

[pl include lecture number]. EQUIPMENT TO SUPPORT LOW COST SURFACING OPTIONS

Contents	<p>Issues covered in this lecture</p> <ul style="list-style-type: none"> • Introduction • Issues with road construction equipment • The Equipment • Grading Options • Stone Crushing Options
1.0 Introduction	<p>Lecture 13 raised the issues linked to the low-cost road surfacing. This lecture describes the appropriate equipment for implementing the low-cost surface improvement options. A study¹ that investigated the low-cost surfacing options found that laterite is a “wasting” surface as it deteriorates rapidly from rainfall and traffic. A list of alternative surface options was identified. Lecture 13 provides that list. In the backdrop of the development of low-cost alternative surfacing options, the issue of the identification of appropriate low-cost equipment has also come into the forefront. Another study² dealt with the appropriate equipment issues. The content of this lecture is mainly drawn from the outputs of this study.</p> <p>The at the end of the lectures the students will:</p> <ul style="list-style-type: none"> (i) understand the issue linked to the equipment for roadworks; (ii) be familiar with different equipment that are necessary for the implementation of the alternative surfacing options; (iii) be made aware of the equipment supply, demand and operating costs related issues in the region; (iv) be familiar with different grading options and they will be able to identify the best grading strategy for different road surfaces; and (v) be familiar with different stone crushing technologies and will be able to devise the optimum stone crushing strategy under a host of variables.
2.0 Issues with Equipment	<p>The main issues linked to the use, availability, accessibility and affordability of low-cost equipment in the implementation of different alternative surfacing options are:</p> <ul style="list-style-type: none"> (i) identification of appropriate equipment for the roadworks; (ii) assessment of current ownership and future demand of the identified equipment; (iii) supply situation of the identified equipment; (iv) equipment operating costs; and (v) assessment of the options when two or more equipment are available for performing similar roadworks.
3.0 The Equipment	<p><i>List of equipment and operating costs</i></p> <p>There are hundreds of roadwork related equipment available globally and in the region. However, their suitability is dependent on a number of factors including the nature of road works being undertaken. A list of 22 items of appropriate equipment has been identified for different alternative surfacing options (Lecture 13 notes provide a list of alternative road surfacing options).</p>

¹ Ministry of Transport (2007), *Rural Road Surfacing Research: SEACAP 1 Final Report (Volume 1)*, Intech Associates and TRL Limited

² MART-ASIST-DFR (1996), ‘Intermediate Equipment for Labour-Based Roadworks, Workshop Report’, *MART Working Paper No. 5*, MAET-ASIST-DFR, Accra Ghana, 19 & 20 April 1996

The table below provides the list under different equipment categories: haulage, compaction, watering, concreting, bituminous related, grading and crushing equipment. The table also provides typical models available in the region and their estimated per hour operational costs.

List of required equipment

Equipment	Typical Model / Brand	Financial operating cost (US\$/hr, 2008 values)
Haulage		
Tipper Truck	Hyundai HD 72	18.5
Flat Truck	Isuzu FRR33H4	13.7
Tractor 2WD	Kobuta MX 500	10.1
Tractor 4WD	Kobuta 9570	12.8
Trailer	Local manufacture	0.41
Wheelbarrow	Local manufacture	0.31
Compaction		
Roller (ride on vibratory)	Komatsu 100 JVA	43.4
Roller (pedestrian vibratory)	Komatsu JV08HM	6.8
Roller (towed vibratory)	XCMG YZ12JC	7.5
Roller (ride on deadweight)	Bomag BW 154AD-2	15.3
Roller (deadweight, hand drawn)	Sakai TS 10 H	1.9
Roller (towed deadweight)	Bitelli	0.31
Vibrating Plate	Mikasa MVH-120	4.0
Grading		
Motor grader	See note below	See note below
Towed grader	See note below	See note below
Watering		
Water Bowser (self propelled)	Unknown	45.9
Water Bowser (towed)	Herculano RT 4000	2.4
Concreting		
Concrete Mixer	Local manufacture	2.9
Concrete Vibrator	Mikasa MSX-28	2.2
Bituminous related		
Bitumen Heater	Vina Bima NBT-100	1.7
Bitumen Hand Sprayer	Vina Bima PBT-100	2.4
Crusher		
Mobile small-scale stone crusher	See note below	See note below

Note: Graders and crushers are discussed in Section 4 and Section 5

In general, towed technology (e.g. towed grader) is the least expensive to operate. Self propelled haulage/watering and compaction equipment (e.g. tipper truck, ride on vibratory roller) have been found to be the most expensive equipment type.

Equipment Ownership and Demand

Current ownership of the following equipment is particularly high (ownership rates above 60%; i.e. six out of ten contractors own one or more of the following equipment):

- trucks (mostly tipper trucks)
- wheelbarrows

- compaction equipment
- water bowers (mostly self propelled versions)
- concreting equipment
- graders (motorised only)

The vast majority of contractors owned at least one truck and one compaction equipment. This combination is often regarded as the most necessary equipment for contractors in the rural roads sub sector.

Ownership of tractor-towed based technology is low. Less than 20% of contractors owned tractors and a slightly higher proportion owned trailers in Cambodia and Vietnam. For every equipment type where both a motorised/towed option is available, the demand for the motorised option was higher.

The study also estimated the future equipment demand in the rural roads sub-sector taking into consideration the planned rural road related roadworks in Cambodia, Vietnam and Laos. The equipment requirements are provided in the table below. The table shows that there will be substantial demand for conventional equipment (e.g. tipper truck and ride on deadweight roller). The demand for low-cost equipment (particularly tractor-towed technology) is expected to be moderate.

Annual requirement of equipment, number of units (2007/8-11/12)

Equipment	Total Demand Level
Tipper Truck	***
Flat Truck	***
Tractor 2WD	***
Tractor 4WD	***
Trailer	***
Wheelbarrow	***
Roller (ride on vibratory)	*
Roller (pedestrian vibratory)	**
Roller (towed vibratory)	*
Roller (ride on deadweight)	**
Roller (deadweight, hand drawn)	**
Roller (towed deadweight)	**
Vibrating Plate	***
Water Bowser (self propelled)	**
Water Bowser (towed)	**
Concrete Mixer	**
Concrete Vibrator	**
Bitumen Heater	*
Bitumen Hand Sprayer	*
Notes: *** - high (total demand over 1,000 units in three countries) ; ** - medium (demand between 400 and 1,000); * - low (demand below 400)	

Equipment Supply

In general there are no major constraints in equipment supply in the three countries. Sophisticated equipment (e.g. motor graders) are normally only available in large cities. The equipment is available year round and there is no supply constraint in any particular month/months of the year. The overall observation is that the supply meets the current demand and the future equipment demand is most likely to be met.

Among Cambodia, Vietnam and Laos, only Vietnam currently has a substantial equipment manufacturing potential. However, Vietnamese manufacturers are

currently facing stiff competition from Chinese manufacturers.

4. Grading Options

Graders are commonly used in the maintenance of unsealed road surfaces to restore the correct shape and reduce surface roughness. They are also used on paved roads to shape shoulders and drains and in construction for earthwork shaping and finishing.

Graders and Grading options

There are two general types of graders:

- **motor graders:** they run on their own power source. They require only one operator and no external equipment. They are expensive; and
- **towed grader:** they are towed by an external power source, usually by a tractor. They require one additional operator.

In addition, manual labourers may also be used to create correct shape and camber for a road. The labourers will require a number of hand tools including shovels and rakes.

Grader availability in the region

There are many motor graders available in the region. Medium sized motor graders (between 120-180 HP) are the most common in the three countries. The most common model is the CAT 120H. Large motor graders (greater than 180 HP) are also available but they are not as common as the medium sized ones. The general consensus among the contractors in the region is that they are not appropriate for works on rural roads. This is due to their large weight and wide turning circle. Small graders or compact graders (less than 120HP) are not common in the study countries. A typical small motor grader model, produced in the US, is the LeeBoy 635. The table below provides information of different motor grader types. Motor graders are costly equipment. The purchase price of a new motor grader ranges from US\$ 60,000 to 160,000.

Overview of motor graders

Variable	Motor Grader		
	180 HP +	120-180 HP	<120 HP
Typical model & brand	Komatsu 705A	CAT 120H	LeeBoy 635
Weight (tonnes)	17.62	12.65	3.5
Power (HP)	200	140	48
Blade width (m)		3.66	2.5
Purchase cost (US\$)	New	160,000	140,000
	Second-hand (5 yrs)	105,000	95,000
Hire cost (US\$/month)	4,000	3,500	1,510
Suitable for rural roads (earth)	NO	YES	YES
Suitable for rural roads (gravel)	NO	YES	YES
No. of operators required	1	1	1
Locally produced	NO	NO	NO
Locally available	YES	YES	NO
Supporting equipment	None	None	None

Two types of towed graders were found in the region. The Cam-Grader, which is produced in Cambodia, is the smallest. It weighs less than 1 Tonne. It costs US\$ 2,500 to buy a new one. It only requires a 2WD tractor with more than 35HP to pull it. The main disadvantage of Cam-Grader is that it is only suitable for light grading work on earth roads. Another towed grader is the UK manufactured Simba which weighs 1.35 Tonnes. It is considerably more expensive (a new one costs US\$

16,000) and requires a 4WD tractor with more than 70 HP to pull it. It can, however, perform light grading operations on both earth and gravel roads. The following table provides a comparison between Cam-Grader and Simba.

Overview of towed graders

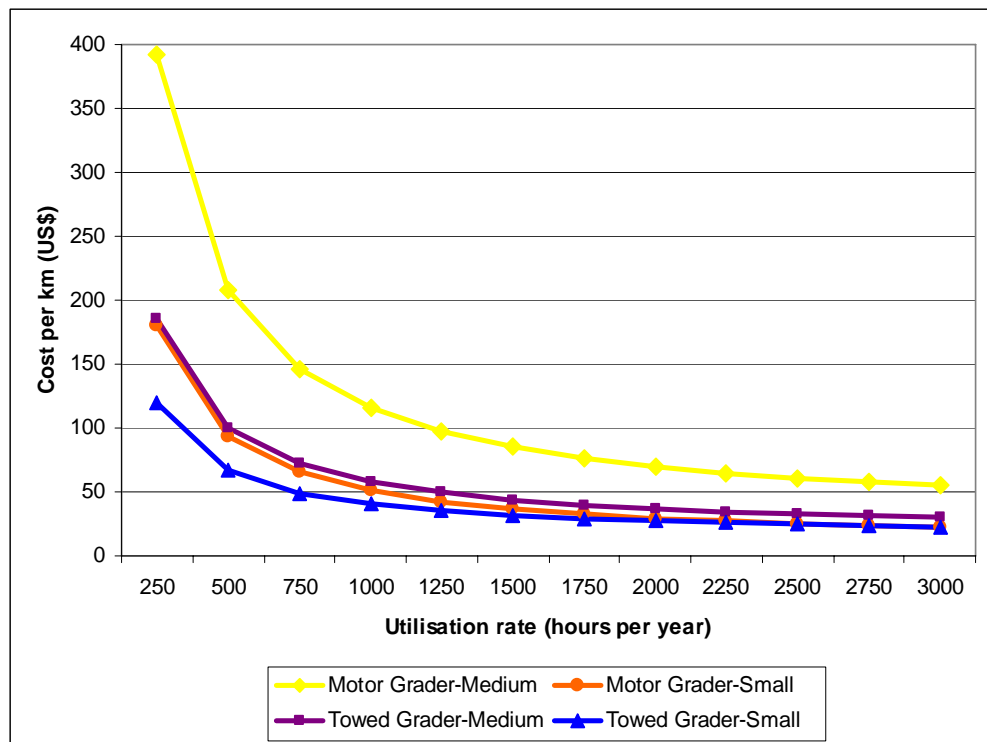
Variable		Towed Grader	
		>1 tonne	< 1 tonne
Typical model & brand		Simba	Cam-Grader
Weight (tonnes)		1.35	0.88
Power (HP)		-	-
Blade width (m)		3 to 4	2.3
Purchase cost (US\$)	New	16,000	2,500
	Second-hand (5 yrs)	10,860	1,700
Hire cost (US\$/month)		400	60
Suitable for rural roads (earth)		YES	YES
Suitable for rural roads (gravel)		YES	NO
No. of operators required		2	2
Locally produced		NO	YES
Locally available		NO	YES (Cambodia)
Supporting equipment	Details	Tractor > 70HP	Tractor > 35 HP
	Cost (new), (US\$)	42,000	25,000
	Cost (second-hand, 5 yrs)(US\$)	17,000	10,000
	Hire (US\$/month)	1,800	1,500

Grader Operating costs

The unit operating costs of equipment depends on their rate of utilisation rate (hours of operation per annum): the higher the utilisation rate, the lower the unit operating cost. The more productive and expensive equipment are more likely to be cost effective when utilisation rates are high. An average motor grader in Cambodia and Vietnam operates for approximately 900 hours per year. Unit operating costs are also dependent on whether the equipment is purchased new or second hand. The following figure shows grader operating costs for various utilisations rates when the equipment is purchased new.

The figure shows that at low utilisation levels, small towed graders (e.g. the Cam-Grader) are the least cost option for light grading on rural roads. However, as the utilisation rate approaches 2,000 hours per year, the unit operating costs of the small motor grader and small towed grader become identical. The medium sized motor grader is costlier to run compared to other graders. These findings are different for second-hand purchasing and hiring options.

Cost of grading (per km) when equipment is purchased new



Source: Equipment supplier interviews, equipment manufacturers and consultant's estimates

Optimum motor grader strategies

The following table provides the optimum strategies to be followed in choosing a grader. In most of the cases the best option to follow is the use of a small motor grader. However, a small towed grader is the most cost effective option for earthen roads when the rate of annual utilisation is below 2,000 hours. For an annual utilisation rate below 2,000 hours and for gravel roads the best option is to use Simba towed grader.

Optimum strategies for grader usage

Option	Surface	Utilisation rates (hours/year)	
		<2,000	>2,000
Purchase (New)	Gravel	Small Motor Grader	Small Motor Grader
	Earth	Cam-Grader	Small Motor Grader/Cam-Grader
Purchase (Second-hand)	Gravel	Simba	Small Motor Grader
	Earth	Cam-Grader	Small Motor Grader
Hire	Gravel	Small Motor Grader	Small Motor Grader
	Earth	Small Motor Grader	Small Motor Grader

5. Stone Crushing Options

Stone crushing equipment is used for crushing stone to produce aggregate. There are three main uses of crushed aggregate in construction. It can be used as a base and sub-base for paved roads for improved drainage and strength. When treated with bitumen it provides a hard-wearing road surface. Crushed material can also be added to natural material to improve the engineering characteristics of gravel roads. Aggregate is also used extensively in the construction industry in the production of concrete.

Crushing options

There are three methods of acquiring crushed rock or gravel (aggregate) as a

construction material:

- excavating suitable material and manually breaking it to the required size. This is known as **hand knapping**;
- purchase ready-crushed material from a **commercial quarry**; or
- use a **mobile crusher**

Mobile crushers and their availability in the region

Mobile stone crushers are used to produce aggregate on the construction site. Small scale mobile crushers are popular in Vietnam. However, their use is not common in Cambodia and Laos. Vietnam produces mobile crushers with a brand name of Hoa Phat. There are other small mobile stone crushers also available in the region. They are mainly Chinese made and the most common brand is the Shibang. The following table provides models that are available in the region from these manufacturers.

Summary information of mobile crushers available in the region

Crusher model, Brand	Country of origin	Price (US\$)	Weight (tonnes)	Size of input stones (mm)
NHHP-PEX15, Hoa Phat	Vietnam	1,420	0.4	150*250
NHHP-PEX175, Hoa Phat	Vietnam	2,560	0.9	175*300
NHHP-PEX215, Hoa Phat	Vietnam	4,245	2.0	215*300
PE150x250, Shibang	China	1,850	0.81	125*125
PE250x400, Shibang	China	5,400	2.8	210*210
PE400x600, Shibang	China	12,000	6.5	340*340

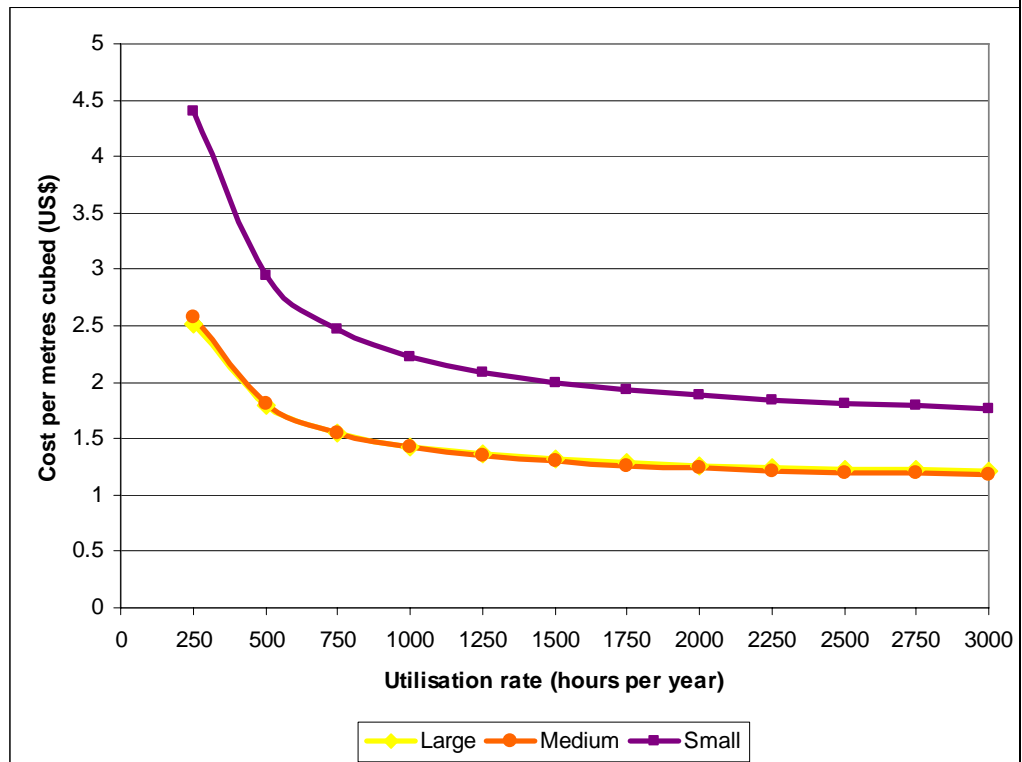
Operating costs

The following figure shows the operating costs of mobile crushers when they are purchased new. The unit operating costs of a small mobile crusher is higher than medium and large versions. Unit operating costs of medium and large sized mobile crushers are similar.

The fixed cost component (e.g. depreciation, interest payment etc.) of mobile crushers forms less than 15% of the average operating costs. On the other hand variable costs form over 80%. One of the main reasons is that the crushers require replacement of worn out jaws fairly frequently.

The cost of hand knapping is estimated at approximately US\$42 per cubic metre. Hand knapping is only cost effective when the required volume of material is low (less than 15 cubic metres for the entire operation) and when the construction site is located in isolated areas.

Mobile crusher operating costs when purchased new



Purchased material from a quarry needs transporting to the construction site (unless the quarry is at the construction site). Therefore, the cost per unit volume of crushed material from a quarry includes a fixed component (the cost of the material at the quarry gate) and a variable component (a function of haulage distance). In Vietnam, the cost of crushed stone at the quarry site range between US\$3.74 per cubic metre (for limestone) and US\$7.16 (for “hard” stone). The cost of haulage is estimated at US\$6.91 per cubic metre/km for distances less than 30km.

Optimum strategies for sourcing crushed aggregate

The optimum strategies for sourcing crushed aggregate at this time are summarised as:

- Hand knapping is the most cost effective option where the required volume of broken stone aggregate is low (under 15 cubic metres for the entire operation) and the construction site is located in remote areas.
- The use of medium and large (Hoa Phat) mobile crushers is the most cost effective option for any quantity over 15 cubic metres (for the entire operation). If the utilisation rate of a mobile crusher will be more than 1,000 hours per annum then it is best to purchase a mobile crusher. For low utilisation rate (below 1,000 hours per year) the best option is to hire a mobile crusher.
- Purchase of crushed material may be more expensive than sourcing aggregate using mobile crushers. However, in many cases this may be the only option available to a contractor given that the contractor is unable to organise the required resources (manpower or machines). It may also be the preferable option when there is a requirement for high quality product or specific material. This is as the commercial quarry can offer better quality and wide ranging sized products.

Optimum strategies for sourcing crushed material

Option	Hand Knapping	Mobile Crusher		Quarry Purchase
		Hire	Purchase	
Volumes of crushed material under 15 cubic metres (for the entire operation) and isolated areas	✓			
Utilisation rates below 1,000 hours per annum		✓		
Utilisation rates above 1,000 hours per annum			✓	
Unable to access resources (human and equipment) in the required time				✓
Strict requirement for good and consistent quality crushed material				✓

Further Reading

The student should refer to the following documents:

1. ITT Ltd. (2008), *Enhancing the Use of Locally Made, Low Cost Equipment for The Road Sector (SEACAP 020): Combined Module Report*, ITT Ltd., Ardington
2. Ministry of Transport (2007), *Rural Road Surfacing Research: SEACAP 1 Final Report*, Intech Associates and TRL Limited, np
3. Petts R C (2004), *Evaluation of Mark 2 Cambodia Light Grader (LCS Working Paper No 19)*, Intech Associates, np
4. Intech Associates (2004), *Introducing the DTW “Cam-Grader”, A Low Cost Rural Road Grader, LCS Working Paper No. 19*, Intech Associates, np
5. MART-ASIST-DFR (1996), ‘Intermediate Equipment for Labour-Based Roadworks, Workshop Report’, *MART Working Paper No. 5*, MAET-ASIST-DFR, Accra Ghana, 19 & 20 April 1996

Questions for students

- What are the main equipment categories required to implement the low-cost surface improvement options? Provide examples under each of the category.
- What is the existing situation concerning the general ownership of equipment by contractors, the equipment supply, potential demand of equipment in the region?
- As of the time of the study (see Further Reading 1) what are the optimum strategies for choosing graders?
- As of the time of the study (see Further Reading 1) what are the optimum strategies for sourcing crushed material for use in a construction site?