour force), maintenance and repair management, management of stores, as well as basic training in the use of work study techniques.
- Accountancy and financial management, with special emphasis on cost accountancy and the rate of return on capital investments.
- Human resources management, including understanding of the importance of incentives and motivation, attitudes of men and women towards their work, social welfare, nutrition and health.

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

BASIS OF SUCCESSFUL LABOUR-BASED PROGRAMMES

Based upon an analysis of previous experience, a labour-based approach has been successful when there has been national programmes, with long-term political support and financial commitment. The most successful are those programmes that are not targeted at short-term emergency relief efforts.

assess needs

There also has to be a sound assessment of the technical feasibility and economic efficiency of using labour-intensive methods, including recognition of technological and institutional capacities of the various institutions involved. Thus, technical, institutional, organisation and socio-economic aspects need to receive full attention during preliminary work. These need to be continued through pilot projects, initial training programmes, and subsequent national programmes. Detailed issues that need to be considered include:

- Technical matters such as design and construction standards, specifications, tools and equipment, and methods of construction.
- Institutional matters including the decentralisation necessary for grassroots success and the centralisation necessary to plan and co-ordinate a large programme.
- Strong organisations need to be established with good management systems and a balance achieved between decentralisation and centralisation.
- Organisational aspects need to be considered, such as the design of appropriate management structures and systems (recording, reporting, controlling, monitoring and evaluation) and training. Training needs to be extensive and good at what it set out to do.
- Socio-economic aspects need to be considered such as wage rates, conditions of employment, labour supply, role of women, and social and economic impact studies. Prior agreement needs to be reached between the different parties with regard to wage rates, conditions of employment and the role and responsibilities of the community.

conclusions – need for co-ordination

In conclusion, there has to be good co-ordination between the government, government departments, those administering the programme, local authorities, those providing technical assistance and donors.

MAINSTREAMING A NATIONAL PROGRAMME

Rural roads constructed and maintained by highly labour-intensive means can create 5 to 7 times more employment per unit of expenditure than by equipment-intensive methods. However, it is also possible to create a significant increase in employment opportunities per unit of expenditure across a wide range of civil construction including most municipal or urban engineering services and by using private sector contractors.

These national programmes of rural road construction indicate how to establish a large-scale employment creation programme for the construction of public works. The process not only results in greater employment but also in the generation of individual and community capacities in technical and institutional terms. National programmes have been established through:

- The adoption of a long-term national perspective in which a programme is developed;
- Attention to technical, institutional, administrative, organisational and socio-economic detail during the preparatory lead-in phase and throughout the programme;
- Institution building at community, regional & national levels; and
- Extensive training at site, multi-site and national levels.

Further details on the steps that need to be taken for achieving and mainstreaming a long-term labour-based programme are give in an attachment to this lecture.

FURTHER READING

The student should refer to the following documents:

1 **Bentall, P.H.** (1990): *Project GHA/84/008 - Ghana Feeder Roads Project Labour-based rehabilitation and maintenance-Final Report.* World Employment Programme, ILO, CTP 116, Geneva, May 1990.

2 **Edmonds, G.A. and J.D.G.F. Howe** (1980): Roads and resources: *appropriate technology in road construction in developing countries.* London, (Inter Technology Publications Ltd.)

3 **Hagen, S. and C. Relf** (1988): *The District road improvement and maintenance programme-better roads and job creation in* Malawi. International Labour Organisation, Geneva.

4 **Karlsson, L.** (1987): *Pilot projects on* Labour-*based road construction and maintenance in Thailand. Findings and Recommendations. World* Employment Programme, CTP 62, Geneva, January 1987.

5 **McCutcheon, R.** (1983): *District pilot project of labour-intensive road construction and maintenance, Botswana-Final Report.* World Employment Programme CTP 17, Geneva, September 1983.

6 **McCutcheon, R.** (1995): *Employment creation in Public Works: labour-intensive construction in Sub-Saharan Africa, the implications for South Africa.* Habitat International.

6. Questions for students:

- *What do you understand by the term a 'technology neutral' contract?*
- *What types of locally available materials might an engineer incorporate in the road design?*
- *What are "method type" specifications?*
- *What are some of the factors in choosing labour-based methods?*
- *What is an “optimal balance” of labour and equipment?*
- *What are some of the reasons for successful applications of labour-based programmes?*
- *How should you go about mainstreaming a labour-based programme?*

ATTACHMENT – MAINSTREAMING LABOUR-BASED TECHNOLOGY

APPROACH

For long-term success to be achieved a four phased approach should be adopted for mainstreaming a labour-based programme:

Phase 1: *Orientation*

Phase 2: *Preparatory Work: Analyses and Design*

Phase 3: *Pilot/Initial Training*

Phase 4: *Expanded Training - National Programme.*

The above approach has to be located within an appropriate institutional framework at national, regional and local levels. A "lead-in" time is necessary before the programme can be fully implemented. During this lead-in period phases 1 and 2 should be carried out.

PHASE ONE

Sensitisation of all concerned must be carried out and agreement reached at national regional and local levels as to:

- Concepts and objectives: asset creation plus significant additional employment opportunities per unit of expenditure;
- Nature of long-term "programmes"; and
- Conditions of employment, wages and linking of payment to production.

During phase 1, local and national authorities need to be briefed as to the type, standard, funding and method of construction, and the importance of training, institutions (local and national), and long-term political and financial commitment, especially for the maintenance activities essential to preserve the value of the investments. Agreement must also be sought that labour-intensive public works programmes are not just emergency or drought relief projects. To achieve this, a long-term programme must be drafted.

PHASE TWO

The second phase comprises the following aspects:

Analysis:

- Institutional (local and national);
- Organisation;
- Levels of funding;
- Specific technical analyses;
- Criteria for staff recruitment;
- Identification of initial communities and training sites.

Preparatory Work:

- Design, specifications and documentation;
- Administrative, technical and training manuals;
- Selection of trainees;
- Briefing of communities;
- Establishment of priorities.
- Revision of forward plans.

PHASE THREE

This phase concentrates on:

- The orientation and training of trainers;
- Starting pilot projects and embryonic training programmes;
- Revision of training and national programmes; and
- Revision of manuals and reporting systems prior to the initiation of large-scale national programmes.

PHASE FOUR

In this phase the initial training programmes are expanded within each sub-sector into a national programme. But the expansion should only be allowed to proceed in the following manner:

- At the rate at which the training programme can produce skilled site supervisors and managers (training must pay as much attention to character as technical competence);
- To the degree to the degree to which local communities have the capacity to absorb the trained personnel;
- To the degree to which the national institution is able to absorb the trained management personnel and maintain its overall planning, co-ordinating, and monitoring and evaluation role.

Through the "programme" (as opposed to "project") approach the institution is established together with the human resources required to implement the work from site level through to national planning and co-ordination. The four-phased approach, outlined above, is the result of many, years of experience and analysis.

24: ORIENTATION COURSE

SAMPLE QUESTIONS

*The student should answer nine questions, choosing one question from each of the nine groups. The time set for the examination is **90 minutes** and the student should spend about 10 minutes in answering each question. Put the exam question number at the top of each answer – for example 3 c).*

1. DEVELOPMENT POLICIES OF MINISTRY OF RURAL DEVELOPMENT

a) *Why are rural road policies necessary and what are the specific responsibilities of the Department of Rural Roads in MRD in setting these policies?*

b) *What types of rural roads are MRD responsible for maintaining and what problems can arise with regard to the ownership of roads?*

c) *What questions relating to environment and sustainability may need to be addressed by the MRD?*

2. THE CHOICE OF TECHNOLOGY ISSUE

a) *What are some of the disadvantages of adopting Western equipment-intensive technology versus local methods?*

b) *What are the basic factors involved with making a rational choice of technology in engineering design? Explain this by using the example of a rural road programme.*

c) *What are some the design changes that might need to be included in a labour-intensive road specification compared to a conventional machine-intensive approach?*

3. TOOLS AND EQUIPMENT

a) *Why is it not sensible to use poor quality tools for construction and why is the durability of tools so important?*

b) *What are the main factors that usually effect the development of simple equipment for use in roadwork construction and maintenance?*

c) *In what circumstances might manual compaction methods be more appropriate than using machine-based methods?*

4. LOW-COST ROAD SURFACING

a) *Why is it necessary to consider alternative surfacing materials and what are some typical examples of alternative surface options?*

b) *What are some of the reasons and advantages that make stone-based pavements still popular both in developed and less-developed countries?*

c) *Why is community involvement important in implementing a road surfacing project?*

5. TECHNICAL PLANNING AND SURVEYING

a) *What are the main stages in surveying and mapping of roads, and what simple low-cost techniques might be used?*

b) *What are the types of methods that can be used for assessing soil conditions and how might the information be used in project design?*

c) *What are some of the general factors that might need to be identified in the field and that might influence the organisation and cost of a road contract?*

6. DEVELOPMENT ENGINEERING CONTRACTING

a) *What are the advantages of adopting a private sector approach to construction? Explain who are the parties involved and what sorts of factors need to be in place for private sector roadworks to succeed.*

b) *What are the types of problems experienced by small-scale contractors and how has capacity building for such small-scale contractors been assisted in Cambodia to ensure their survival?*

c) *What are the basic steps involved in letting a LBAT contract?*

7. COSTING DEVELOPMENT WORKS AND EQUIPMENT

a) *What are some examples of trade-offs that may have to be made in project design and why is using net present values a useful method of evaluating such trade-offs?*

b) *What is the difference between direct and indirect costs? Give some examples of what are some of the main items that could be included in the preliminaries as indirect costs.*

c) *Why is it necessary to cost equipment properly and what are some of the difficulties in doing it? How will utilisation of equipment vary between developed and developing countries?*

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8. ALTERNATIVE MAINTENANCE STRATEGIES AND METHODS

a) *What is the basic principle for achieving sustainability in road maintenance?*

b) *What are the options available for road maintenance strategies?*

c) *What are the main factors effecting the choice of maintenance approach?*

9. PUTTING THEORY TO PRACTICE

a) *What types of locally available materials might an engineer incorporate in road design?*

b) *What are some of the factors involved in choosing labour-based method, and how do these relate to the concept of the "optimal balance" of labour and equipment?*

c) *What are some of the reasons for successful applications of labour-based programmes and how should you go about replicating this success by mainstreaming a labour-based programme?*