



**REPORT NO. 06181/1**

**ENHANCING THE USE OF  
LOCALLY MADE, LOW COST  
EQUIPMENT FOR THE ROAD  
SECTOR (SEACAP 020)**



**COMBINED MODULE REPORT  
(FINAL)**



**AUGUST 2008**



**BY**

***itt***

## **ITT REPORT 06181/1**

# **ENHANCING THE USE OF LOCALLY MADE, LOW COST EQUIPMENT FOR THE ROAD SECTOR (SEACAP 020)**

## **COMBINED MODULE REPORT (FINAL)**

This document is an output from a DFID financed project. The project has been implemented by IT Transport Ltd with assistance from Khmer Consultant Engineering Corporation (KCEC) of Cambodia and Institute of Science, Transport & Technology (ITST) of Vietnam. The report has been prepared by a team consisting of Messrs Masam Abedin, Farhad Ahmed, Gary Taylor of IT Transport Ltd, and Ron Dennis of the Developing Technologies at the Imperial College London. The views expressed are those of the author(s) and not necessarily those of the funding agency.

**ITT LTD.**  
**The Old Power Station, Ardington, Wantage, OX12 8QJ, UK**  
**2008**

## CONTENTS

|                                                              | Page No |
|--------------------------------------------------------------|---------|
| ABBREVIATIONS .....                                          | iv      |
| EXECUTIVE SUMMARY .....                                      | v       |
| PART A: INTRODUCTION AND METHODOLOGY .....                   | 1       |
| A1. INTRODUCTION .....                                       | 2       |
| A1.1 Background .....                                        | 2       |
| A1.2 The Study and the Module .....                          | 2       |
| A1.3 Structure of the Report .....                           | 3       |
| A2. METHODOLOGY .....                                        | 4       |
| A2.1 Contractor Survey .....                                 | 4       |
| A2.2 Key Informants Interview (KII) .....                    | 5       |
| A2.3 In-depth Interviews/Case Studies .....                  | 5       |
| A2.4 Equipment Performance Model .....                       | 5       |
| A2.5 General Analysis .....                                  | 5       |
| PART B: SURVEY MODULE .....                                  | 6       |
| B1. EQUIPMENT DEMAND .....                                   | 7       |
| B1.1 Equipment Assessment .....                              | 7       |
| B1.2 Unit Equipment Operating Costs .....                    | 7       |
| B1.3 Demand .....                                            | 8       |
| B1.3.1 Rural road development and maintenance plans .....    | 8       |
| B1.3.2 Equipment demand .....                                | 10      |
| B2. EQUIPMENT SUPPLY .....                                   | 13      |
| B2.1 Equipment Supply Constraints Faced by Contractors ..... | 13      |
| B2.2 Existing Suppliers and Manufacturers .....              | 13      |
| B2.3 Equipment Models and Costs .....                        | 15      |
| B2.4 Equipment Importation .....                             | 16      |
| B2.5 Chapter Summary .....                                   | 19      |
| B3. EQUIPMENT FINANCING AND INSTITUTIONAL FRAMEWORK .....    | 20      |
| B3.1. How are Equipment Financed .....                       | 20      |
| B3.2 Constraints Facing SSCs in Equipment Financing .....    | 21      |
| B3.3 Potential Financing Initiatives .....                   | 21      |
| B3.4 Potential Supporting Institutions .....                 | 22      |
| B3.5 Market Entry .....                                      | 23      |
| B3.6 Chapter Summary .....                                   | 24      |
| B4. EQUIPMENT MAINSTREAMING AND CONTRACTOR DEVELOPMENT ..... | 25      |
| B4.1 Demand and supply .....                                 | 25      |
| B4.2 Manufacturing Capacity .....                            | 25      |
| B4.3 Barriers .....                                          | 25      |
| PART C: TOWED GRADER MODULE .....                            | 26      |
| C1. GRADER TYPES .....                                       | 27      |
| C1.1 Introduction to Graders .....                           | 27      |
| C1.2 Grader Types .....                                      | 27      |
| C1.2.1 Motor Graders (Large) (more than 180 HP) .....        | 27      |
| C1.2.2 Motor Graders (Medium Sized) (120 to 180 HP) .....    | 27      |
| C1.2.3 Motor Graders (Small) (less than 120 HP) .....        | 28      |
| C1.2.4 Towed Graders (Medium Sized) (Simba) .....            | 29      |
| C1.2.5 Towed Graders (Small) (Cam-Grader) .....              | 29      |
| C1.3 Summary Overview of Different Graders .....             | 30      |
| C1.4 Chapter Summary .....                                   | 31      |
| C2. GRADER COST EFFECTIVENESS .....                          | 32      |
| C2.1 Introduction .....                                      | 32      |
| C2.2 Unit Grader Operating Costs .....                       | 32      |

|                                                              |           |
|--------------------------------------------------------------|-----------|
| C2.2.1 Grader Operating Costs: Purchased Equipment .....     | 33        |
| C2.2.2 Grader Operating Costs: Hired Equipment .....         | 35        |
| C2.3 Secondary Evidence of Grader Operating Costs .....      | 36        |
| C2.4 Grader Operating Costs Using Manual Labour .....        | 37        |
| C2.5 Chapter Summary .....                                   | 37        |
| <b>C3. GRADER DEMAND AND SUPPLY .....</b>                    | <b>39</b> |
| C3.1 Demand .....                                            | 39        |
| C3.1.1 Assessment of Current Demand .....                    | 39        |
| C3.1.2 Assessment of Future Demand .....                     | 41        |
| C3.2 Supply .....                                            | 42        |
| C3.3 Tractor Capacity .....                                  | 43        |
| C3.4 Chapter Summary .....                                   | 43        |
| <b>C4. GRADER COMPARATIVE ASSESSMENT .....</b>               | <b>45</b> |
| C4.1 Viability .....                                         | 45        |
| C4.2 Cost .....                                              | 45        |
| C4.3 Demand and Supply .....                                 | 45        |
| C4.4 Recommendations .....                                   | 45        |
| <b>PART D: MOBILE SMALL-SCALE STONE CRUSHER MODULE .....</b> | <b>46</b> |
| <b>D1. STONE CRUSHING TECHNOLOGIES .....</b>                 | <b>47</b> |
| D1.1 Advantages and Uses of Crushed Stone and Rock .....     | 47        |
| D1.2 Sources of Crushed Stone and Rock .....                 | 47        |
| D1.3 Deployment of Crushers .....                            | 48        |
| D1.4 Stone Crushing Technologies .....                       | 48        |
| D1.4.1 Crusher types .....                                   | 48        |
| D1.4.2 Jaw crushers .....                                    | 49        |
| D1.5 Chapter Summary .....                                   | 51        |
| <b>D2. MOBILE CRUSHER COST EFFECTIVENESS .....</b>           | <b>52</b> |
| D2.1 Mobile Crushers .....                                   | 52        |
| D2.1.1 Equipment purchase .....                              | 52        |
| D2.1.2 Equipment hire .....                                  | 54        |
| D2.1.3 Comparison between equipment purchase and hire .....  | 54        |
| D2.1.4 Cost of excavation .....                              | 55        |
| D2.2 Manual Crushing .....                                   | 56        |
| D2.3 Purchasing from Commercial Quarry .....                 | 56        |
| D2.4 Chapter Summary .....                                   | 57        |
| <b>D3. MOBILE CRUSHER DEMAND AND SUPPLY .....</b>            | <b>59</b> |
| D3.1 Demand .....                                            | 59        |
| D3.1.1 Assessment of current demand .....                    | 59        |
| D3.1.2 Assessment of future demand .....                     | 61        |
| D3.2 Supply .....                                            | 61        |
| D3.3 Chapter Summary .....                                   | 63        |
| <b>D4. MOBILE CRUSHER COMPARATIVE ASSESSMENT .....</b>       | <b>64</b> |
| D4.1 Viability .....                                         | 64        |
| D4.2 Cost .....                                              | 64        |
| D4.3 Demand and Supply .....                                 | 64        |
| D4.4 Recommendations .....                                   | 64        |
| <b>REFERENCES .....</b>                                      | <b>65</b> |
| Appendices                                                   |           |

## ABBREVIATIONS

|         |                                                                                      |
|---------|--------------------------------------------------------------------------------------|
| DFID    | Department for International Development (UK)                                        |
| DPWT    | Department of Public Works and Transport (Laos)                                      |
| DTW     | Development Technology Workshop (Cambodia)                                           |
| HP      | Horse Power                                                                          |
| ILO     | International Labour Organization                                                    |
| ITST    | Institute of Science, Transport & Technology                                         |
| ITT     | I.T. Transport Ltd.                                                                  |
| KCEC    | Khmer Consultant Engineering Corporation                                             |
| KII     | Key Informant Interview                                                              |
| LAK     | Laotian Kips                                                                         |
| Laos    | Lao People's Democratic Republic                                                     |
| MCTPC   | Ministry for Communications, Transport, Post and Construction (Laos)                 |
| MRD     | Ministry of Rural Development (Cambodia)                                             |
| NCDD    | National Committee for Management of the Decentralization and Deconcentration Reform |
| NDE     | New Dawn Engineering                                                                 |
| NGO     | Non Governmental Organisation                                                        |
| PDRD    | Provincial Department of Rural Development (Cambodia)                                |
| RT2     | Second Rural Transport Project (Vietnam)                                             |
| RT2/RT3 | Second/Third Rural Transport Project                                                 |
| SEACAP  | South East Asia Community Access Programme                                           |
| SIDA    | Swedish International Development Agency                                             |
| SSC     | Small Scale Contactor                                                                |
| TOR     | Terms of Reference                                                                   |
| TRIP    | Tertiary Rural Infrastructure Programme (Cambodia)                                   |
| TRL     | Transport Research Laboratory (UK)                                                   |
| VND     | Vietnamese Dong                                                                      |
| WB      | World Bank                                                                           |
| 2WD     | Two Wheel Drive                                                                      |
| 4WD     | Four Wheel Drive                                                                     |

\*\*\*\*\*

### Approximate Currency Equivalent (as of April 30, 2008)

| CAMBODIA             | VIETNAM             | LAOS               |
|----------------------|---------------------|--------------------|
| 1 US\$ = 3,920 Riels | 1 US\$ = 16,100 VND | 1 US\$ = 8,700 LAK |
| 1 € = 6,140 Riels    | 1 € = 25,200 VND    | 1 € = 13,700 LAK   |
| 1 UK£ = 7,800 Riels  | 1 UK£ = 32,000 VND  | 1 UK£ = 17,300 LAK |

\*\*\*\*\*

## EXECUTIVE SUMMARY

1. This report presents the findings of a study entitled “Enhancing the Use of Locally Made, Low Cost Equipment for the Road Sector” undertaken in three countries in South East Asia: Cambodia, Vietnam and Laos. The project is financed by the Department for International Development (DFID), UK under its South East Asia Community Access Programme (SEACAP). The main objective of the project (SEACAP 020) was to identify “*ways to improve the availability and accessibility of equipment that is necessary and appropriate for the rural road technologies that are emerging from SEACAP projects*”.
2. The project has four main modules. This report is concerned with three of them: (i) the survey module (which focuses on the identification of necessary equipment, the assessment of their demand and supply and the estimation of their performance and costs); (ii) the towed grader module (which focuses on towed graders and considers their suitability and cost effectiveness compared to other grader types); and (iii) the mobile small-scale stone crusher module (examines the suitability of mobile crushers in the production of quality and economical crushed aggregate). The study findings are drawn mainly from the evidence generated through interviews with small-scale contractors in Cambodia and Vietnam and with Key Informants in Vietnam, Cambodia and Laos.

### Survey module

3. Equipment ownership among the contractors was found to be high. In general, Vietnamese contractors owned more equipment than Cambodian contractors. The contractors also hired in equipment. The main source of equipment hire was other contractors.
4. Evidence suggests that there is an occasional surge in demand for certain equipment (mainly haulage, compaction and grading equipment). The potential demand linked to the rural road related roadworks for the conventional equipment (e.g. trucks and compaction equipment) is estimated to be substantial. The demand for tractor-towed based technology has been estimated to be moderate.
5. In general there are no significant equipment supply constraints in Cambodia and Vietnam. The supply meets the demand. There exists a spatial aspect to supply constraint of relatively sophisticated equipment (e.g. motor graders) as they are only available for sale in large cities. No evidence is available that suggest a temporal aspect to supply constraint.
6. Among the study countries only Vietnam has a substantial manufacturing potential. However, evidence suggests that Vietnam is facing stiff competition from Chinese manufacturers at the higher end of the market (e.g. motor graders) and there is evidence that suggest some manufacturers have ceased the production of some equipment as a result of this.
7. Contractors in the region do not import equipment directly; they usually depend on dedicated importers for equipment importation.
8. The overwhelmingly main source of equipment finance by contractors is the private capital; only a small minority of them financed equipment purchase using formal credit. Only a few contractors reported having problems in obtaining formal credit. The main problem cited by the contractors in obtaining formal credit were the strict terms and conditions (e.g. high interest rate, large deposits etc.) linked to credit services.

9. No evidence from Cambodia and Vietnam suggests that potential SSCs face problems in entering the rural road sub-sector market. However, there is a cause for concern in Laos as there is evidence to suggest that an unfavourable climate for existing small-scale contractors and for market entrants. It is advised that the Government of Laos eases some of the constraints facing SSCs.

### **Towed Grader Module**

10. Large and medium sized motor graders were widely available and used for roadworks in the region. Small motor graders (less than 120 HP) were rare. Only two types of towed grader were available (mainly in Cambodia): the CamGrader and the Simba. Most interviewed contractors, however, were unaware of towed graders. Key informants and contractors felt that large motor graders (more than 180 HP) were not suitable for use on small rural roads due to their excessive weight. However, smaller motor graders (less than 180 HP) are lighter as well as having adequate power and versatility of functions and are therefore regarded as suitable equipment for grading rural roads.
11. A cost-effectiveness analysis, that used empirical data in combination with a number of assumptions, suggests that the Cam Grader is the most cost-effective equipment for grading earth roads, whether purchased new or second hand, at low utilisation rates (less than 2,000 hrs/year). The same analysis also suggests that at low utilisation rates and gravel roads, the small-motor grader is the most cost-effective if purchased new and the Simba grader if purchased second hand. At higher utilisation rates and if equipment is hired, the small grader is the most cost effective equipment.
12. The study estimated the potential demand of graders linked to the planned rural road development in the three countries. The number of graders that will be required per year to implement the planned roadworks in Cambodia and Laos is estimated to be low (10 and 8 units, respectively). The grader demand is higher in Vietnam (approximately 180 motor graders and 270 towed graders will be required per year). There appears to be little difficulty amongst contractors in the region in hiring or acquiring tractors, which opens the possibility of the use of towed graders. Many contractors in Vietnam were interested in the possibility of purchasing a towed grader. However, the amount that they would be willing to pay appears to be significantly below the market price. Less than a third of contractors interviewed in Cambodia were interested in purchasing a towed grader. Analysis suggests that the existing stock of motor graders appears adequate to meet the likely future demand that will originate from the rural roads sub-sector in the next five years.
13. The overall conclusion is that there may be only limited opportunities for marketing towed graders in the region, given the adequate availability of the grading equipment. Therefore, there is no cause for concern on the shortage of grading equipment, at least in the near future.

### **Small-Scale Mobile Stone Crusher Module**

14. Mobile crushers owned by the contractors in the region were of the jaw crusher variety. They are lighter and have a simple crushing mechanism.
15. Among the three viable alternative options (hand knapping, using a mobile crusher and purchasing from a commercial quarry), mobile crushers are found to be the most cost-effective. However, hand knapping is the best option in a case when the required volume of broken stone is low or if the construction site is remotely located. When the quality of required crushed material is high and/or there is a special technical requirement,

purchasing from a commercial quarry may become the only option available to the contractor.

16. The current demand for mobile crushers is high in Vietnam but low in Cambodia and Laos. The potential demand for mobile crushers linked to the rural roads sub-sector in Cambodia and Laos (combined) is relatively low (approximately 250 units per year are estimated to be required over the next 5 years). The potential demand in Vietnam is high (over 2,900 units per year). This is due to the anticipated expansion of paved rural road network in Vietnam. Evidence suggests that currently there is no crushing equipment supply constraint in the region.
17. Evidence suggests that many contractors are not aware of the usefulness of the mobile crushers (especially its cost effectiveness) in sourcing crushed stone. It is recommended that the details of the benefits offered by the mobile crushers be disseminated among contractors and equipment suppliers in the region by appropriate authorities to make them aware of their potential advantages. Currently no mobile crusher hire market exists in the study countries. An objective of this dissemination process should be to encourage equipment suppliers to make mobile crushers available for hire, particularly in Vietnam.
18. There is overwhelming evidence from the region that suggests that the market will be able to match the future demand with adequate supply of crushing equipment. Therefore, no intervention aimed at increasing supply is necessary, barring the dissemination of the usefulness of the mobile crushers in sourcing crushed stone among contractors.

## **PART A: INTRODUCTION AND METHODOLOGY**

# A1. INTRODUCTION

## A1.1 Background

A series of Department for International Development (DFID), UK funded research projects are currently being implemented in Cambodia, Laos and Vietnam. They are being funded under DFID's South East Asia Community Access Programme (SEACAP). SEACAP identifies ways to improve sustainable access to rural communities to facilitate access to social and economic facilities and services, thereby creating opportunities for pro-poor growth and poverty alleviation. The objective of the Programme is *"Livelihoods of poor and vulnerable people in SE Asia improved sustainably"*. SEACAP encourages initiatives that allow roads to be constructed and maintained in a sustainable way by local people using local materials, local labour and skills, local enterprises and simple, low cost equipment.

## A1.2 The Study and the Module

This report is one of the outputs from the SEACAP 020 project, Enhancing the Use of Locally Made, Low Cost Equipment for the Road Sector. The main objective of SEACAP 020 is to identify *"ways to improve the availability and accessibility of equipment that is necessary and appropriate for the rural road technologies that are emerging from SEACAP projects"* and that such *"equipment will be appropriate in cost and size for (SSCs) small-scale contractors involved in the rural road construction and maintenance"*. SEACAP 020 activities mainly revolve around four modules: (i) Survey; (ii) Towed Grader; (iii) Mobile Small-scale Stone Crushers; and (iv) Dissemination and Mainstreaming. Although Cambodia is the main focus of SEACAP 020, some project activities are required in Vietnam and Laos. This report combines the findings linked to modules (i), (ii) and (iii) mentioned above.

The 'Survey Module', analyses the current demand and supply of equipment necessary for SSC's in relation to rural roads in the three countries. The main activities included the identification of the equipment necessary and appropriate to support various road technologies<sup>1</sup>, the estimation of operational performances of the identified equipment, the investigation of equipment financing practices and constraints facing SSCs, the identification of potential institutions that can help SSC finance and procure equipment, development and mainstreaming of equipment, and recommendation of follow up initiatives to enable SSCs obtain needed equipment.

The 'Towed Grader Module', analyses the suitability of the towed grader for SSCs in the rural roads sub-sector. This involved a number of activities including the analysis of basic performance norms of the graders, the comparison of the cost effectiveness of towed graders over other alternative strategies and options, the review of commercial aspects of grader ownership and the formulation of strategies to integrate towed graders into national rural road programmes.

The 'Mobile Small-scale Stone Crusher Module' analyses the suitability of mobile small-scale stone crushers<sup>2</sup> for SSCs in relation to rural roads related roadworks. This again involved a number of activities including research of the existing knowledge base, the identification of regional mobile crusher manufacturers, the assessment of the views of existing and potential mobile crusher users, an appraisal of the short and long term market for the mobile crushers and the proposal of strategies to integrate mobile crushers into national rural road programmes.

---

<sup>1</sup> A list of road surfaces is provided in the Appendix to the SEACAP 020 Terms of Reference.

<sup>2</sup> Hereinafter referred as the Mobile Crushers.

### **A1.3 Structure of the Report**

There are four parts to this report. Part A introduces the report and the methodology of the study. Parts B, C and D are the Survey, Towed Grader and Mobile Crusher modules, respectively.

## A2. METHODOLOGY

This chapter describes the methodology that has been adopted to achieve the outputs linked to the three modules. A number of activities were conducted including: (i) contractor surveys; (ii) key informant interviews (KIIs); (iii) in-depth interviews/case studies; (iv) development of equipment performance and cost models; and (iv) general analysis.

### A2.1 Contractor Survey

The contractor surveys provided the most important source of data for this report. The objective of the exercise was to ascertain the commercial behaviour of contractors regarding the necessary equipment. A detailed questionnaire was developed for this purpose (Appendix I). This questionnaire was administered face to face by trained surveyors.

The Terms of Reference (TOR) of the study provided a list of SSCs to be surveyed. They included 22 Cambodian trained by the International Labour Organisation (ILO) upstream project and 42 Vietnamese contractors who carried out work on the Second Rural Transport Project (RT2). From the original list, four Cambodian contractors and 33 Vietnamese contractors were successfully identified and interviewed. Where the contractors could not be interviewed from the original list (because the contractor no longer operated or was not able/willing to be interviewed), they were replaced by appropriate small-scale contractors. This involved establishing a set of criteria for each country. This was done with the help of local experts. The contractor selection criteria were:

#### **Cambodia**

- enlisted with Seila/NCDD<sup>3</sup>
- bid for a road project under Seila in it's final year (2006)
- not VAT registered
- has an updated trade licence

#### **Vietnam**

- have worked on a road project under RT2/RT3
- employ under 50 full time staff<sup>4</sup>
- total value of capital assets under \$200,000<sup>5</sup>
- total annual turnover of under \$200,000<sup>6</sup>

#### **Laos**

- registered and classified as Level II or Level III contractors with the Department of Public Works and Transport (DPWT)

A total of 79 contractors were surveyed (Table 1). Of them 39 were Cambodian and 40 were Vietnamese. No Laotian contractors were surveyed because none could be found that satisfied the selection criteria. A further analysis showed that this is because few SSC's are operating in the rural roads sub-sector.

---

<sup>3</sup> The Seila Program is an aid mobilization and coordination framework for support to Cambodia's decentralization and deconcentration reforms. The Seila Programme came to a close in December 2006. The activities of Seila are now being carried out by the National Committee for Management of the Decentralization and Deconcentration Reform (NCDD). Details on the Seila programme can be accessed using the following link: <http://www.seila.gov.kh/indexs.asp?language=kh&pgid=1>

<sup>4</sup> Government of Vietnam definition of small scale contractor

<sup>5</sup> Government of Vietnam definition of a small business is commercial entity with capital value assets of under 1 billion Vietnamese Dong (VND) (1998) (available online at [www.taichinh-kinhte.com](http://www.taichinh-kinhte.com)). This value equals 2.6 billion VND after applying GDP growth over the period. Vietcom Bank describes a small business with capital value assets of under 10 billion VND. The value of \$200,000 (3.2 billion VND) was chosen to take a balance of these two definitions. It was also the opinion of many experts that few small scale contractors would be identified with a lower threshold capital asset value.

<sup>6</sup> Vietcom bank definition of small scale business.

## **A2.2 Key Informants Interview (KII)**

A series of interviews, using a structured questionnaire, were conducted with experts in the rural road sub-sector in order to establish their views on the necessary equipment (Table 1). They were designed to complement the contractor surveys. The responses have been incorporated throughout this report. The interviews were conducted face to face. Appendix II provides the list of interviewees.

**Table 1: Extent of activities in this study**

| <b>Activity</b>                | <b>Cambodia</b> | <b>Vietnam</b> | <b>Laos</b> | <b>Total</b> |
|--------------------------------|-----------------|----------------|-------------|--------------|
| Contractor surveys             | 39              | 40             | None        | 79           |
| Key informant interviews       | 13              | 9              | 5           | 27           |
| Equipment supplier interviews  | 8               | 7              | 7           | 22           |
| In-depth contractor interviews | 2               | 1              | 2           | 5            |

## **A2.3 In-depth Interviews/Case Studies**

A number of in-depth interviews were carried out with contractors. The objective was to understand their views on a number of issues including the problems faced by them and details regarding the commercial environment. A total of three SSCs in the rural road sub-sector were interviewed in Cambodia and Vietnam. Two SSCs in the building construction industry were also interviewed in Laos (Table 1).

Equipment suppliers in Cambodia, Vietnam and Laos were also surveyed using a pre-defined questionnaire (Table 1). Appendix III provides the questionnaire. This provided an invaluable source of information for this study, especially in the analysis of the supply side of the equipment.

## **A2.4 Equipment Performance Model**

A spreadsheet-based equipment cost model has been developed for this study to determine unit equipment operating costs. The model utilises a number of inputs including purchase costs, operating life, utilisation rates, interest rates, costs of different inputs (e.g. fuel, lubricants, operator wages etc.).

## **A2.5 General Analysis**

A thorough search of relevant secondary sources was performed and the relevant documents were reviewed. Such information has complemented the information collected from primary sources.

## **PART B: SURVEY MODULE**

## B1. EQUIPMENT DEMAND

### B1.1 Equipment Assessment

MART Working Paper No. 5 (MART-ASIST-DFR, 1996) provides a comprehensive list of intermediate equipment for labour-based small-scale contracting in the road sector. From the list, a total of 22 equipment (under seven categories) were short-listed for Cambodia, Vietnam and Laos to support various road technologies that have emerged from the SEACAP road surfacing research. The main document that assisted in the short-listing was a SEACAP project report (Ministry of Transport, 2007).

Appendix IV provides the details of the exercise. Where two or more competing equipment were suitable for a particular technology type, the lowest cost option was given preference. A deviation from this approach was required in the case of the haulage equipment, whereby, the appropriate equipment is dependent on the haulage distance<sup>7</sup>.

The following list provides the equipment that was found appropriate in the context of the three countries to implement different road surfacing options:

|                               |                                 |                                  |
|-------------------------------|---------------------------------|----------------------------------|
| <b>Haulage</b>                | <b>Concreting</b>               | <b>Compaction</b>                |
| Tipper truck                  | Concrete mixer                  | Roller (ride on vibratory)       |
| Flat truck                    | Concrete vibrator               | Roller (pedestrian vibratory)    |
| Tractor 2WD                   |                                 | Roller (towed vibratory)         |
| Tractor 4WD                   | <b>Grading</b>                  | Roller (ride on deadweight)      |
| Trailer                       | Motor grader <sup>8</sup>       | Roller (deadweight, hand drawn)  |
| Wheelbarrow                   | Towed grader                    | Roller (towed deadweight)        |
|                               |                                 | Plate compactor                  |
| <b>Watering</b>               | <b>Bitumen related</b>          | <b>Crusher</b>                   |
| Water bowser (self-propelled) | Bitumen heater and hand sprayer | Mobile small-scale stone crusher |
| Water bowser (towed)          |                                 |                                  |

### B1.2 Unit Equipment Operating Costs

An equipment cost model was built to estimate the operating costs of different short-listed equipment. The operating cost model uses a number of inputs including:

- purchase price and salvage value;
- maintenance cost;
- tyre costs;
- fuel and lubrication costs; and
- operator wages etc.

Table 2 provides the unit financial operation costs of different equipment. Unit operating costs for graders and crusher are not included in Table 2 as they are dealt separately in Part C and Part D respectively of this report. Appendix V provides the detailed item-wise operating cost values. Information on productivity values and utilisation rates are available in Appendix

<sup>7</sup> Tractor/trailer combinations are appropriate for shorter haulage distances (e.g. under 10km). On the other hand Tipper/Flat Trucks are more suitable for longer haulage distances (say over 10km).

<sup>8</sup> Motor graders and self propelled water bowsters were not recommended for contractors because they are not intermediate items of equipment. However, their importance as a substitute to towed graders, makes analysis of this equipment a necessary requirement. For this reason, such equipment have been added to the short-list.

VI. Information linked to utilisation rates and other cost items were collected from contractors and suppliers. Productivity values were estimated using data supplied by equipment manufacturers.

**Table 2: Financial operating costs of typical equipment**

| Equipment                       | Typical Model / Brand      | Description       | Financial operating cost (US\$/hr) |
|---------------------------------|----------------------------|-------------------|------------------------------------|
| Tipper Truck                    | Hyundai HD 72              | 6 cum capacity    | 18.5                               |
| Flat Truck                      | Isuzu FRR33H4              | 4 cum capacity    | 13.7                               |
| Tractor 2WD                     | Kobuta MX 500              | 53 HP             | 10.1                               |
| Tractor 4WD                     | Kobuta 9570                | 93 HP             | 12.8                               |
| Trailer                         | Local manufacture          | 3 cum capacity    | 0.41                               |
| Wheelbarrow                     | Local manufacture          | 0.09 cum capacity | 0.31                               |
| Roller (ride on vibratory)      | Komatsu 100 JVA            | CE 10T            | 43.4                               |
| Roller (pedestrian vibratory)   | Komatsu JV08HM             | CE 10T            | 6.8                                |
| Roller (towed vibratory)        | XCMG YZ12JC                | 12T               | 7.5                                |
| Roller (ride on deadweight)     | Bomag BW 154AD-2           | 8T                | 15.3                               |
| Roller (deadweight, hand drawn) | Sakai TS 10 H              | 1T                | 1.9                                |
| Roller (towed deadweight)       | Bitelli                    | 1T                | 0.31                               |
| Vibrating Plate                 | Mikasa MVH-120             | 400x585 mm        | 4.0                                |
| Water Bowser (self propelled)   | Unknown                    | 5,000l capacity   | 45.9                               |
| Water Bowser (towed)            | Herculano RT 4000          | 500l capacity     | 2.4                                |
| Concrete Mixer                  | Local manufacture          | 560l capacity     | 2.9                                |
| Concrete Vibrator               | Mikasa MSX-28              | 28x1000 mm        | 2.2                                |
| Bitumen Heater & Hand Sprayer   | Vina Bima NBT-100, PBT-100 | 1 cum capacity    | 4.1                                |

Source: Contractor surveys; Equipment supplier surveys; IT Transport (2003); Larcher (1997)

Notes: cum – cubic metres; CE - compaction effort; T-tonnes; l - litres

Where data were not available from primary sources (e.g. information on towed water bowzers), operating cost values were derived from secondary sources, including IT Transport (2003) and Larcher (1997).

Overall the operating cost values appear to be consistent with other study findings including a study done in Mozambique in 2003 (IT Transport, 2003). Table 2 shows that, in general, towed technology is the least expensive to operate. Self propelled haulage/watering and compaction equipment have been found to be the most expensive equipment.

### **B1.3 Demand**

This section provides an estimate for the overall demand of the identified equipment. Projected transport road work activities have been approximated from rural transport strategies in the three countries. Estimates of roadwork activities and the equipment productivity rates were used in the demand estimation.

#### **B1.3.1 Rural road development and maintenance plans**

The rural road linked roadwork volumes for three countries have been estimated using their rural roads development plans (Ministry of Rural Development, 2007; Ministry of Communication Transport Post and Construction, 2007, World Bank, 2006).

a) Current network

Table 3 presents the current length and the projected quantum of works in the rural road sub-sector. Vietnam has by far the largest network length (over 175,000 km). Cambodia's and Laos's rural road network lengths are considerably lower than Vietnam (24,000 and 17,500 km respectively). The summary rural road network characteristics are provided below:

- earth roads constitute between 60-62% in all three countries;
- gravel roads constitute between 31-39% in these countries; and
- paved roads constitute 5% and 7% in Laos and Vietnam, respectively. Cambodia has no paved rural roads.

**Table 3: Rural road summaries and plans for the years 2007/08-2011/12**

| Variable                               | Surface | Cambodia | Vietnam <sup>9</sup> | Laos <sup>10</sup> |
|----------------------------------------|---------|----------|----------------------|--------------------|
| Current network size (km)              | Paved   | 0        | 12,028               | 880                |
|                                        | Gravel  | 9,452    | 54,523               | 6,158              |
|                                        | Earth   | 14,578   | 109,917              | 10,556             |
| Projected development (km/yr)          | Paved   | 103      | 17,006               | 110                |
|                                        | Gravel  | 1,381    | 0                    | 770                |
|                                        | Earth   | 0        | 0                    | 1,320              |
| Projected periodic maintenance (km/yr) | Paved   | 0        | 1,718                | 55                 |
|                                        | Gravel  | 2081     | 3,138                | 388                |
|                                        | Earth   | 0        | 6,326                | 665                |
| Projected routine maintenance (km/yr)  | Paved   | 103      | 35,819               | 66                 |
|                                        | Gravel  | 5,475    | 37,288               | 459                |
|                                        | Earth   | 0        | 75,173               | 786                |

b) Projected development

Vietnam will undergo a large construction programme as a result of the government's objective to pave 55% of the rural road network. However, this will not result in an overall expansion of the network but a conversion from gravel and earth surfaced roads. Cambodia's plan is to pave 50% of the tertiary road network and to improve over 6,900 km of gravel roads over the period. Laos plans to add over 500km of paved roads, 3,800km of gravel roads and 6,500km of earth roads to its network over the five year period.

c) Projected periodic and routine maintenance

Over the 5-year period, approximately 10,400 km of gravel roads will be periodically maintained in Cambodia. In the same period Laos plans to periodically maintain approximately 5,500km of rural roads. The total estimated length that Vietnam will put under periodic maintenance is 56,000 km (approximately a third of the rural road network) over the same period.

<sup>9</sup> For current network size refer to Vietnam Roads Administration, 2004. For projected rural road works refer to Project Appraisal Document, Third Rural Transport Project, World Bank, 2006.

<sup>10</sup> For current network size refer MCTPC, Provincial Road Maintenance Management System, 2007. These values are estimates; data for Lao PDR varies significantly between different sources. This depends mainly on whether special classed roads are included. These form 56% of the rural road network but are constructed and maintained by private industries not the MCTPC. See <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/EXTEAPREGTOPT RANSPORT/0,,contentMDK:20767668~menuPK:2069285~pagePK:34004173~piPK:34003707~theSitePK:574066,00.html>. For projected rural road works refer to National Strategy on Accelerated Provision of Rural Transport Infrastructure, MCTPC, 2007.

Cambodia, Vietnam and Laos have planned to place a total 5,600km, 148,300km and 1,300km of rural roads (respectively) under annual routine maintenance operations. The summary of the strategies are provided in Appendix VII.

### B1.3.2 Equipment demand

#### a) Assessment of current demand

It is difficult to estimate the market demand for equipment given that it is a function of a number of factors (e.g. the level of road building activities, activities in other sectors, current contractor equipment ownership etc.). The current market equipment demand for rural road related activities is a function of the small-scale contractors' equipment ownership and hiring level. Such information is available from contractor surveys and the results are presented in Table 4 (see Appendix VIII details). The ownership and level of hiring related information is used in the assessment of the current market demand.

Equipment ownership was high (ownership rates above 60%) for the following equipment in Vietnam and Cambodia:

- 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. Such a combination is often regarded as the most necessary equipment for contractors in the rural road sub-sector.

Table 4 also shows that ownership of tractor-towed based technology was low, although slightly higher in Cambodia than in Vietnam. Less than 20% of contractors owned tractors and a slightly higher proportion owned trailers in the two countries. For every equipment type where both a motorised/towed option is available, the demand for the motorised option was higher. All the contractors that owned (hired) graders owned (hired) the motor grader. 53% (13%) of the contractors owned (hired) a self propelled water bowser, whereas, only 24% (4%) owned (hired) a towed water bowser.

**Table 4: Contractors that own or have hired equipment in the last 12 months**

| Equipment                         | Percentage of contractors that own/hire[a] |          |           |          |           |          |
|-----------------------------------|--------------------------------------------|----------|-----------|----------|-----------|----------|
|                                   | Total                                      |          | Cambodia  |          | Vietnam   |          |
|                                   | Own                                        | Hire     | Own       | Hire     | Own       | Hire     |
| Trucks                            | 90 (5)                                     | 51 (3.5) | 82 (4.2)  | 51 (3)   | 98 (5.6)  | 50 (4)   |
| Tractors                          | 16 (1.4)                                   | 10 (1)   | 21 (1.5)  | 15 (1)   | 13 (1.2)  | 5 (1)    |
| Trailers                          | 27 (1.3)                                   | 15 (1.1) | 33 (1.3)  | 3 (1)    | 20 (1.4)  | 28 (1.1) |
| Wheelbarrows                      | 77 (15.5)                                  | 1 (2)    | 67 (18.2) | 0 (0)    | 88 (13.4) | 3 (2)    |
| Compaction                        | 94 (5.2)                                   | 43 (1.4) | 87 (3.7)  | 44 (1.2) | 100 (6.4) | 43 (1.7) |
| Water bowers                      | 70 (1.9)                                   | 16 (1.2) | 59 (1.8)  | 18 (1)   | 80 (2)    | 15 (1.5) |
| Concreting equipment              | 81 (8)                                     | 8 (3.7)  | 62 (4.8)  | 5 (3)    | 100 (9.9) | 10 (4)   |
| Mobile small-scale stone crusher  | 16 (1.8)                                   | 3 (1)    | 0 (0)     | 0 (0)    | 33 (1.8)  | 5 (1)    |
| Graders                           | 61 (1.9)                                   | 37 (1.3) | 44 (1.5)  | 51 (1.3) | 78 (2.1)  | 23 (1.4) |
| Bitumen heaters and hand sprayers | 43 (3.3)                                   | 14 (2.6) | 13 (2)    | 3 (4)    | 73 (3.6)  | 25 (2.5) |

Source: Contractor surveys

Note: [a] The values in brackets refer to the average number of equipment owned/hired per owning/hiring contractor

In Vietnam ownership was higher for bitumen and mobile small-scale stone crushing equipment (no Cambodian contractor owned the latter). This finding is expected considering the higher current proportion and anticipated growth of paved roads.

Ownership rates and the average number of equipment owned were higher in Vietnam than in Cambodia. One possible explanation is that the contractors surveyed in Vietnam were larger in size than the Cambodian contractors (see Appendix IX and X).

Table 4 shows that the hiring rates and the average number of equipment hired were similar in Cambodia and Vietnam. Trucks, compaction equipment and graders were the equipment most hired. This is expected given that they are the basic equipment for roadworks.

The conclusions from the above discussions are: (i) the current equipment ownership among the Cambodian and Vietnamese contractors was high; (ii) In general, the equipment ownership among Vietnamese contractors was higher than Cambodian contractors; (iii) Despite high equipment ownership, the contractors hired in equipment. This shows that there is an occasional surge in demand for such equipment.

#### b) Assessment of future demand

The future equipment demand has been estimated by using the projected volume of rural roads related roadworks and productivity values of the equipment (see Appendix VI). Table 5 presents the estimated future equipment demand arising from rural roadworks. Table 5 values represent the number required annually to carry out the planned roadworks. In the demand assessment the following assumptions apply: (i) where possible, the low-cost equipment was given preference over sophisticated equipment; (ii) the equipment availability and efficiency levels are 50%<sup>11</sup> and 80%, respectively; and (iii) the demand is only linked to the rural roadworks. The demand from other sectors was ignored.

**Table 5: Annual requirement of equipment, number of units (2007/8-2011/12)**

| Equipment                       | Cambodia | Vietnam | Laos | Total Demand Level |
|---------------------------------|----------|---------|------|--------------------|
| Tipper Truck                    | 455      | 11,955  | 208  | ***                |
| Flat Truck                      | 89       | 2,532   | 63   | ***                |
| Tractor 2WD                     | 162      | 4,242   | 81   | ***                |
| Tractor 4WD                     | 93       | 1,705   | 40   | ***                |
| Trailer                         | 279      | 2,139   | 26   | ***                |
| Wheelbarrow                     | 327      | 3,798   | 210  | ***                |
| Roller (ride on vibratory)      | 6        | 60      | 4    | *                  |
| Roller (pedestrian vibratory)   | 18       | 656     | 3    | **                 |
| Roller (towed vibratory)        | 11       | 70      | 9    | *                  |
| Roller (ride on deadweight)     | 4        | 621     | 6    | **                 |
| Roller (deadweight, hand drawn) | 4        | 1,120   | 3    | **                 |
| Roller (towed deadweight)       | 0        | 1,433   | 45   | **                 |
| Vibrating Plate                 | 49       | 16,790  | 31   | ***                |
| Water Bowser (self propelled)   | 65       | 539     | 50   | **                 |
| Water Bowser (towed)            | 11       | 934     | 18   | **                 |
| Concrete Mixer                  | 74       | 804     | 47   | **                 |
| Concrete Vibrator               | 74       | 804     | 47   | **                 |
| Bitumen Heater & Hand Sprayer   | 1        | 179     | 1    | *                  |

Source: Consultant's estimates

Notes: \*\*\* - high (demand over 1,500 units) ; \*\* - medium (demand between 500 and 1,500); \* - low (demand below 500)

<sup>11</sup> This level of availability is assumed to factor in effects of factors linked to the delay in sourcing spares and the limited repair capacity if the equipment breaks down at the construction site, time to move equipment from one construction site to another, and the low utilisation rate in rainy season.

Table 5 shows that there will still 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 moderate.

The demand estimation utilises a model which simplifies the rural road sub-sector characteristics. Therefore, the values in Table 5 are only approximate estimates; however, the model provides a good analysis for the relative level of demand between equipment types.

#### **B1.4 Chapter Summary**

This chapter assessed the equipment necessary to support various road technologies emerging from the SEACAP road related research. A total of 22 equipment were identified and productivity norms provided. The chapter also assessed current and future equipment demand. Equipment ownership among the contractors was high. Contractors also hired in equipment, particularly haulage, compaction and grading equipment reflecting an occasional surge in demand. Potential future demand will be high for conventional equipment (e.g. trucks and compaction equipment). The demand for tractor-towed based technology has been estimated to be moderate.

## B2. EQUIPMENT SUPPLY

This chapter presents the issues linked to equipment supply, in particular, the supply constraints faced by contractors, availability of suppliers and manufactures in the region, equipment available regionally and their purchase costs and importation practices.

### B2.1 Equipment Supply Constraints Faced by Contractors

Contractors were asked whether they faced difficulty in obtaining the identified equipment. Table 6 presents the results of the analysis. Cambodian contractors faced no problems accessing equipment. The Vietnamese contractors faced some equipment supply constraints; however, the overwhelming majority encountered no problems. It can therefore be concluded that supply covers the level of demand and in general there are no equipment supply constraints.

**Table 6: Contractors facing difficulty in equipment procurement**

| Equipment                         | Percentage of contractors that have had difficulty acquiring |          |         |
|-----------------------------------|--------------------------------------------------------------|----------|---------|
|                                   | Total                                                        | Cambodia | Vietnam |
| Trucks                            | 1                                                            | 0        | 3       |
| Tractors                          | 1                                                            | 0        | 3       |
| Trailers                          | 1                                                            | 3        | 0       |
| Wheelbarrows                      | 0                                                            | 0        | 0       |
| Compaction                        | 4                                                            | 0        | 8       |
| Water bowsers                     | 4                                                            | 0        | 8       |
| Concreting equipment              | 1                                                            | 0        | 3       |
| Mobile small-scale stone crusher  | 4                                                            | 0        | 8       |
| Graders                           | 4                                                            | 0        | 8       |
| Bitumen heaters and hand sprayers | 8                                                            | 0        | 15      |

Source: Contractor surveys

Evidence from key informants and supplier interviews suggest that there is little overall supply for towed graders and mobile small-scale stone crusher (Cambodia and Laos only) but this being mainly due to low demand.

Most experts (and contractors) claim that equipment can only be purchased in major cities (e.g. Phnom Penh, Hanoi, Ho Chi Minh, Vientiane). It can therefore be concluded that a spatial constraint to equipment supply exist. However, this should not necessarily act as a disadvantage to contractors. The dis-benefits associated with lack of availability of equipment for purchase in local areas will be offset by lower retail prices in main cities.

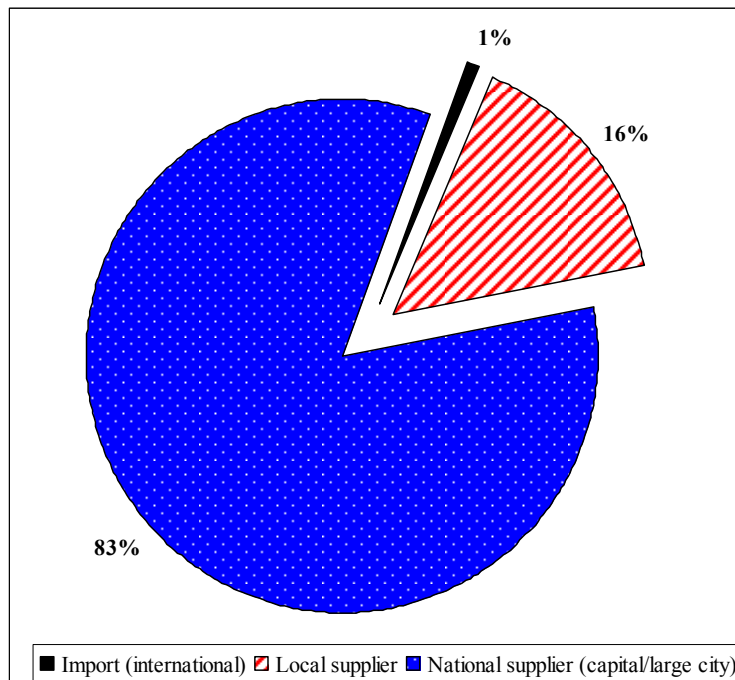
Contractors and equipment suppliers were also asked about the temporal aspect of equipment demand and supply. It is evident from their response that there was no significant temporal variation of equipment demand that could not be matched by suppliers.

Appendix XI provides details on the contractors' response regarding constraints in supply.

### B2.2 Existing Suppliers and Manufacturers

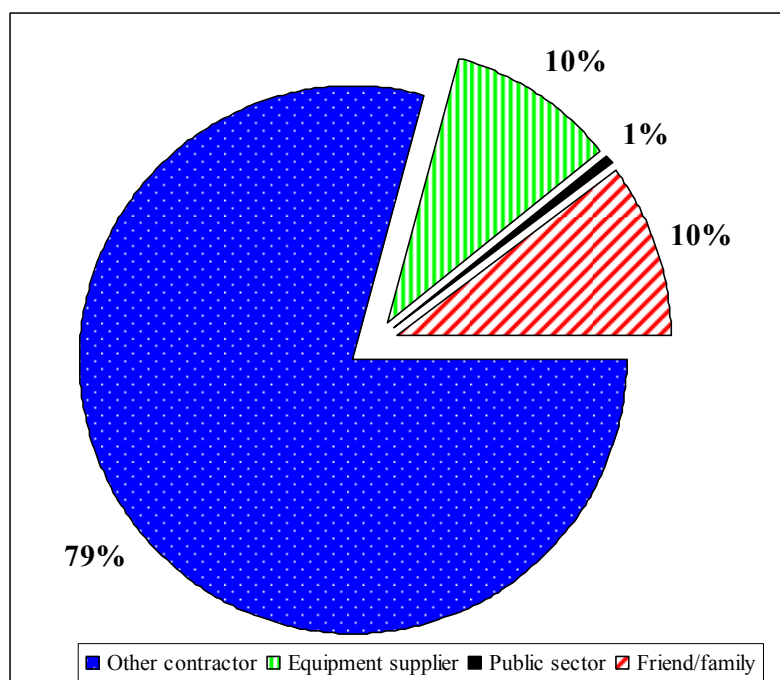
There are many equipment suppliers in the region, providing contractors with a huge choice of outlets. A non-exhaustive list of equipment suppliers is presented in Appendix XII for each equipment type. Contractors were asked where they acquired their equipment and their responses are presented in Figure 1. An overwhelming majority of the contractors (83%) purchased their equipment from one of the above main cities (Figure 1). Only one in six of

the equipment was purchased from local suppliers and they were mainly wheelbarrows, trailers and concrete mixers.



**Figure 1: Source of equipment purchased**

When contractors needed extra equipment an overwhelming majority (roughly 80%) rented them from other contractors (Figure 2). Renting equipment from commercial equipment suppliers was not common. Approximately 10% of contractors rented equipment from equipment suppliers; however the proportion is considerably higher in Cambodia (21%) than in Vietnam (3%) (see Appendix XIII and XIV). This means that the equipment suppliers tend not to rent equipment out. Contractors also rented equipment from friends and family (10%).



Source: Contractor survey

**Figure 2: Source of equipment hire**

Data on equipment hire out rates were collected in Cambodia. Table 7 presents the rates against different equipment with their brand and model. Hire out rates for different equipment range from US\$ 3,800 (for motor grader) to US\$ 50 per month (concrete vibrator). These rates were exclusive of driver/operator wages.

**Table 7: Typical hire rates in Cambodia**

| Equipment                     | Brand & Model     | Description        | Hire Rate (per month, US\$) |
|-------------------------------|-------------------|--------------------|-----------------------------|
| Tipper truck                  | HINO FD2JDBD      | 5 m <sup>3</sup>   | 3,000                       |
| Flat truck                    | FUSO EF639        | 5 tonnes           | 3,000                       |
| Tractor (2WD)                 | BELARUS 800 D-243 | 86 Hp              | 1,500                       |
| Tractor (4WD)                 | BELARUS 820 D-243 | 86 Hp              | 1,800                       |
| Wheelbarrow                   | Unknown           | 0.2 m <sup>3</sup> | 40 [a]                      |
| Roller (Ride on vibratory)    | Komatsu JV 100A   | 10 tonnes          | 2,000                       |
| Roller (Towed deadweight)     | Unknown           | Unknown            | 300                         |
| Roller (Pedestrian vibratory) | BOMAG BW 71 E-2   | 0.5 tonnes         | 500                         |
| Roller (Deadweight)           | CAT CB 214 C      | 2.4 tonnes         | 1,200                       |
| Roller (Hand drawn)           | BOMAG BW 75 S     | 1 ton              | 700                         |
| Plate compactor               | Mikasa MT-52FW    | 3 Hp               | 250                         |
| Concrete mixer                | Unknown           | 0.2 m <sup>3</sup> | 350                         |
| Concrete vibrator             | Mikasa MSX 28     | 35*1000mm          | 50                          |
| Motor grader                  | CAT 14G           | 180 HP             | 3,800                       |

Note: [a] estimated from the daily hire out rate

### B2.3 Equipment Models and Costs

The equipment supplier survey has provided a large database of information on brands and models of the equipment being used by the contractors. Such models vary greatly in price and specifications. Table 8 provides a summary of the most typical brands and models available in the region with their purchasing costs. There also exists an active second-hand equipment market in the region. Anecdotal evidence suggests that most of the second-hand equipment comes from the neighbouring countries (Thailand and China).

**Table 8: Typical equipment models & purchase costs**

| Equipment                        | Brand / Model                 | Description                   | Cost (US\$) |                      |
|----------------------------------|-------------------------------|-------------------------------|-------------|----------------------|
|                                  |                               |                               | New         | 2nd hand (age in yr) |
| Tipper Truck                     | Hyundai HD 72                 | 6 m <sup>3</sup>              | 35,000      | 25,000 (3)           |
| Flat Truck                       | Isuzu FRR33H4                 | 4 m <sup>3</sup>              | 25,000      | 14,500 (3)           |
| Tractor 2WD                      | Kobuta MX 500                 | 53 HP                         | 25,000      | 16000 (2)            |
| Tractor 4WD                      | Kobuta 9570                   | 95 HP                         | 42,000      | 20,000 (4)           |
| Trailer                          | Unknown                       | 3 m <sup>3</sup>              | 1,500       | 500 (5)              |
| Wheelbarrow                      | Unknown                       | 0.09 m <sup>3</sup>           | 30          | Unknown              |
| Roller (ride on vibratory)       | Komatsu JV 100A               | (CE <sup>12</sup> ) 10 tonnes | 130,000     | 90,000 (6)           |
| Roller (pedestrian vibratory)    | Komatsu JV08HM                | 0.73 tonnes (CE, 5 tonnes)    | 12,500      | 5,000 (5)            |
| Roller (towed vibratory)         | XCMG YZ12JC                   | 12 tonnes                     | 29,500      | Unknown              |
| Roller (ride on deadweight)      | Bomag BW 154AD-2              | 8 tonnes                      | Unknown     | 12,000 (8)           |
| Roller (deadweight, hand drawn)  | Sakai TS 10 H                 | 1 ton                         | Unknown     | 3,500 (9)            |
| Roller (towed deadweight)        | Bitelli                       | 1 ton                         | 1,000       | Unknown              |
| Vibrating Plate                  | Mikasa MVH-120                | 400*585 mm                    | 2,545       | Unknown              |
| Concrete Mixer                   | Hoa Phat JZC-350              | 560 L                         | 2,920       | Unknown              |
| Concrete Vibrator                | Mikasa MSX-28                 | 28*1000 mm                    | 305         | Unknown              |
| Mobile Small-Scale Stone Crusher | Hoa Phat NHHP-PEX215 (diesel) | 215*300 mm stone capacity     | 4,145       | Unknown              |
| Motor Grader                     | CAT 120H                      | 140 HP                        | 150,000     | 110,000 (5)          |
| Towed Grader                     | Cam Grader                    | 0.88 tonnes                   | 2,500       | Unknown              |
| Bitumen Heater & Hand Sprayer    | Vina Bima NBT-100, PBT-100    | 1 m <sup>3</sup>              | 10,000      | Unknown              |

Source: Equipment supplier surveys

## B2.4 Equipment Importation

### a) Importation practices

The early part of the chapter shows that the present equipment market appears to be functioning satisfactorily. Information on the contractor importation practices, available from contractor surveys, further corroborates such a conclusion (Table 9). Appendix XV presents detailed results. Table 9 shows that only a small minority of the contractors ever imported or considered importing equipment (the overall results range from 0% to 6% for different equipment types). From Table 9 it can also be concluded that contractors depend on dedicated importers for the importation of the equipment rather than direct importation.

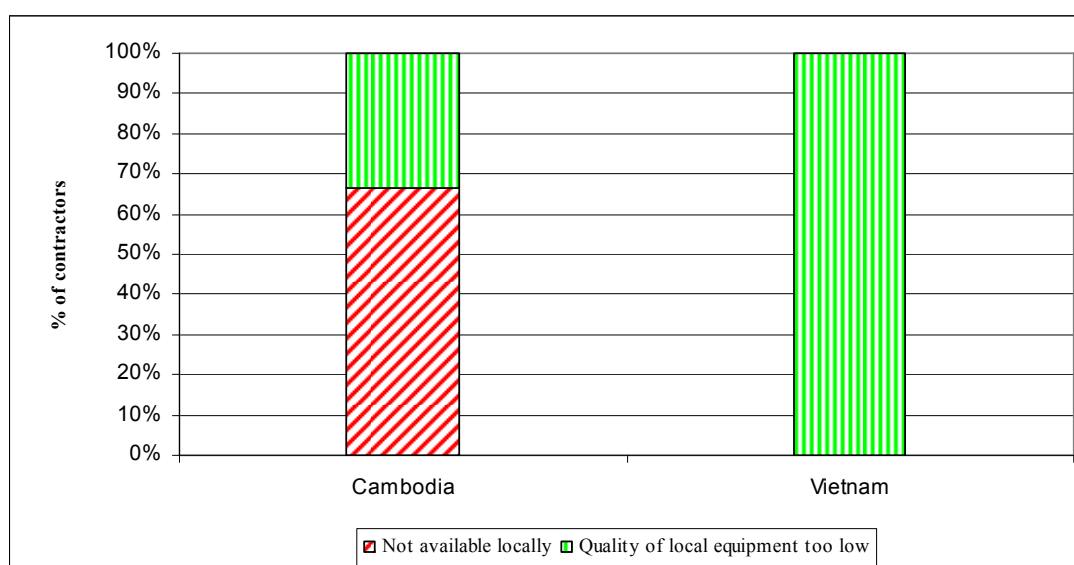
<sup>12</sup> Compaction effort

**Table 9: Contractors that imported or considered importing equipment**

| Equipment                         | Percentage of contractors imported/considered importing |          |         |
|-----------------------------------|---------------------------------------------------------|----------|---------|
|                                   | Overall                                                 | Cambodia | Vietnam |
| Trucks                            | 4                                                       | 3        | 5       |
| Tractors                          | 0                                                       | 0        | 0       |
| Trailers                          | 1                                                       | 0        | 3       |
| Wheelbarrows                      | 0                                                       | 0        | 0       |
| Compaction                        | 6                                                       | 5        | 8       |
| Water bowsers                     | 1                                                       | 0        | 3       |
| Concreting equipment              | 3                                                       | 0        | 5       |
| Mobile small-scale stone crusher  | 0                                                       | 0        | 0       |
| Graders                           | 3                                                       | 0        | 5       |
| Bitumen heaters and hand sprayers | 4                                                       | 0        | 8       |

Source: Contractor surveys

Contractors, who imported or considered importing equipment, were asked questions regarding the reasons for considering the option. The only reason cited by Vietnamese contractors was the poor quality of locally available equipment (see Figure 3). The response was different in Cambodia: only a third imported or considered importation as an option due to poor equipment quality. Two thirds of the Cambodian contractors, who considered importation, did so because the equipment was not available locally.



Source: Contractor surveys

**Figure 3: Reasons why importation considered**

#### b) Common sources and practices for importation

Contractors were asked on common sources and practices for importation of equipment. Their responses show that when a contractor decides to directly import an item of equipment they would normally hire a shipping agent to conduct the necessary preparatory work. The contractors also pick up the equipment at the border/port. In northern Cambodia and Laos, contractors have been known to drive trucks across the Thai border.

Table 10 shows the typical countries from which such equipment is imported from. This information is based on the data gathered from equipment suppliers and key informant interviews. The list of equipment exporting countries is not exhaustive and it only presents the major countries that are active in the supply of equipment to these three countries. Table

10 shows that the major exporting countries include Japan, South Korea, China, Thailand and the USA.

**Table 10: Equipment exporting countries to Cambodia, Vietnam and Laos**

| <b>Equipment</b>                 | <b>Import from</b>                    |
|----------------------------------|---------------------------------------|
| Tipper Truck                     | Japan, South Korea, Thailand, USA     |
| Flat Truck                       | China, Japan, South Korea, Thailand   |
| Tractor 2WD                      | Belarus, China, Thailand, US          |
| Tractor 4WD                      | Belarus, China, Thailand, US          |
| Trailer                          | China, Thailand                       |
| Wheelbarrow                      | China, Thailand                       |
| Roller (ride on vibratory)       | China, Japan                          |
| Roller (pedestrian vibratory)    | Japan, Thailand                       |
| Roller (towed vibratory)         | China, Japan                          |
| Roller (ride on deadweight)      | Italy, Japan, Thailand, USA           |
| Roller (deadweight, hand drawn)  | Japan, UK                             |
| Roller (towed deadweight)        | Italy                                 |
| Vibrating Plate                  | China, Japan                          |
| Concrete Mixer                   | France, Italy, Thailand               |
| Concrete Vibrator                | Japan, South Korea, Thailand          |
| Mobile Small-Scale Stone Crusher | China                                 |
| Motor Grader                     | China, Japan, USA                     |
| Bitumen Heater & Hand Sprayers   | Germany, Japan, South Korea, Thailand |

Source: Equipment supplier surveys

### c) Barriers to importation

Data gathered from the contractors, who considered importing equipment, show that the biggest barrier to importation is their general lack of knowledge of the required procedures. This explains the hiring of a shipping agent to conduct the necessary preparatory work.

There are also other importation barriers (as evident from key informant and equipment supplier interviews) that include:

- a requirement to hold importation licence;
- high importation tax/fee;
- long delivery time;
- inability of contractors to visit the country where the equipment is sourced in order to inspect the goods;
- lack of language skills throughout the process;
- cost of shipping agent; and
- availability of shipping agent (they tend to only exist in capital cities).

### d) Feasibility of producing equipment locally

Investigation in to the equipment manufacturing potential of the countries suggests that Cambodia and Laos currently have very limited manufacturing potential. Nonetheless, they are able to manufacture smaller equipment (e.g. wheelbarrows and concrete mixers). They are also able to produce makeshift equipment with modification of some of the mainstream equipment (e.g. self propelled and towed water bowsers from trucks and trailers, see photographs below). It is common practice to operate with makeshift bitumen heaters (using an empty drum) and bitumen hand sprayers (using a watering can).



### **Makeshift Water Bowser in Laos**

On the other hand Vietnam has a much more advanced manufacturing base. The country is able to manufacture a number of equipment including:

- tipper truck;
- flat truck;
- tractors (2WD and 4WD);
- trailers;
- wheelbarrows;
- vibrating plates;
- concrete mixers;
- concrete vibrators;
- mobile small-scale crushers;
- concrete mixers;
- bitumen heaters and hand sprayers

Contractors, key informants and equipment suppliers stated that locally produced equipment were not as cost effective as foreign ones, especially with the recent influx of modern and cheap Chinese models. For this reason equipment of foreign origin are still more popular. The cost effectiveness gap between local and foreign equipment is most stark with the more technologically advanced equipment, where some manufacturers have abandoned the manufacture of certain equipment types (e.g. the 1-5 Machinery Company based near Hanoi no longer produces motor graders and rollers).

Appendix XVI provides a non-exhaustive list of equipment manufacturers.

### **B2.5 Chapter Summary**

Contractor survey results show that, in general, there are no equipment supply constraints. However, sophisticated equipment (e.g. motor graders) are generally only available in large cities. Therefore, there is a spatial aspect to supply constraint. Nonetheless, this is not a major issue as purchasing prices are likely to be lower than if they were available in rural areas. No evidence linked to the temporal aspect to supply constraint was found. Evidence shows that contractors frequently hire equipment from other contractors.

Only Vietnam currently has a substantial manufacturing potential. However, Vietnamese manufacturers are currently facing stiff competition from Chinese manufacturers producing low priced versions. This has resulted in some manufacturers having to stop the production of some equipment. Evidence suggests that generally the contractors do not import equipment themselves. They usually depend on dedicated importers.

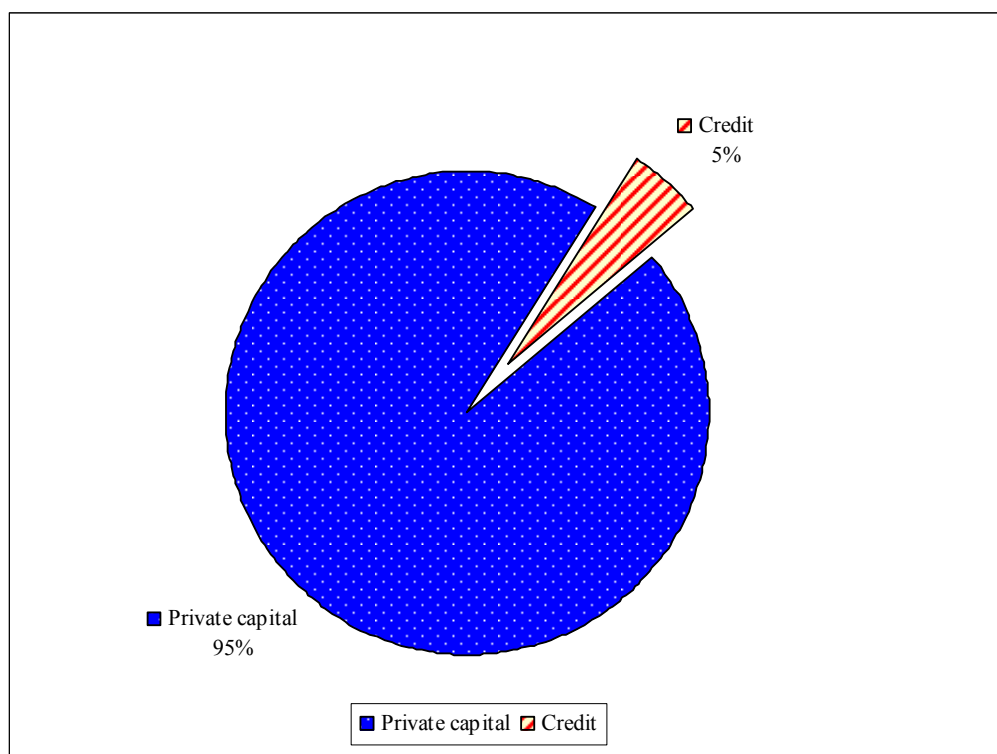
### B3. EQUIPMENT FINANCING AND INSTITUTIONAL FRAMEWORK

This chapter discusses how purchase of equipment is financed by the contractors, what constraints they face and their opinions on potential solutions. Market entry into the rural road sub-sector is also discussed, as well as the potential supporting institutions.

#### B3.1. How are Equipment Financed

Contractor surveys collected information on financing practices of contractors. An overwhelming majority of the contractors (95%) reported that they financed equipment purchase through raising capital privately (Figure 4). The remaining 5% of contractors reported to have financed equipment purchase using formal credit. No equipment purchase was financed through grants or other methods. The results were corroborated by the key informants: they stressed that these two methods were the only modes of equipment finance. Vietnamese contractors are more likely to borrow capital from banks than Cambodian contractors. (see Appendix XVII and XVIII).

However, credit finance is becoming increasingly popular. According to key experts and contractors, credit has traditionally been accessed informally through the community (family and friends), but banks now form the main source of credit finance. A recent economic report on Vietnam concluded a similar trend across all sectors of the economy (The Economist, 2008). ACLEDA bank of Cambodia and Agri Bank of Vietnam are the only two banking institutions cited by the contractors as sources of credit.



Source: Contractor surveys

**Figure 4: Method of equipment finance**

### B3.2 Constraints Facing SSCs in Equipment Financing

Figure 5 shows the results of the analysis on the constraints faced by contractors in financing equipment purchase.

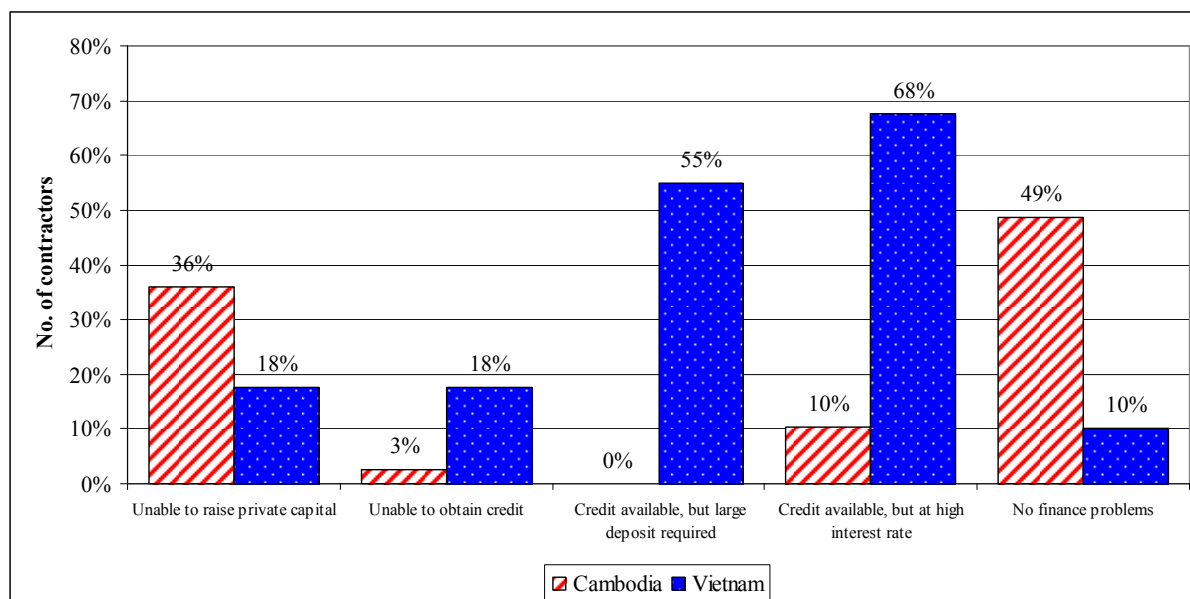
Inability to raise private capital was the main constraint perceived by Cambodian contractors. Unfavourable conditions attached to the products/services banks provide was the main constraint for Vietnamese contractors. Research on the products that ACLEDA bank offers show that similar restrictions exist in

**Box 1: Sample Borrowing Terms and Conditions for Small Business Loan in Cambodia**

- Minimum loan of 6 million Riels (approximately US\$1,500)
- Maximum loan of 40 million Riels (approximately US\$10,000)
- Interest rate of 2.75% per month
- Maximum loan period of 24 months;
- Liquid deposits amounting to 100% of the loan value OR secured with property amounting to 125% of the loan value

Source: ACLEDA Bank

Cambodia (see Box 1), however, these restrictions are perceived to be a greater problem in Vietnam. Box 1 shows that small scale contractors are not able to borrow amounts large enough to purchase expensive equipment (e.g. motor graders). However, they could use the loan to contribute towards the amount required (especially if purchased second hand). Loan periods of 24 months will also act as a major constraint to contractors especially if there are delays in project commencement and/or payment.



Source: Contractor surveys

**Figure 5: Financial barriers**

### B3.3 Potential Financing Initiatives

Some experts expressed their opinions on various financing options ranging from establishing equipment pools to hire purchase agreements to direct supply. Many key informants preferred not to intervene in the market. However, the only option that received general acceptability from key informants was hire purchase agreements, whereby contractors receive equipment built into a contract and the value of the equipment is deducted from the work payments. Initially the equipment will be owned by the client so the equipment is essentially loaned and

therefore interest payments need to be included in the contract. Such a scheme has been implemented before in the ILO Upstream Project in Cambodia. Nonetheless, this method can run into trouble if: (i) the client is unable to pay on time; (ii) the work is not completed on time for some reasons (e.g. contractor's/client's fault, or reasons beyond the control of any of the contracting parties). These problems can be overcome by introducing clauses into the contract. For example, in the Ugandan Transport Rehabilitation Project (ILO), interest payments were frozen if the contracting agency was unable to pay the contractor on time or guarantee work (Deelen and Bonsu, 2002).

### B3.4 Potential Supporting Institutions

Contractors were asked which institutions could assist them to access equipment. An overwhelming majority of Cambodian contractors (92%) opined that there are no potential supporting institutions (Figure 6). The same figure for Vietnam was also considerable (42%).

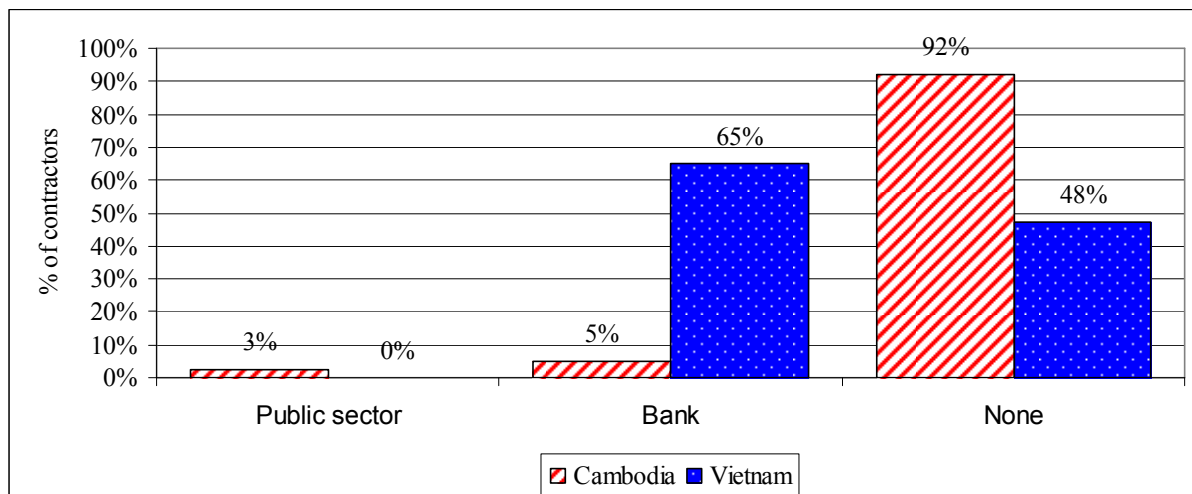
58% of Vietnamese contractors cited banks as potential supporting institutions. The same

figure for Cambodia was only 5%. The most likely explanation for such a difference is that the Vietnamese contractors are more familiar than their Cambodian counterparts in obtaining credit from banks. Also the business community may have more faith with banks in Vietnam than in Cambodia due to a more mature financial sector. Ministries and public sector institutions, NGOs and donors were only cited by one contractor (in Cambodia) as a potential source of support. These findings are corroborated by key informants (Box 2)

#### Box 2: Quote from a key informant

“There are no public institutions that can currently help contractors in equipment procurement,” **Mr. Ros Sar, Director of Department of Rural Development, Siem Reap, Cambodia**

Source: personal interview



Source: Contractor surveys

**Figure 6: Potential supporting institutions in equipment finance**

Many key experts felt that the public sector can and should incorporate a more comprehensive capacity building service for contractors so that they can be educated on managing and conducting rural road projects. A SEACAP<sup>13</sup> study also recommended that capacity within the rural transport sub-sector be improved. There have been capacity building initiatives in the past, but these were mainly incorporated into individual programmes e.g. the ILO Upstream Project had a contractor development component and the SEILA programme

<sup>13</sup> Institutional, Incentive and Capacity Study of the Local Transport Network, SEACAP 16, July 2005

had a capacity building component called the Technical Support Unit to Commune Council. It is recommended that these initiatives be refreshed and expanded so that they are available to all contractors and applicable to all rural road works.

### **B3.5 Market Entry**

Evidence (key informant interviews and contractor surveys) indicates that there are no market entry barriers for small scale contractors in Vietnam and Cambodia. Empirical evidence from other studies also corroborates this finding. Klerx and Lay (2001) estimated a total of approximately 500 SSCs in Cambodia in 2001. This figure might have increased substantially in the last seven years. A study in Vietnam<sup>14</sup> mentioned the existence of approximately 5,500 SSCs (those who have less than 50 employees) in 2002 in Vietnam. It appears from the study quoted SSC figures that the rate of growth in SSC numbers in Vietnam was very high (over 60% per year). Furthermore, a SEACAP<sup>15</sup> study concluded that SSCs in Vietnam were operating on a good economic and technical platform to take advantage of the opportunities available in the rural transport sub-sector.

However, small businesses have difficulty entering the rural road sub-sector in Laos and there are many reasons for this. Experts and SSCs (active in the building industry) state that the most important reasons is that a free market environment has only been functioning for the past decade and is therefore can be considered at a very early stage and the rural road sub-sector is not large enough to attract potential contractors.

Small contractors in Laos are still unlikely to enter into the market in the near future for other reasons. Mainly, large contractors are not prohibited from bidding for the smallest projects and the smallest projects are attractive enough for large contractors to consider. This problem is exemplified with an analysis of the contracts awarded on the Lao-Swedish Road Sector Project III's Basic Access Component (LSRSP III-BAC). In 2006/7, the vast majority of projects were won by a handful of contractors. The smallest project in the component was worth US\$3,500 (Bokeo province) – a size and value that can be regarded as suitable for a SSC. However, this was effectively incorporated into one large project worth approximately US\$100,000 and consequently awarded to a (large) contractor. The average size of rural road projects under the LSRSP III-BAC programme in the year 2006/7 was approximately US\$ 60,000.

Key informants also suggested that small contractors in Laos were being crowded out of the market. This is as projects are being tendered at the provincial level rather than at the community level which can be very unfavourable to small contractors who tend not have a large portfolio of work across

a province. In addition, tender documents tend to disqualify small contractors based on their small equipment fleet and discourage them from bidding due to their lack of financial

#### **Box 3: Quotes from Laotian Building Construction Contractors**

“In order to enter the rural road market you need at least one billion Kip!,” **Mr Khamoune Inthisane, Inthasane Construction, Vientiane, Laos**

“I would like to work in the rural road sub-sector but the market is too small,” **Mr Khounsy Thongsavath, Construction Co. Ltd., Vientiane, Laos**

Source: personal interview

<sup>14</sup> Vietnam: The Vital Construction Industry, July 2004

<sup>15</sup> Research into the Role of the Private Sector in Rural Transport, SEACAP 14, May 2005

resources. An analysis of a typical bidding document for the Lao-Swedish Road Sector Project III Maintenance Component (LSRSP III-MC) requires that contractors have access to at least one tipper truck, a bulldozer, a motor grader and a roller. This will require a significant investment for a contractor planning on entering the market.

In-depth discussions with building contractors show that there are further constraints (see Box 3). They state that they face too much competition from medium and large sized companies who can offer lower unit prices because they have the most sophisticated equipment. They claim that small companies do not have the financial resources to cover the negative cash flows often experienced during the work and sometimes even after it is completed due to late payment. They have also stated that they can't obtain access to staff appropriately skilled.

### **B3.6 Chapter Summary**

An overwhelming majority of the contractors (95%) reported that they financed equipment purchase by raising capital privately. The remaining 5% of contractors reported to have borrowed money. Only a handful of contractors cited problems in obtaining credit. The main problems cited were unfavourable terms and conditions linked to the products being offered by banks. Contractors rated financial institutions substantially higher than public sector institutions as potential sources of help in procuring equipment.

## **B4. EQUIPMENT MAINSTREAMING AND CONTRACTOR DEVELOPMENT**

This chapter first summarises the findings from Chapter B2 to B4. Where appropriate, recommendations have been provided.

### **B4.1 Demand and supply**

The equipment market demand and supply mechanism is functioning correctly, therefore no major initiatives to increase the volume of supply in the market should be considered.

The current level of equipment ownership is high among the Vietnamese and Cambodian contractors. A majority of the contractors in the two countries owned the main construction equipment. In spite of high equipment ownership the contractors also rent equipment.

The potential estimated equipment demand in Cambodia, Vietnam and Laos for the years 2007/8-2011/12 is high for conventional equipment (e.g. tipper truck, ride on deadweight roller) and moderate for low-cost equipment (tractor-towed technology).

### **B4.2 Manufacturing Capacity**

Vietnam's manufacturing capacity is broad and developing fast. There is no need to introduce any intervention that would discourage healthy market competition. Cambodia and Laos have a limited manufacturing base, but do locally modify some equipment (e.g. water bowsers). Such creative initiatives should be encouraged, but there is not need for mainstreaming interventions as such community driven initiatives tend to thrive on being able to fill a niche in the local economy.

### **B4.3 Barriers**

There are no significant barriers for the SSCs to enter the rural roads sub-sector in Vietnam and Cambodia. However, only a few SSCs are currently operating in Laos due to a multitude of factors. It is advised that the Government of Laos eases some of the constraints facing SSCs.

Many Cambodian contractors cited the inability to raise private capital as a major barrier in financing equipment purchase. Banks have recently been offering new products in Cambodia but the uptake has been slow. The major problem cited by the Vietnamese contractors was the strict credit conditions set out by banks. However, in spite of these barriers, no intervention is recommended because the equipment market is performing satisfactorily.

Many contractors and key informants felt that hire purchase agreements be introduced where contractors receive equipment built into a contract and the value of the equipment is deducted from the works payment. Contracting agencies should consider incorporating these into their programmes, but only in special cases where it is perceived that shortage of equipment could pose a problem in smooth project implementation.

Contractors felt that there were no supporting institutions (apart from banks) that could help contractors procuring equipment. Most contractors and key experts suggest that an effective contractors association be set up to support contractors. Such an initiative should be considered by the relevant ministry along with potential stakeholders.

## **PART C: TOWED GRADER MODULE**

## **C1. GRADER TYPES**

### **C1.1 Introduction to Graders**

A grader is an engineering machine used in road construction to set a smooth surface and create the correct shape and camber for a road. They 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. There are two general types of graders; motor graders (which provide their own power source) and towed grader (which require an external power source).

A typical motor grader has the engine and driver's cab situated above two axles at the rear, a third axle at the front and a large blade in between (Figure 7). A towed grader performs the same basic function but unlike a motor grader it requires a tractor to pull it. The most common arrangement is one axle at the rear. The towed grader is the predecessor of the motor grader and has been used for grading operations on unsealed roads since at least 1909 (Petts and Jones, 1991).

Tractors can be used for a multitude of activities both within the rural roads sub-sector (e.g. haulage, watering, compaction etc.) as well as in other industries (e.g. agriculture). Motor graders are a highly specialised piece of equipment and have higher productivity levels than towed graders. They can also perform other activities (e.g. shaping embankments and creating drainage ditches).

### **C1.2 Grader Types**

This section describes the most common grader technologies available in the region. Three motor graders (one small, one medium and one large sized) and two towed graders (the Simba and the DTW Cam-Grader) have been analysed.

#### **C1.2.1 Motor Graders (Large) (more than 180 HP)**

The information gathered from the equipment supplier survey indicates that large motor graders (over 180 HP engines) are available in the region. However, medium sized versions are the most common. The most typical large grader model in the region is the Komatsu 705A. The cost of new and the second-hand (5 years old) models are typically US\$ 160,000 and US\$ 105,000, respectively. They can be hired for approximately US\$ 4,000 per month (excluding operator wages). It has a 200 HP engine and weighs approximately 18 tonnes<sup>16</sup>.

Motor grader operators and key experts in the region have expressed their scepticism about the utility of such (heavy and large) machines for narrow rural roads. There was concern that machines of this size would not be able to turn efficiently and more importantly that the large weight may damage the roads. Overall it can be concluded that large motor graders are not suitable for rural road related roadworks.

#### **C1.2.2 Motor Graders (Medium Sized) (120 to 180 HP)**

The most common motor graders in the region are medium sized (between 120 to 180 HP). The equipment supplier survey shows that Chinese models (Changlin 165H) are the cheapest, starting at US\$ 75,000. However, models from Japan and the USA dominate the market. The most common model is the CAT 120H. The costs of a new and a second hand CAT 120H are

---

<sup>16</sup> See [http://www.komatsu.com/ce/products/motor\\_graders.html](http://www.komatsu.com/ce/products/motor_graders.html)

approximately US\$ 140,000 and US\$ 95,000 (5 years old), respectively. It weighs approximately 13 tonnes and has a blade width of 3.66 m.

Motor grader operators in Cambodia and Vietnam unanimously stated that a motor grader of such specifications was perfectly suitable for heavy and light grading on both gravel and earth rural roads.

### C1.2.3 Motor Graders (Small) (less than 120 HP)

Motor graders less than 120HP are often called ‘compact graders’. A survey of equipment suppliers in the three study countries indicate that these graders are not common and subsequently no models could be identified. There are only a few manufacturers producing motor graders of this size.



Source: [http://www.apelle.com/images/7222\\_ft.jpg](http://www.apelle.com/images/7222_ft.jpg)

**Figure 7: A Compact Motor Grader (LeeBoy 635)**

A typical model is the LeeBoy 635 (Figure 7). It has a 48HP Kobuta Diesel Engine, weighs approximately 3.6 tonnes and has a mouldboard width of approximately 2.5m.<sup>17</sup> A new LeeBoy 635 costs approximately \$60,000<sup>18</sup>, and a 5 year and 10 year old one costs approximately \$25,000 and \$50,000, respectively. The potential uses of these graders in the region have been discussed with experienced motor grader operators. They stated that these models had the same versatility of functions as large/medium motor graders and they would be useful in carrying out routine maintenance work on both gravel and earth rural roads. However, they may not be suitable for heavy grading work and would be impractical for roads wider than 10 metres.

---

<sup>17</sup> Information available at: <http://www.leeboy.com/uploadedFiles/635B%20Motor%20Grader.pdf>

<sup>18</sup> Factory gate price.

#### C1.2.4 Towed Graders (Medium Sized) (Simba)

The SIMBA (Figure 8) is manufactured in the UK in two sizes. The standard Simba RG3 version weighs 1.35 tonnes, costs US\$ 16,000<sup>19</sup> and requires a 70 hp tractor. There is also a heavy duty 4.4 tonne version (costs approximately US\$ 35,000). Three blade sizes are available: 3m, 3.5m and 4m. A Simba grader was imported by the Tertiary Road Improvement Project (TRIP) in Cambodia for a trial. Those involved in the trial claimed that it was not compatible with a 2WD agricultural tractor, which is common in rural areas. However, it is capable of performing light grading operations on both earth and gravel roads when it is used in combination with a 4WD tractor<sup>20</sup>.

Other towed graders of similar size include the Arthur Garden (2 tonnes) towed grader which has been produced in Zimbabwe since 1951. In the year 2000, the manufacturer produced their 2000<sup>th</sup> unit with an ex-works price of less than US\$ 8,000 (Gongera and Petts, 2000). No evidence has been found that Arthur Garden towed graders were used for roadworks in the SE Asia region.



Source: [www.simba.co.uk/roadgrader.php](http://www.simba.co.uk/roadgrader.php)

**Figure 8: The Simba Towed Grader**

#### C1.2.5 Towed Graders (Small) (Cam-Grader)

These graders are designed and produced by DTW, an international NGO in Phnom Penh (Figure 9). They were designed and produced in DTW workshops with the transfer of skills to local manufacturers in mind. The price is \$2,500 (2004 prices) and it requires a 30 hp (minimum) tractor. There are no hydraulic parts and many parts are made with spares from the locally ubiquitous Toyota Camri and therefore can be locally sourced. It has a 2.3 m blade width and is designed for a 4m carriageway to be cut in two passes. The equipment only weighs 0.88 tonnes.

Testing of the Mark I Cam-Grader was carried out in Takeo Province of Cambodia in 2003 and the findings were used to update the design for the Mark II grader. An evaluation of the Cam-Grader was carried out in Svay Rieng province in 2004. The operation of the grader was reported to be successful, produced a smooth regular camber at an estimated cost of \$20 per km and was relatively easy to turn whilst being coupled to a 2WD Kobuta L2801 35HP tractor.<sup>21</sup> The equipment is suitable for tight turns. It is light enough for the operator to

<sup>19</sup> See [www.simba.co.uk/roadgrader.php](http://www.simba.co.uk/roadgrader.php). c.i.f. price quoted by SIMBA in March 2007.

<sup>20</sup> Although the Simba did not receive a positive review by its user(s) on the TRIP trial project, the contractors did comment that it was capable of performing light grading operation on earth and gavel roads if the equipment was used properly (e.g. with a 4WD tractor)

<sup>21</sup> LCS Paper 19, Evaluation of Mark 2 Cambodia Light Grader, 2004

decouple the grader from the tractor, to lift the front of the equipment, to and turn the equipment on its (back) wheels.

A total of five were manufactured and operated under the TRIP 3 project. While talking to contractors on the use of these graders, it was found that they perceived the use of the graders problematic and did not expect to make further use of them. The apparent ineffectiveness of the Cam-Grader during these trials may be partly due to the contractors' use of inappropriate towing equipment (e.g. trucks instead of tractors), as well as applying the grader to an unsuitable road surface. The overwhelming consensus of the users of this equipment is that it can only satisfactorily perform light grading operations and only on earth roads.



**Figure 9: Cam-Grader**

### **C1.3 Summary Overview of Different Graders**

Table 11 shows an overview of different grading options. It can be seen that the cost of a grader may range from US\$ 2,500 to 160,000 (new) or US\$ 1,700 to 105,000 (second-hand, five years old). Motor graders fall into three main categories: large (>180 HP), medium (120-180 HP) and small (less than 120 HP). Only two types of towed graders are available in the region: the Simba and the Cam Grader. The only locally manufactured towed grader is the Cam-Grader. All of them are suitable for the grading of rural roads except large motor graders, which are inappropriate for use on rural roads due to their size. There is also reservation about the use of the Cam-Grader in the grading of rural roads with gravel surface. The small motorised grader is not locally available.

**Table 11: Overview of grading technologies**

| Variable                          |                                         | Motor Grader |            |            | Towed Grader   |                |
|-----------------------------------|-----------------------------------------|--------------|------------|------------|----------------|----------------|
|                                   |                                         | 180 HP +     | 120-180 HP | <120 HP    | >1 tonne       | < 1 tonne      |
| Typical model & brand             |                                         | Komatsu 705A | CAT 120H   | LeeBoy 635 | Simba          | Cam-Grader     |
| Weight (tonnes)                   |                                         | 17.62        | 12.65      | 3.5        | 1.35           | 0.88           |
| Power (HP)                        |                                         | 200          | 140        | 48         | -              | -              |
| Blade width (m)                   |                                         |              | 3.66       | 2.5        | 3 to 4         | 2.3            |
| Purchase cost (US\$)              | New                                     | 160,000      | 140,000    | 60,200     | 16,000         | 2,500          |
|                                   | Second-hand <sup>22</sup>               | 105,000      | 95,000     | 40,000     | 10,860         | 1,700          |
| Hire cost (US\$/month)            |                                         | 4,000        | 3,500      | 1,510      | 400            | 60             |
| Suitable for rural roads (earth)  |                                         | NO           | YES        | YES        | YES            | YES            |
| Suitable for rural roads (gravel) |                                         | NO           | YES        | YES        | YES            | NO             |
| No. of operators required         |                                         | 1            | 1          | 1          | 2              | 2              |
| Locally produced                  |                                         | NO           | NO         | NO         | NO             | YES            |
| Locally available                 |                                         | YES          | YES        | NO         | NO             | YES (Cambodia) |
| Supporting equipment              | Details                                 | None         | None       | None       | Tractor > 70HP | Tractor >35 HP |
|                                   | Cost (new), (US\$)                      | N/A          | N/A        | N/A        | 42,000         | 25,000         |
|                                   | Cost (second-hand) (US\$) <sup>23</sup> | N/A          | N/A        | N/A        | 17,000         | 10,000         |
|                                   | Hire (US\$/month)                       | N/A          | N/A        | N/A        | 1,800          | 1,500          |

Source: Equipment supplier interviews, Equipment manufacturers, Consultants estimates. Hire rates of the CAT 120H, Simba and Cam-Grader were derived from the Komatsu. Second-hand rates for the Simba and Cam-Grader were derived from the CAT 120H.

### C1.4 Chapter Summary

This chapter discussed grader types and their characteristics. From the review of different type of graders it appears that only medium and small motor graders and the Simba towed graders are appropriate for grading work on both earth and gravel rural roads. The Cam-Grader is not suitable for heavy grading work on rural roads. Large motor graders (above 180HP) are likely to be too cumbersome to be effectively used on rural roads.

<sup>22</sup> 5-year old

<sup>23</sup> Ibid

## C2. GRADER COST EFFECTIVENESS

### C2.1 Introduction

This chapter presents the grader operating costs. It first introduces the productivity rates of different graders, and then compares operating costs at varying levels of utilisation and commercial options.

### C2.2 Unit Grader Operating Costs

Two estimates have been made of the comparative operating costs of grading earth and gravel roads using motor graders and towed graders: one based on ownership of equipment and the other based on hire of equipment. The criterion for comparison is the cost per kilometre for each type which depends on the length and width of road graded per day. It was difficult to obtain consistent data on this from contractors as it is dependent on a number of factors including condition of the road surface, type of soil etc. The only data available for towed graders was from limited trials. However, no comparative data was available for motor graders. The comparison therefore used the data from Petts and Jones (1991) of 2km/day for a motor grader. Towed grader productivity was derived using the findings of a trial conducted by ITT in Kisii District, Kenya.<sup>24</sup> This trial found the productivity of the towed grader to be 90% of the productivity of the motor grader in light grading work. Table 12 below shows the productivity levels used in this study. These grader productivity rates were verified with grader operators in the region. Only light grading work was evaluated, because trials in Cambodia have shown that the towed grader is not suitable for tasks of greater difficulty. Large motor graders (above 180 HP) were not evaluated as they were considered unsuitable for grading small rural roads (discussed in Chapter C1).

**Table 12: Grader productivities (for light grading)**

| Variable                             | Motor Grader        |                 | Towed Grader       |                   |
|--------------------------------------|---------------------|-----------------|--------------------|-------------------|
|                                      | Medium (120-180 HP) | Small (<120 HP) | Medium (> 1 tonne) | Small (< 1 tonne) |
| Size                                 |                     |                 |                    |                   |
| Model                                | CAT 120H            | LeeBoy 635      | Simba              | Cam-Grader        |
| Productivity (Earth roads) (km/hour) | 0.4                 | 0.4             | 0.36               | 0.36              |
| Productivity (Gravel) (km/hour)      | 0.4                 | 0.4             | 0.36               | -                 |

Source: Petts and Jones (1991) and consultant's estimates

The cost-effectiveness of various equipment depends on the utilisation rate (number of hours used per annum). More productive and expensive equipment are more likely to be cost effective when utilisation rates are high. They are more likely to have higher utilisation capacities and will require less servicing. Jones and Robinson (1996) mentioned that in developing countries annual utilisation rates of equipment could be very low (often in the region of 200-500 hours per year). Evidence from contractor surveys has found that motor grader utilisation rates are typically 900 hours per year in Cambodia and Vietnam. The analysis below considers the cost effectiveness of the equipment for a range of utilisation levels.

<sup>24</sup> The trial results are unpublished. However, figures were provided by the project manager.

### C2.2.1 Grader Operating Costs: Purchased Equipment

Table 13 provides the grader cost estimates when the motor grader is used for 900 hours per year for light grading on rural roads (Appendix XIX provides details). Table 13 also provides cost per km figures. This facilitates a direct comparison between the towed and motor graders. The most cost effective equipment was found to be the Cam-Grader with a 2WD tractor. This conclusion remains valid whether the graders are used in combination with a new or a second-hand 2WD tractor. A new small motor grader is more cost effective than the Simba grader and a new 4WD tractor combination. However, the Simba grader with a second-hand tractor is slightly cheaper to operate than a second-hand small motor grader. The medium sized motor grader is less economically viable, either new or second-hand, for light grading on rural roads.

**Table 13: Grading costs after equipment is purchased and at a motor grader utilisation of 900 hours per year**

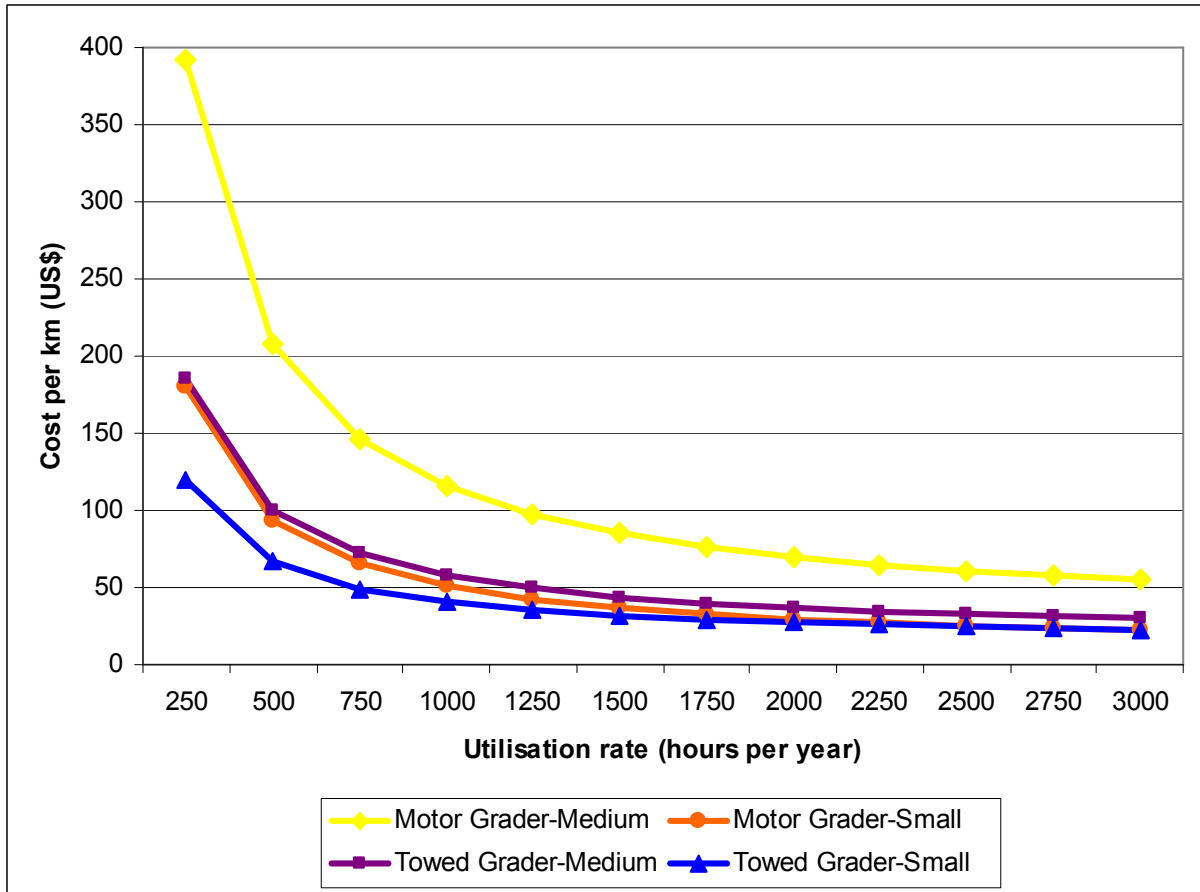
| New/Second-hand | Model & Brand             | Technology             | Size   | Operating Costs (US\$/hour) | Cost per km (US\$) |
|-----------------|---------------------------|------------------------|--------|-----------------------------|--------------------|
| New             | CAT 120H                  | Motor Grader           | Medium | 50.49                       | 126.21             |
| New             | Lee Boy 635               | Motor Grader           | Small  | 22.31                       | 55.78              |
| New             | Simba & Kobuta 9570       | Towed Grader & Tractor | Medium | 22.60                       | 62.77              |
| New             | Cam-Grader & Kobuta MX500 | Towed Grader & Tractor | Small  | 15.60                       | 43.33              |
| Second-hand     | CAT 120H                  | Motor Grader           | Medium | 49.32                       | 123.31             |
| Second-hand     | Lee Boy 635               | Motor Grader           | Small  | 21.49                       | 53.73              |
| Second-hand [a] | Simba & Kobuta 9570       | Towed Grader & Tractor | Medium | 18.44                       | 51.24              |
| Second-hand [a] | Cam-Grader & Kobuta MX500 | Towed Grader & Tractor | Small  | 13.09                       | 36.36              |

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

[a] For second hand options, the towed graders are purchased new with a second hand tractor.

Figure 10 and Figure 11 show the costs of grading at various utilisation rates when the equipment is purchased new and second-hand, respectively.

At low utilisation levels, small towed graders (e.g. the Cam-Grader) are the most cost effective option for light grading on rural roads when all the equipment is purchased new. However, as the utilisation rate approaches 2,000 hours per year, the small motor grader is as cost effective. The medium sized motor grader is not as cost effective as the small motor grader or either of the towed graders. Therefore, in the case of purchase of new items of equipment and low utilisation rates (<2,000 hours per year), the most cost-effective options are the Cam-Grader for earth roads and the small motor grader for gravel roads. At higher utilisation rates (>2,000 hours per year), the small motor grader is the most cost-effective option for both earth and gravel roads.



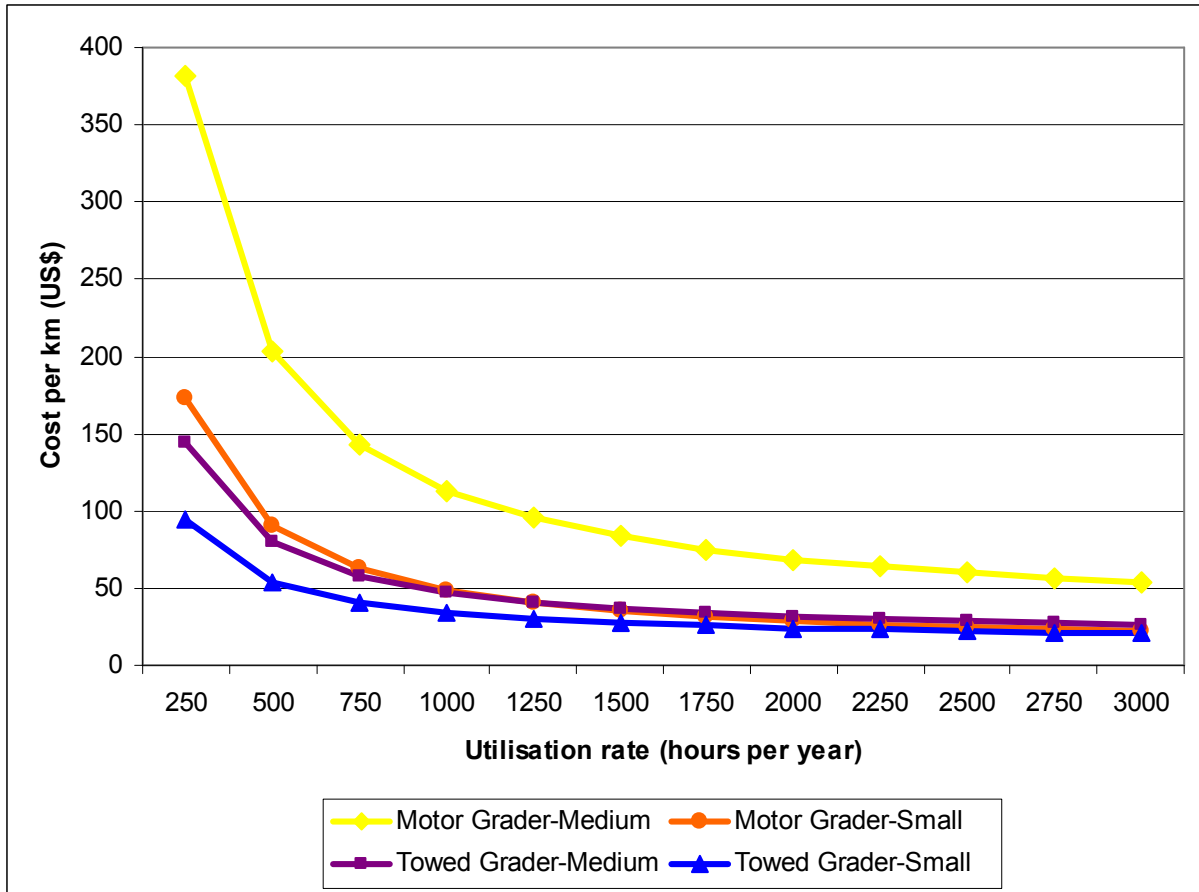
Source: Equipment supplier interviews, equipment manufacturers and consultant’s estimates

**Figure 10: Cost of grading (per km) when equipment is purchased new**

When equipment is purchased second-hand and utilisation levels are low, the Cam-Grader is the most cost effective option. However, as utilisation approaches 2,000 hours per year the small motor grader is almost as cost effective. The Simba towed grader is more cost effective than the small motor grader at low utilisation levels. The medium sized motor grader is the least cost effective option.

Based on this analysis, the most cost effective options are to use the Cam-Grader for earth roads and the Simba grader for gravel roads when the utilisation rate is low (less than 2,000 hours per year). For higher utilisation rate (more than 2,000 hours per year), the small motor grader is the most cost effective for both earth and gravel roads.

As the equipment cost models used input data that were collected from the region. Therefore, the margin of error in the estimation of unit operating costs is expected to be low.



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

**Figure 11: Cost of grading (per km) when equipment is purchased second-hand**

C2.2.2 Grader Operating Costs: Hired Equipment

Table 14 provides the grader hiring option cost estimates for utilisation rates of 2,000 hours per year (average of 170 hours per month). Appendix XX provides the detailed results. At such utilisation levels, the most cost effective equipment to hire is the small motor grader (e.g. Lee Boy 635). This analysis also holds for different utilisation rates: high as well as low (Figure 12). The Cam-Grader is more cost effective than the Simba. The medium sized motor grader is not economically viable under such circumstances.

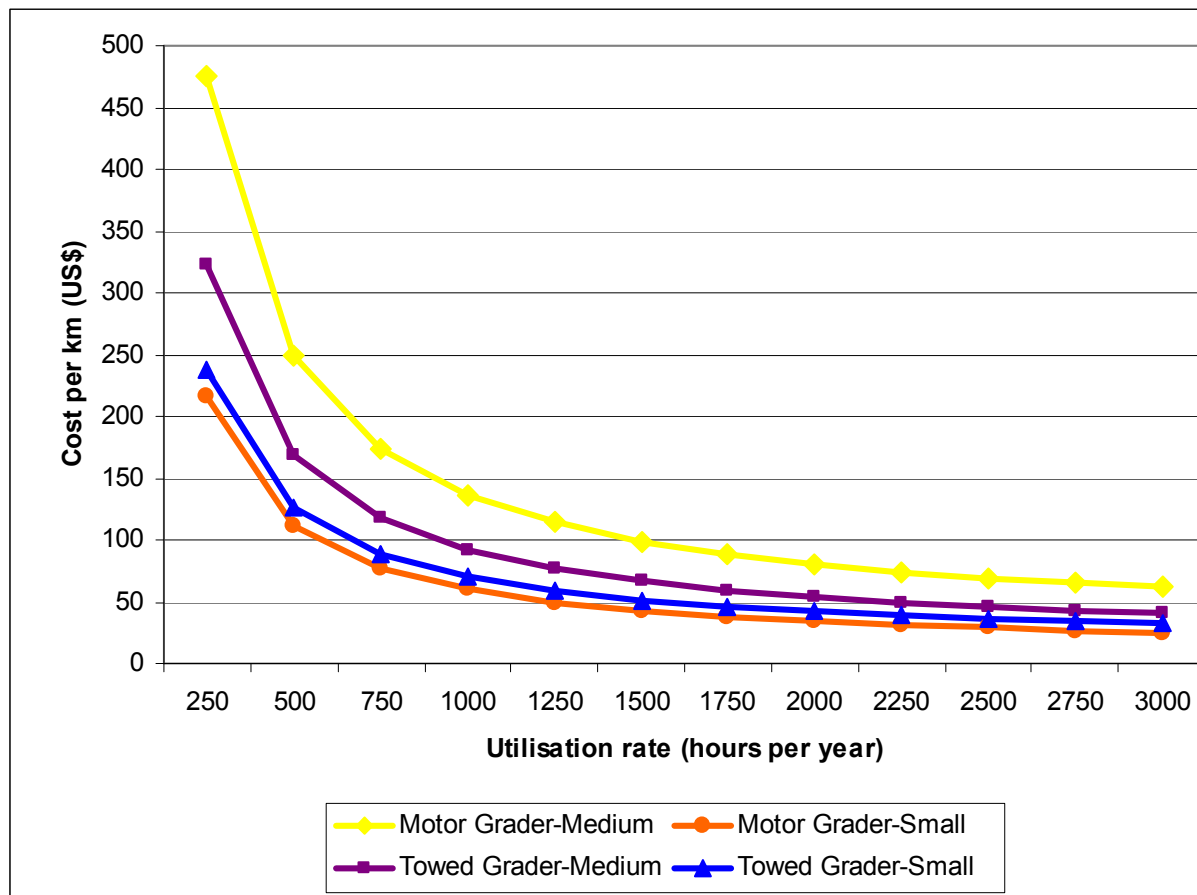
**Table 14: Grading costs after equipment is hired and at a motor grader utilisation of 2,000 hours per year**

| Model & Brand             | Technology             | Size   | Total Operating Costs (US\$/hour) | Cost per km (US\$) |
|---------------------------|------------------------|--------|-----------------------------------|--------------------|
| CAT 120H                  | Motor Grader           | Medium | 32.1                              | 80.4               |
| Lee Boy 635               | Motor Grader           | Small  | 13.6                              | 34.1               |
| Simba & Kobuta 9570       | Towed Grader & Tractor | Medium | 19.4                              | 53.9               |
| Cam-Grader & Kobuta MX500 | Towed Grader & Tractor | Small  | 15.1                              | 42.0               |

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

When hiring of equipment for grading (both earth and gravel roads) is considered as an option, the best strategy for the contractors is to use the small motor grader. In the absence of small motor graders the best option is to go for the Cam-Grader and the Simba for earth and

gravel roads respectively. However, because the hiring rates of some of the graders are hypothetical figures, there may be a higher margin of error associated with the results<sup>25</sup> when compared with the purchase option. Therefore, the results can be regarded as the best estimate based on the data available in the region.



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

**Figure 12: Cost of grading (per km) when equipment is hired**

### C2.3 Secondary Evidence of Grader Operating Costs

Information on the comparative costs and efficiency rates of towed and motor graders is not easy to find. Even where information is available, it is difficult to make a meaningful comparison between different studies because of varying assumptions. In many cases the assumptions are not clearly mentioned. Table 15 presents the findings on the cost of grader operations in different studies. Petts and Jones (1991) quote grading cost figures based on trials carried out in Kenya in 1987: motor grader – US\$ 182/km and towed grader – US\$ 97/km. Assumptions of Petts and Jones (1991) included: (i) owner-operated graders; (ii) 5 hour working day; and (iii) a working speed of 2km/hour. The towed grader that was analysed was a 2-tonne model typically used in Sub-Saharan Africa. Taking into account effects of inflation, equivalent costs at current prices would roughly be double<sup>26</sup>: \$364/km for the motor grader and \$194/km for the towed grader.

<sup>25</sup> It is possible that this may be larger than the difference in cost effectiveness between the small grade and the Cam Grader

<sup>26</sup> Assumed inflation of 4% per year

**Table 15: Estimated costs of grader operations quoted in different studies**

| Study                           | Towed Grader (US\$/km) |         | Motor Grader (US\$/km) |           |
|---------------------------------|------------------------|---------|------------------------|-----------|
|                                 | Small [a]              | Medium  | Small                  | Medium    |
| SEACAP 020 (2008) [b]           | 43 (36)                | 63 (51) | 56 (54)                | 126 (123) |
| Petts and Jones (1991)          | 97                     |         | 182                    |           |
| Intech Associates (2004)        | 20                     | N/A     | N/A                    |           |
| Lebo and Schelling (2001)       | 270                    |         | N/A                    |           |
| World Bank <sup>27</sup> (2006) | 51 - 205               |         |                        |           |

Notes: [a] Within bracket figures are for second-hand grader operations

[b] 900 hours/yr operation

A more recent World Bank paper (Lebo and Schelling, 2001) quotes a figure of US\$ 270 /km for Kenya at 2000 prices. This is equivalent to approximately \$340/km at today's prices. Intech Associates (2004) quotes a grading cost figure of US\$ 20/km (approximately US\$ 24/km at current prices) for the Mark I Cam-Grader.

From the above discussions making comparisons of grader operation costs between this study and other study results is not straightforward. The calculated cost ratio of towed grader versus motor grader operations using the figures quoted by Petts and Jones (1991) is 0.53. This is similar to the ratios from the current study which were between: 0.78 (small) and 0.50 (medium). The consistent conclusion from the above is that the costs of operations of towed graders are considerably lower than that of motor graders. The World Bank estimates that the cost of light grading is between US\$51 to 205 per km (average of US\$110 per km) and this is consistent with the findings presented in this report for utilisation rates between 500 to 2500 hours per year.

## C2.4 Grader Operating Costs Using Manual Labour

The cost of grading earth and gravel roads is approximately US\$120 using manual labourers (Appendix XXI provides further details on the assumptions used to derive this figure). Therefore the use of manual labourers will only be cost effective over grader machines if grader utilisation rates are low (approximately 250 hours per year or less).

## C2.5 Chapter Summary

If the annual requirement of road that requires grading is less than 100 metres, then the most cost effective option for a contractor is to use labourers, otherwise it is most cost effective to use a grading machine. The most cost-effective options of using graders are summarised in Table 16 for different utilisation rates.

**Table 16: 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            |

[a] For second hand options, the towed graders are purchased new with a second hand tractor.

<sup>27</sup> [http://siteresources.worldbank.org/INTROADSHIGHWAYS/Resources/rocks\\_2-3\\_statistics1.xls](http://siteresources.worldbank.org/INTROADSHIGHWAYS/Resources/rocks_2-3_statistics1.xls)

Costs were also compared using information from other studies. Although exact comparisons are difficult due to differing data and assumptions, the consistent conclusion is that the operating costs of towed graders, in general, are lower than that of medium sized motor graders. The ratio of the cost of towed graders operations to medium sized motor grader operations can be as low as 0.5. For the light grading or rural roads, small towed graders and small motor graders appear to be the most cost-effective options in most cases.

### C3. GRADER DEMAND AND SUPPLY

This chapter deals with the demand and supply situation in relation to the available graders. The evidence is mainly drawn from the contractors surveys conducted in Vietnam and Cambodia.

#### C3.1 Demand

##### C3.1.1 Assessment of Current Demand

Chapter B1 explains the difficulties associated with the estimation of equipment market demand. The study used information on the small-scale contractors' ownership and hiring level (contractor surveys generated such information) in the assessment of current market demand of graders. Table 17 summarises the ownership and hiring related information.

Motor grader ownership level was high among the Vietnamese contractors (78%) when compared with Cambodian contractors (44%). 44% and 23% of the Cambodian and Vietnamese contractors, respectively, were found to have hired motor graders in the 12 months before the survey. None of the contractors owned or hired a towed grader during the period.

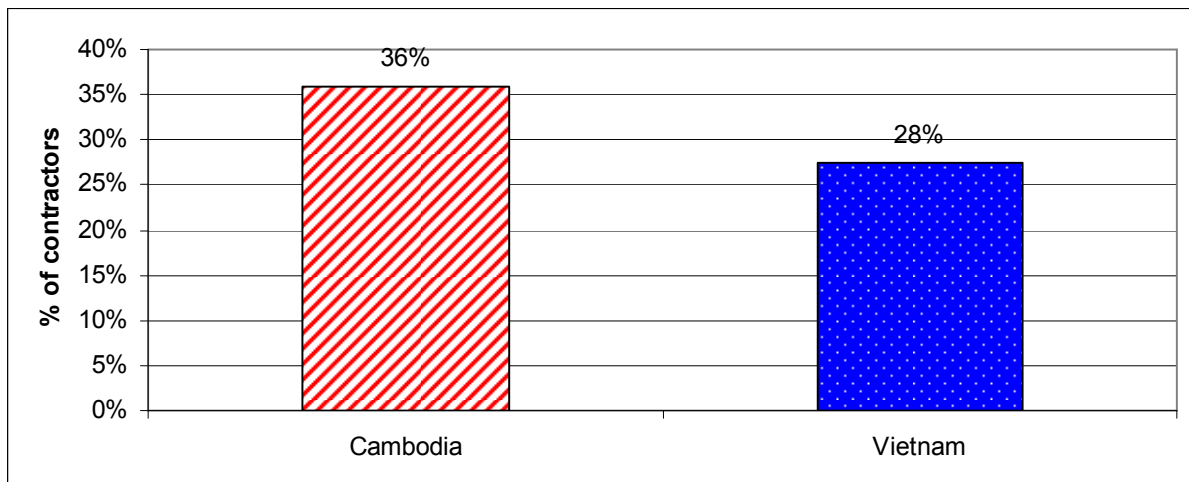
**Table 17: Contractors that own or have hired grader in the last 12 months**

| Equipment    | Percentage of contractors that own/hire[a] |          |          |          |          |          |
|--------------|--------------------------------------------|----------|----------|----------|----------|----------|
|              | Total                                      |          | Cambodia |          | Vietnam  |          |
|              | Own                                        | Hire     | Own      | Hire     | Own      | Hire     |
| Motor Grader | 61 (1.9)                                   | 37 (1.3) | 44 (1.5) | 51 (1.3) | 78 (2.1) | 23 (1.4) |
| Towed Grader | 0 (0)                                      | 0 (0)    | 0 (0)    | 0 (0)    | 0 (0)    | 0 (0)    |

Source: Contractor surveys

Note: [a] The values within brackets refer to the average number of equipment owned/hired per owning/hiring contractor

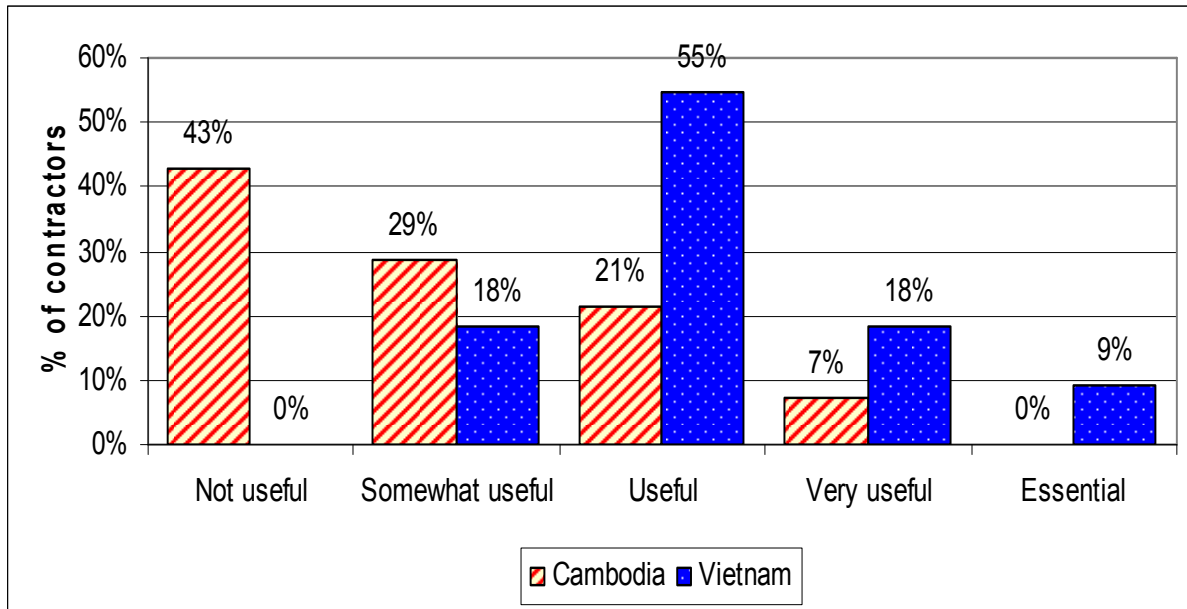
Approximately a third of Cambodian contractors and a quarter of Vietnamese contractors were aware of towed graders (Figure 13), therefore, awareness of towed graders were low. All the contractors that claimed to know about towed graders were correctly able to articulate its main functions.



Source: Contractor surveys

**Figure 13: Towed grader awareness (% aware)**

The Vietnamese contractors were found to be more favourable on the potential usefulness of towed grader (Figure 14). All of the Vietnamese contractors who were aware of towed graders believed that it has some level of usefulness. However, roughly 40% of the Cambodian contractors that were aware of the towed grader felt that it was not a useful item of equipment.

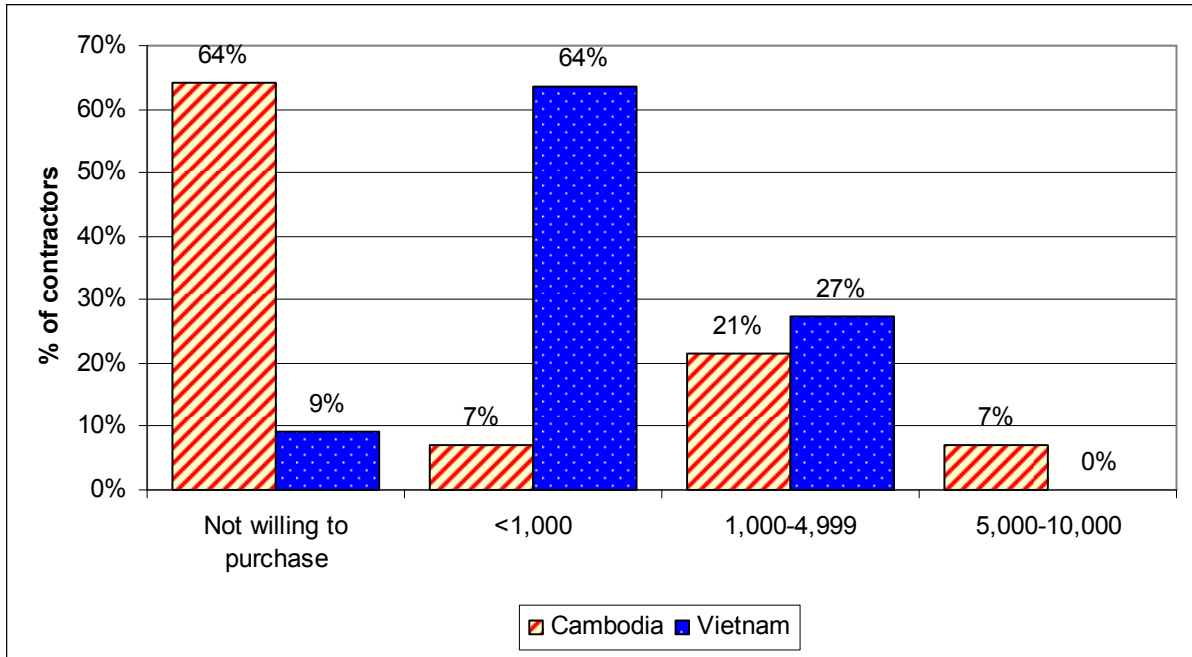


Source: Contractor surveys

**Figure 14: Towed grader usefulness**

Contractors who were aware of the towed grader were also asked whether they would purchase a towed grader<sup>28</sup> and if so how much they would be willing to pay for one (Figure 15). The majority of Cambodian contractors (roughly two thirds) would not be willing to purchase a towed grader. An overwhelming majority of the Vietnamese contractors (91%) who were aware of towed graders would be willing to buy one. However, approximately two out of three contractors, who were aware of towed graders, would only buy them if the purchase price was less than US\$ 1,000. This price is way below the price of the cheapest towed grader, the Cam-Grader (approximately US\$ 2,500). None of the Vietnamese contractors were willing to buy a towed grader for US\$ 5,000 or more. And only 7% of the Cambodian contractors would buy a towed grader if the purchase cost was between US\$ 5,000-10,000. There were no contractors who would buy a towed grader at a cost of over US\$ 10,000. This means that the cost of Simba (US\$ 16,000) is considerably higher than the price that any of the contractors would be willing to pay.

<sup>28</sup> They were not asked whether they would buy a tractor as well.



Source: Contractor's survey

**Figure 15: Contractors willing to purchase a towed grader and at what price (US\$)**

### C3.1.2 Assessment of Future Demand

The future equipment demand was again estimated using the projected rural road related roadwork volumes and productivity values of the appropriate equipment<sup>29</sup> (explained in Section B1.3.2). Table 18 presents the number of units that will be required to carry out the planned roadworks in the three countries. In the assessment of demand a number of assumptions apply (also explained in Section B1.3.2).

**Table 18: Annual requirement of equipment, number of units (2007/8-2011/12)**

| Equipment    | Cambodia | Vietnam | Laos |
|--------------|----------|---------|------|
| Motor Grader | 17       | 180     | 8    |
| Towed Grader | 10       | 274     | 8    |

Source: Contractor surveys

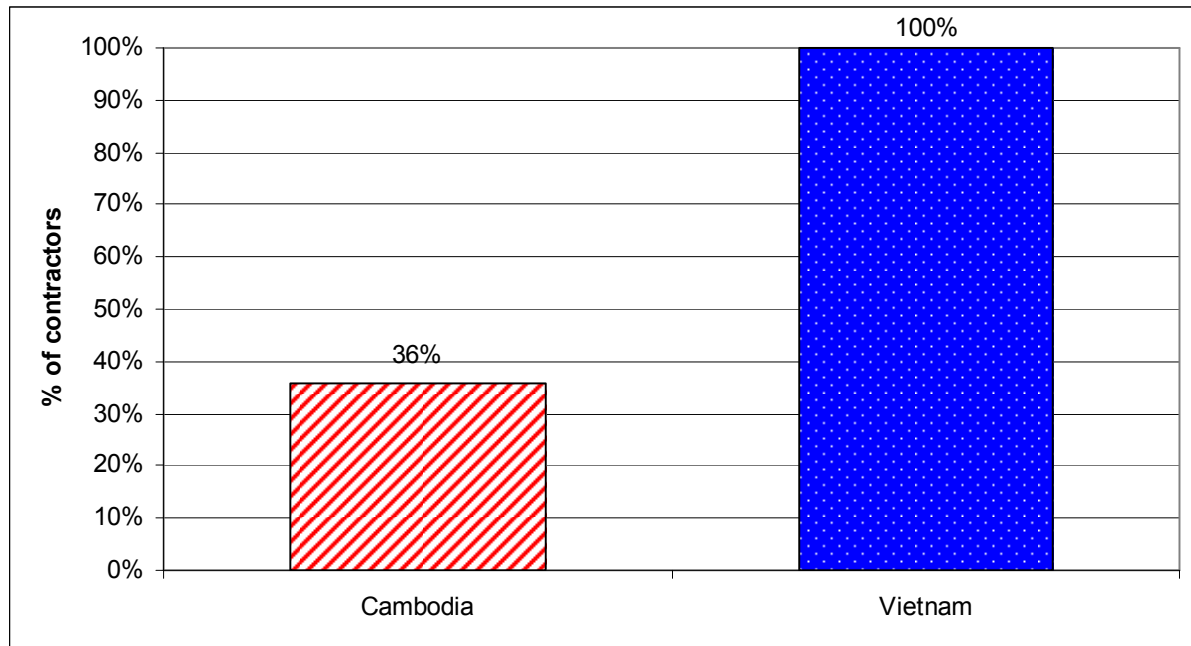
It can be seen from Table 18 that the potential future demand for towed graders is low in Cambodia and Laos, where the requirement is 10 and 8 units (respectively) per year to carry out roadworks linked to rural roads. Given the low demand for towed graders in Cambodia or Laos, it appears that any strategy that increases the supply of towed graders will not be required and would potentially be counter productive. The demand for towed graders is comparatively higher (over 270 units per annum) in Vietnam than in Cambodia and Laos, where there will be a high volume of rural road related projects. However, a total of 65 motor graders were owned by Vietnamese contractors who were interviewed in this study, and therefore, highly likely that on a national level SSCs involved in rural road related roadworks own the required number of motor graders (approximately 180 units annually). Therefore, in Vietnam strategies should not be aimed at increasing the supply of towed graders, but instead

<sup>29</sup> 0.4 km/hour for the motor grader. 0.36 km/hour for the towed grader. Please note that grader demand values were not subjected to an efficiency down-scale of 80%. Because the productivity values stated are regarded as being accurate. Please refer to Section B1.3.2 for further details

focused on inducing a shift in contractor demand from medium and large motor graders to small motor graders and towed graders.

### C3.2 Supply

Contractors who were aware of the towed grader were asked if they had adequate access if they required one. The results are provided in Figure 16. All Vietnamese contractors believed that there would be no supply constraints. However, these figures should be treated with caution as none of the contractors actively sought to acquire a towed grader. The figures only reflect the contractors' perceptions on towed grader availability.



Source: Contractor's survey

**Figure 16: Contractor's who state they have adequate access to the towed grader**

Design Technology Workshop (DTW) is the only manufacturer of towed graders in Cambodia, Vietnam and Laos that the authors are aware of. DTW have manufactured a total of five units so far. None of the equipment suppliers interviewed sold a towed grader. It can be concluded that there are only a few units in Cambodia, Vietnam and Laos. Moreover, the current demand for towed graders appears to be limited (see Table 17).

This analysis has been corroborated by key informants, the vast majority of which felt that if a contractor required a towed grader they could access one, but few wish to acquire one.

Motor graders on the other hand are ubiquitous in the region. There are ample suppliers of motor graders in Cambodia, Vietnam and Laos (see Appendix XXII). Among the three countries, Vietnam has the broadest manufacturing base. However, Vietnam is facing stiff competition from China which has recently been introducing cheap equipment into the region. Many key experts and contractors claim that Vietnamese equipment is not as cost effective as the Chinese versions. This is having a negative effect on Vietnamese manufactures. For instance, 1-5 Machinery Company, a Hanoi based Vietnamese manufacturer, has stopped the production of motor graders.

### C3.3 Tractor Capacity

Evidence from the contractor surveys (Table 19) shows that a very small proportion of contractors own or hire the 2WD tractor (5% and 0% of the interviewed contractors in Cambodia and Vietnam, respectively). However, over 20% of Cambodian and 8% of Vietnamese contractors own at least a 4WD tractor. Some of the contractors have also hired 4WD tractors in the 12 months previous to the interview. Overall, one in ten contractors hired 4WD tractors.

**Table 19: Contractors that own or have hired tractors in the last 12 months**

| Equipment      | Percentage of contractors that own/hire[a] |        |          |        |          |       |
|----------------|--------------------------------------------|--------|----------|--------|----------|-------|
|                | Total                                      |        | Cambodia |        | Vietnam  |       |
|                | Own                                        | Hire   | Own      | Hire   | Own      | Hire  |
| Tractor 2WD    | 3 (1.5)                                    | 0 (0)  | 0 (0)    | 0 (0)  | 5 (1.5)  | 0 (0) |
| Tractor 4WD    | 14 (1.4)                                   | 10 (1) | 21 (1.5) | 15 (1) | 8 (1)    | 5 (1) |
| Tractors (All) | 16 (1.4)                                   | 10 (1) | 21 (1.5) | 15 (1) | 13 (1.2) | 5 (1) |

Source: Contractor surveys

Note: [a] The values in brackets refers to the average number of equipment owned/hired per owning/hiring contractor

Contractors were also asked whether they have had any difficulty acquiring tractors and the results are shown in Table 20. It is evident that contractors have not experienced major difficulties in acquiring tractors. Only a few contractors in Vietnam (3%) found it difficult to acquire 4WD tractors. It is concluded that although ownership and hiring rates of tractors are only low to moderate, there are no supply constraints of tractors in Cambodia and Vietnam. This finding is corroborated by key informants who stated that there were no constraints in tractor supply.

There are number of outlets that supply tractors in Cambodia, Vietnam and Laos (Appendix XXII presents a non-exhaustive list).

**Table 20: Contractors facing difficulty in acquiring tractors**

| Equipment      | Percentage of contractors that have had difficulty acquiring |          |         |
|----------------|--------------------------------------------------------------|----------|---------|
|                | Total                                                        | Cambodia | Vietnam |
| Tractor 2WD    | 0                                                            | 0        | 0       |
| Tractor 4WD    | 1                                                            | 0        | 3       |
| Tractors (All) | 1                                                            | 0        | 3       |

Source: Contractor surveys

### C3.4 Chapter Summary

This chapter presents the findings of demand and supply of graders in Vietnam and Cambodia. The motor grader ownership level is high among Vietnamese contractors (78%) and Cambodian contractors (44%). None of the SSCs either owned or hired a towed grader in the 12 months prior to interviews. However, more Cambodian contractors hired motor graders (44%) than Vietnamese contractors (23%). This shows that there is considerable demand for motor graders in overall terms. Only a small proportion of the contractors in the two countries were even aware of towed graders. Cambodian contractors were found to have slightly higher level of awareness than their Vietnamese counterparts.

The potential future demand linked to the anticipated rural roadworks, for towed graders is low in Laos and Cambodia. The demand for towed graders is much higher in Vietnam. However, it appears that there is adequate equipment supply to meet the projected demand.

Therefore, no outside intervention that increases supply is warranted. Rather it is recommended that the contractors' awareness in relation to the benefits of using small motor graders and towed graders be raised. Such an action would encourage a demand shift from medium and large motor graders to small motor graders and towed graders.

## **C4. GRADER COMPARATIVE ASSESSMENT**

### **C4.1 Viability**

The Simba and small to medium sized motor graders are appropriate equipment for light grading on rural roads, while the Cam-Grader is only appropriate for earth surfaces. Large motor graders are generally not considered appropriate for use on small rural roads.

### **C4.2 Cost**

The cost of purchase of the cheapest towed graders and tractors (new 2WD) is US\$ 2,500 and US\$25,000 respectively. The hiring cost of tractors in the study countries is approximately US\$1,500 per month. The costs of motor graders start from US\$ 60,000. Large and medium sized motor graders can be hired for US\$ 4,000 and US\$ 3,000 per month, respectively. The study found no evidence of small motor graders, the Simba or the Cam-Grader, available for hire or for purchase second-hand in the region.

At low utilisation rates (less than 2,000 hours per year) the most cost effective option is:

- the Simba for gravel roads (when equipment is purchased new);
- the small motor grader for gravel (when equipment is purchased second-hand); and
- the Cam-Grader for earth roads

At high utilisation rates (2,000 hours per year or more) the small motor grader is the most cost effective option.

If equipment is being hired, then the small motor grader is the most cost effective option at all utilisation rates.

The medium sized motor grader is not a cost effective option for light grading on rural roads.

### **C4.3 Demand and Supply**

Motor grader ownership is high and towed grader ownership and awareness amongst contractors is low. Most contractors are not willing to pay more than US\$ 1,000 for one or are not willing to purchase one at all. It can be concluded that the current demand for towed graders is low. Approximately 10 towed grader units are required annually to implement the rural roadwork requirement over the next 5 years in Cambodia and Laos. Therefore it can be concluded that future potential demand is low. Over 270 units of towed graders are required in Vietnam.

### **C4.4 Recommendations**

The small motor grader and towed graders are viable equipment for rural roads as well as being competitive in terms of costs. However, as the anticipated rural roadworks in Cambodia and Laos require few units of towed graders, it is not recommended that any mainstreaming initiative be introduced. This can have the effect of distorting the market for grading equipment. Towed grader demand is significant in Vietnam; however, contractors are already able to meet the equivalent grading capacity using the existing stock of motor graders. It is therefore recommended that the favourable attributes of small motor graders and towed graders be disseminated between contractors and equipment suppliers so that they are aware of the potential benefits of their use. This may encourage a demand shift to smaller and intermediate equipment among contractors in the rural road sub-sector which can produce significant efficiency gains.

**PART D: MOBILE SMALL-SCALE STONE CRUSHER  
MODULE**

## **D1. STONE CRUSHING TECHNOLOGIES**

This chapter introduces the main issues involved in crushing stone and rock. The main stone crushing technologies are also discussed. Some more details are provided in Appendix XXVI.

### **D1.1 Advantages and Uses of Crushed Stone and Rock**

The use of crushed rock or gravel (aggregate) as a construction material has a number of advantages over naturally occurring stone and gravel including: (i) allows better packing together than the more rounded particles that tend to be found in natural materials. This results in improved strength; (ii) allows better control over aggregate mixes to meet standards and specifications; (iii) provides more surface area that improves the cement concrete strength; and (iv) crushed material is free from silts and clayey-like fines found in natural materials that are detrimental in achieving the desired construction quality. In summary, the use of crushed aggregate in construction as opposed to the uncrushed aggregate results in a much stronger final material.

There are three main uses for crushed aggregate in construction. They can be used as a base and sub-base for paved roads for improved drainage and strength. When mixed with bitumen they provide a hard-wearing surface for bituminous road. Crushed material may 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 that provides strength and hardness in concrete. The aggregate can also be generated by recycling construction waste material (Appendix XXIV and XXV provide more details on recycling construction rubble)

### **D1.2 Sources of Crushed Stone and Rock**

There are a number of approaches to sourcing crushed stone and rock: they can be broken manually or using a mobile crusher and can also be purchased from a commercial quarry.

Excavating suitable stone or rock and manually breaking it to the required size is known as hand knapping. Typically a person can break approximately 0.1 tonne (0.035cu.m) of hard rock or stone per 8 hour day (Mitchell and Mwanza, 2005). For a layer thickness of 30cm this is equivalent to an area of roughly 0.12 m<sup>2</sup> per day per person. For a 6m wide paved road it will require 48 person days for the construction of a metre length of the road pavement. Apart from the requirement of large labour force, quality control is also a significant issue with hand knapping.

The other extreme is the purchase ready-crushed material from a commercial quarry. Commercial quarries are common in all the three study countries. However, they may not be located close to the construction site and the contractors may incur considerable costs in transporting the crushed stone or rock to the site. This however, can be the most convenient option for contractors as it does not require any investment in machines or personnel. Other advantages can be a more consistent quality and the availability of a range of stone sizes.

An intermediate solution for SSCs is to own or hire a mobile stone crusher to produce aggregate on the construction site. However, the cost-effectiveness of this option is dependent on the closeness of the stone or rock sources. Another important issue affecting the cost is whether the contractor has to pay any fee for extracting the material. Mobile crushers may also be used to produce aggregate from recyclable construction waste (e.g. concrete). This is

most likely to be feasible if construction sites that are located close to urban centres where recyclable material is most available. This process also avoids waste material disposal costs.

### D1.3 Deployment of Crushers

Crushers can either be deployed at the source of the raw material or at the construction site. Both the options involve a number of steps that are listed below:

#### Crush at source

- Excavation of material
- Breaking material into sizes that can be fed into a crusher
- Transportation of broken material to crusher
- Loading material into crusher
- Transportation of crushed material to construction site
- Dumping crushed material at working area

#### Crush at construction site

- Excavation of material
- Breaking material into sizes that can be fed into a crusher
- Transportation of broken material to construction site
- Dumping broken material at construction site
- Loading material into crusher
- Dumping crushed material at working area

The identified activities may be carried out manually or using equipment (e.g. the use of a front end loader). To determine the best solution, it is necessary to evaluate both the options carefully. There are a number of operational issues involved. For example, the weight of the rocks that can be fed into the upper end of mobile crushers can only be up to 100kg.

An important issue linked to the sourcing of crushed stone is that a permit is required in order to mine natural resources in all three countries. The process of acquiring a permit can be long and difficult. Key informants in Vietnam informed that it could take 1-2 years to acquire a permit as the process involves a number of ministries (e.g. Ministries that deal with the issues of labour, finance, environment and natural resources etc.). However, most key informants stated that small scale extraction of minerals without a permit was generally tolerated by the authorities, especially when quarrying very small volumes of river or hillside gravel without intense operations such as blasting.

### D1.4 Stone Crushing Technologies

#### D1.4.1 Crusher types

There are two basic varieties of crusher technology: (i) **impact machines** where material is broken by impact against a hard surface; and (ii) **crushing machines** where two surfaces open and close cyclically to trap and crush the material. Again there are two types of impact machines:

- **impact crushers** in which the lumps are picked up by a rotating mechanism and flung at high velocity against a fixed hard surface where they shatter; and
- **hammer mills** in which the lumps are broken up by flailing hammers.

Impact crushers are particularly suited to hard brittle materials. They are the most energy efficient type of crusher. However, the machines need to be large to absorb the impacts and vibration. They are not generally used as mobile machines.

There are two main types of crushing machines:

- **cone crushers** in which the material is fed into a conical cylinder and an eccentric mechanism rotates to crush the material against the inner face of the cone. As the material drops down inside the cone, the gap gets smaller so it is crushed into smaller

pieces. The gap at the outlet is controlled to obtain the required size of crushed material.

- **jaw crusher** in which the material is fed into the gap between a fixed jaw and an oscillating jaw. As the material drops down between the jaws the gap gets smaller. This helps in crushing the material into smaller pieces. By controlling the gap at the outlet of the jaws the required aggregate size can be obtained.

Both types of crushing machines involve considerable scraping between the movable member and the material being crushed. Therefore, the power requirements and wear of the crushing members are greater than for impact machines. The crushing machines are likely to produce material which is more uniform in size and shape than impact machines. These types are also most suitable as small-scale mobile crushers given their simple design and smoothness in operation.

Among the crushing machines, the jaw type has the simplest crushing mechanism. Cone crushers tend to be larger and heavier. Therefore, they are less suitable. The contractor survey revealed that all the mobile crushers owned by the Vietnamese contractors were of the jaw crusher variety.

#### D1.4.2 Jaw crushers

Figure 17 shows the details of a typical jaw crusher. It is a machine comprising a diesel engine or electric motor that drives an eccentric shaft through a belt drive. The eccentric shaft moves the reciprocating jaw backwards and forwards against the fixed jaw to crush the stone or rock. A large flywheel smoothes out the drive power. The mechanical design is simple and straightforward to maintain.

Jaw crushers are generally smaller in size than other types of crusher and this makes them the most suitable as mobile units. The typical unit, shown in Figure 17, can easily be transported to the operational site using a truck or a trailer. Usually mounting the crusher on a trailer for towing is the best option for moving a crusher to and around a site in the region.

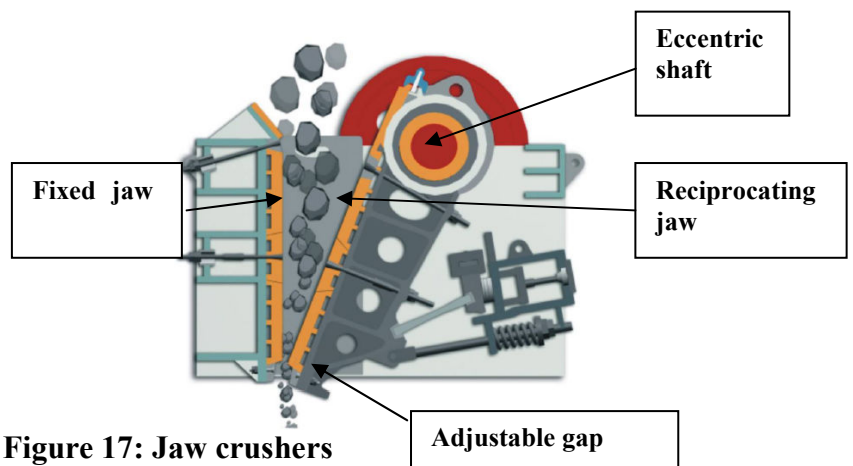


Table 21 provides details of typical jaw crushers. The types of small mobile stone crushers encountered in the region are manufactured by Hoa Phat and Shibang. Hoa Phat is based in Vietnam and Shibang is a Chinese based company. Approximately half of the crushers owned by the surveyed contractors are Hoa Phat models (generally purchased new) and the other half being crushers of Chinese origin (generally purchased second-hand). The most common model was Hoa Phat's NHHP-PEX215. (see Appendix XXIII). Internationally, Red Rhino, a UK based company, produces the 4000 and 5000 Series crushers. However, they are

significantly more expensive (Figure 18). New Dawn Engineering (NDE), a Swaziland based company, also produces a manually operated mobile crusher (Pemberton-Pigott, 1997). The cost of this machine, however, is more expensive than Hoa Phat's smallest model, which is diesel powered.

**Table 21: Typical jaw crushers**

| 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                   |
| 4000, Red Rhino              | UK                | 45,000       | 1.5             | 150*400                   |
| 5000, Red Rhino              | UK                | 65,000       | 2.9             | 200*500                   |
| Rock Crusher (manual) ,NDE   | Swaziland         | 1,650        | 0.2             | 150*150                   |
| Rock Crusher (electric) ,NDE | Swaziland         | 3,650        | 0.2             | 150*150                   |

Source: Hoa Phat, Shibang, Red Rhino



Source: <http://www.redrhinocrushers.com/index.aspx>

**Figure 18: Red Rhino 4000**

The primary maintenance problem of jaw crushers is the wear of the jaws. This results from the high pressure grinding action with the stone or rock. In order to minimise this problem, the jaws need to be very hard but also adequately tough to avoid fracture. This requires a high-cost alloy steel with sophisticated heat treatment facilities. This would not be possible locally due to the high cost. However, a trade-off needs to be made between cost and life of the jaws. Table 22 compares jaws for crushers made in Vietnam and one made in the UK. Table 22 shows that the running cost of the cheaper local jaws is almost a tenth of the longer life jaws. However, contractors in Vietnam reported that the average life of the local jaws was only 215 hours. This is considerably lower than the 1,200 hours claimed by the manufacturer, (see Appendix XXIII). This increases the unit operating cost from US\$13 to US\$73 per 100 hours. The re-calculated unit operating cost is still approximately a half of the operating cost of longer life jaws. This means that although jaws have a short life, they are more cost-effective. Other advantages of the local jaws include their wider availability in the region and the ease with which they can be changed.

**Table 22: Comparative Costs of Crusher Jaws**

| <b>Brand of Crusher</b> | <b>Country of Origin</b> | <b>Stated life of Jaws (Hours)</b> | <b>Cost of Replacement Jaws (US\$)</b> | <b>Cost per 100hrs of Operation (US\$)</b> |
|-------------------------|--------------------------|------------------------------------|----------------------------------------|--------------------------------------------|
| NHHP-PEX215             | Vietnam                  | 1,200                              | 156                                    | 13                                         |
| Red Rhino 4000          | UK                       | 2,000 to 2,500                     | 3,000                                  | 133                                        |

Source: Hoa Phat, Phantom

### **D1.5 Chapter Summary**

Crushed rock or gravel offers a number of advantages over naturally occurring stone or gravel. The main uses of crushed aggregate in the construction industry are for use in paved and gravel roads and in concrete works. Contractors can obtain the crushed materials using three different options: (i) breaking stones manually (hand knapping); (ii) purchasing from a commercial quarry; and (iii) using a mobile crusher.

There are many different types of crushing technology. Jaw crushers are the most suitable for SSC as they are smaller and lighter than other alternatives. The main producer in the region is Hoa Phat. It produces three types of mobile crushers. Their costs range between US\$1,400 to US\$4,300. In addition, Shibang models from China are also common. The primary maintenance problem of mobile crushers is the replacement of jaws. The local jaws seem to be more cost effective than their foreign counterparts.

## D2. MOBILE CRUSHER COST EFFECTIVENESS

In this chapter the economics of mobile stone crushers are evaluated. This is done by comparing the costs of using mobile crushers against alternative methods: (i) crushing the stone manually; and (ii) purchasing aggregate from government or commercial quarries.

The evaluation is carried out for three sizes of jaw crushers produced in Vietnam by Hoa Phat. These models are similar to that shown in Figure 17. The specifications of the three crushers are provided in Appendix XXVII.

### D2.1 Mobile Crushers

The cost-effectiveness of equipment depends on several factors, including utilisation rates (number of hours used per annum). More productive and expensive equipment is more likely to be cost effective when utilisation rates are high. In developing countries, annual utilisation rates of equipment can be very low (Jones and Robinson, 1996). The evidence from the contractor surveys for this study shows that average mobile crusher utilisation rates are approximately 1,000 hours per year in Vietnam. However, the analysis of the cost effectiveness of the equipment is conducted in this study for a range of utilisation levels.

#### D2.1.1 Equipment purchase

Table 23 provides the mobile crusher operating cost estimates for a utilisation rate of 1,000 hours per year. Appendix XXVIII provides the detailed analysis results. Table 23 also contains the cost per unit volume of output. This facilitates a direct comparison between the mobile crushers with other viable alternatives.

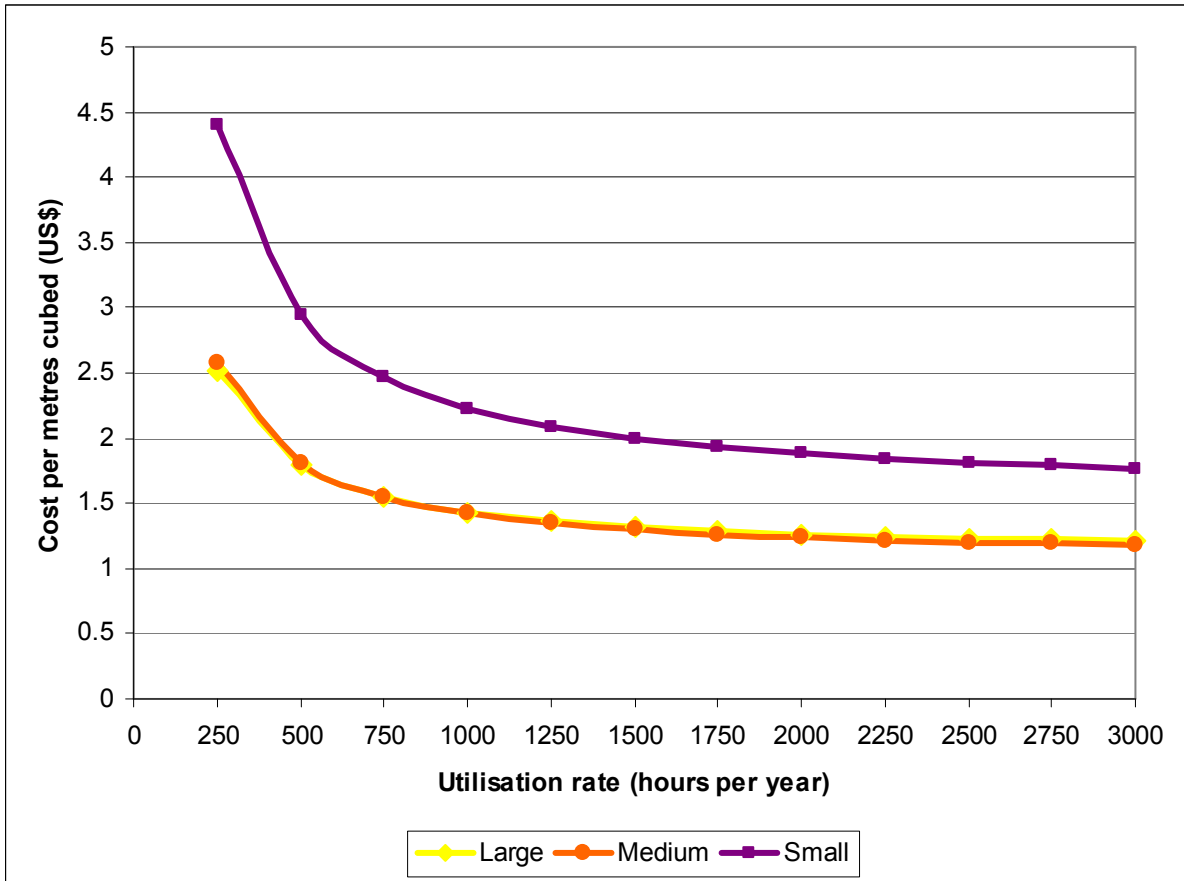
**Table 23: Mobile crusher cost when utilised for 1000 hours per year (equipment purchase)**

| Model & Brand         | Size   | Total Operating Costs (US\$/hour) | Cost per m <sup>3</sup> (US\$/hr) |
|-----------------------|--------|-----------------------------------|-----------------------------------|
| NHHP-PEX215, Hoa Phat | Large  | 8.50                              | 1.43                              |
| NHHP-PEX175, Hoa Phat | Medium | 6.39                              | 1.42                              |
| NHHP-PEX15, Hoa Phat  | Small  | 4.46                              | 2.23                              |

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

The small mobile crusher is the cheapest to run in terms of cost per hour as the fixed (e.g. depreciation, interest etc.) and variable costs (e.g. fuel, maintenance etc.) are lower for a smaller machine.

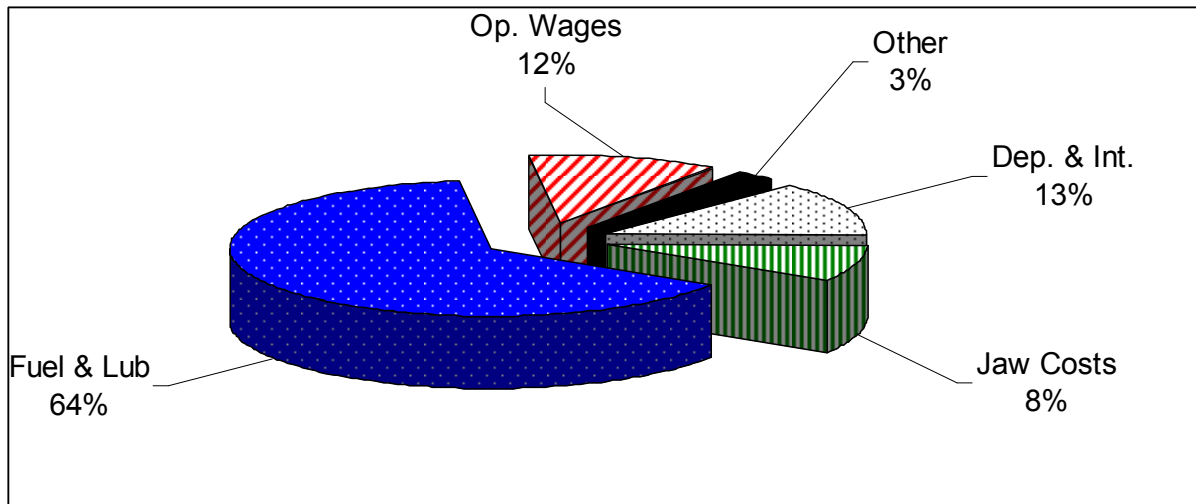
However, when the basis of comparison is the amount of output (cost per cubic metre), the small mobile crusher is found to be considerably more expensive than its larger counterparts. For utilisation rates of 1,000 hours per year, the most cost effective crushers are the large and medium sized mobile crushers. These have almost the same cost per cubic metre of crushed stone at US\$1.43 and US\$1.42 per cubic metre respectively. Over a range of utilisation rates, the cost effectiveness of the medium and large sized mobile crushers are virtually the same (see Figure 19).



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

**Figure 19: Mobile crusher operating costs (equipment purchase) (US\$/m<sup>3</sup>)**

Figure 20 shows the proportion of different operating cost components of a large Hoa Phat mobile crusher. The fixed ownership costs (depreciation cost plus the interest payment cost) represent 13% of the total operating costs. The majority of costs are variable costs. Costs linked to fuel and lubrication comprise approximately two-third of the overall operating costs (64%). The costs of jaw replacement are also significant (8%). This illustrates an important cost difference between mobile stone crushers and other items of equipment. For most items of construction equipment, ownership costs are around 50% or more of the total operating costs. For example, a study in Mozambique calculated that the depreciation and interest costs of a motorised roller (5 tonnes) form 58% of the overall operating costs (ITT, 2003). Similarly, Petts and Jones (1991), based on evidence from Kenya, calculated the depreciation and interest costs of a motor grader at 56% of the overall operating costs.



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

**Figure 20: Mobile crusher (large, NHHP-PEX215) operating cost when utilised for 1,000 hours/year**

#### D2.1.2 Equipment hire

Contractor survey results indicate that only two Vietnamese contractors (5% of sample) hired a mobile crusher in 12 months prior to the interview. In both cases, the contractors hired from other contractors on a basis that did not equate with normal market prices. Also this study could not identify an equipment supplier that rented mobile crushers out. For this reason hiring rates for mobile crushers could not be ascertained empirically. However, the Red Rhino 4000 and 5000 series crushers are currently being rented out in UK for approximately US\$200 and \$400 per day, respectively. This equals an average monthly hire to purchase ratio<sup>30</sup> of approximately 0.10. This evidence has been used to derive the monthly hire rates for the three Hoa Phat mobile crusher models (Table 24). Table 24 also shows the overall rental operating costs of the three mobile crushers for a utilisation rate of 2,000 hours per year (approximately 170 hours per month). Appendix XXIX provides the detailed analysis. At such utilisation rates, the medium sized crusher was calculated to be the most cost effective at US\$1.39 per cubic metre crushed stone.

**Table 24: Mobile crusher rental rates and operating costs for average annual utilisation rates of 2,000 hours**

| Model & Brand        | Size   | Rental rates (US\$/month) | Total Operating Costs (US\$/hour) | Cost per m <sup>3</sup> (US\$) |
|----------------------|--------|---------------------------|-----------------------------------|--------------------------------|
| Hoa Phat NHHP-PEX215 | Large  | 427                       | 8.68                              | 1.45                           |
| Hoa Phat NHHP-PEX175 | Medium | 257                       | 6.26                              | 1.39                           |
| Hoa Phat NHHP-PEX15  | Small  | 143                       | 4.17                              | 2.08                           |

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

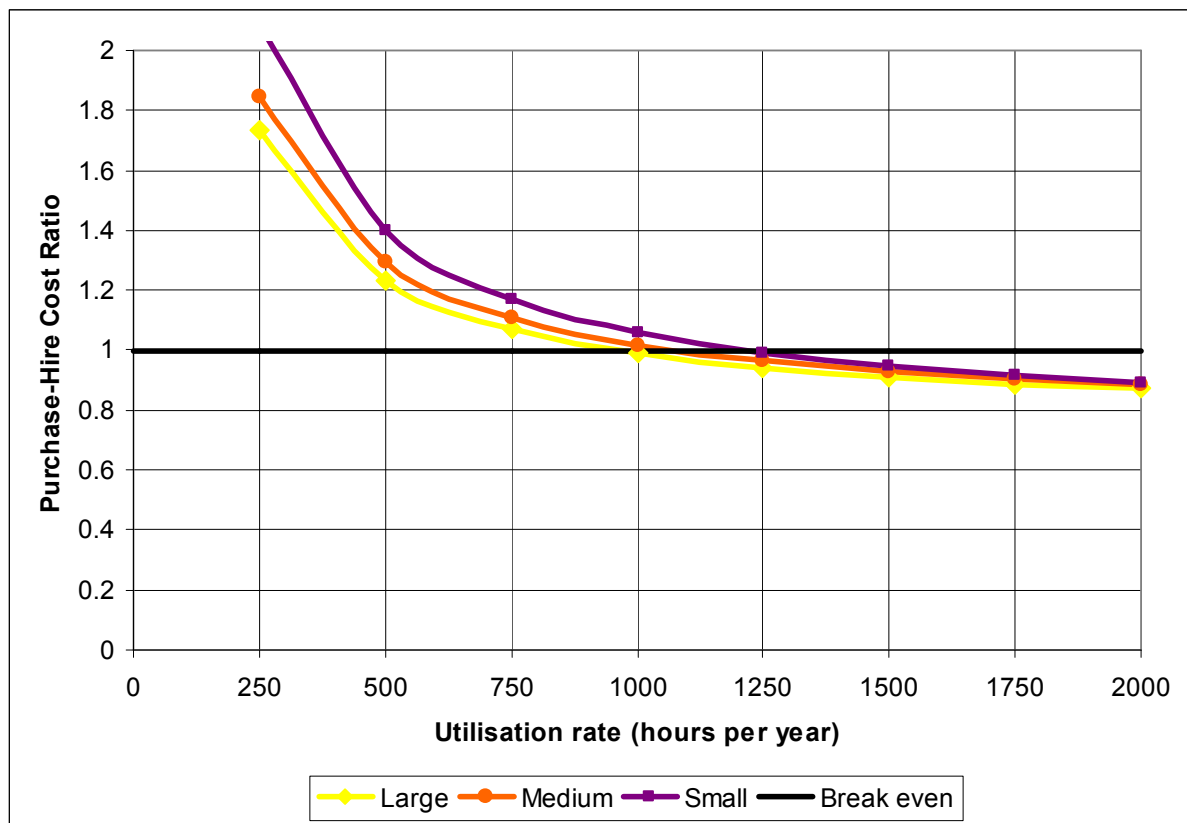
#### D2.1.3 Comparison between equipment purchase and hire

Figure 21 presents a comparison between the cost of purchasing and hiring a mobile crusher (in cubic metre terms). It presents the ratios of the cost of purchasing at utilisation rates varying between 250 and 2,000 hours per annum against the cost of hiring at a utilisation rate

<sup>30</sup> Based on 20 working days per month

of 2,000 hours per annum, a rate which reflects the approximate rate of constant annual usage<sup>31</sup>. The analysis assumes that the mobile crusher can be hired for short periods of time (e.g. on a daily basis).

At low utilisation rates (under 1000 hours per annum), it is cheaper to hire a mobile crusher than purchase one. At a utilisation rate between 1,000 to 1,250 hours per year there is little difference in cost between renting and purchasing (see the break even line in Figure 21). Above 1,250 hours per year, it is more cost effective to purchase a mobile crusher than to hire. This conclusion is generally consistent for all three sizes of crusher considered.



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

**Figure 21: Ratio of purchase cost (at various utilisation rates) to hire cost (utilisation rate of 2,000 hours/year)**

#### D2.1.4 Cost of excavation

The above analysis only takes into account the cost of running the mobile crusher machines to break excavated material into the final required size. It does not take into consideration material excavation costs. In order to make a direct comparison between alternative methods, there is a need to add the costs of material excavation.

It has been estimated that a person is able to excavate 0.8 cubic metres of stone per day (Stiedl, 1998). Based on this assumption<sup>32</sup>, the cost of excavation by hand has been estimated at US\$ 1.88 per cubic metre (see Table 25).

<sup>31</sup> Based on 8 hours per day and 20 days per month.

<sup>32</sup> It is assumed that the daily wage rate for an unskilled construction labourer is US\$ 1.5 per day

## D2.2 Manual Crushing

Table 25 presents the estimated cost of breaking stone manually. The following major assumptions apply in the estimation of the cost: (i) the cost includes the cost of excavation and breaking of the stone (hand knapping); (ii) the productivity rates of manual stone excavation and manual stone breaking are 0.8 cubic metres and 0.036 cubic metres per labourer per day ( Stiedl, 1998; Mitchell and Mwanza, 2005); (iii) the wage rate of unskilled labourer is US\$ 1.5 per day; (iv) the average diameter of the broken stone is 20mm. It can be seen from Table 25 that the cost of producing crushed stone manually is approximately US\$43.50 per cubic metre. This unit cost is at least 10 times higher than the cost of producing crushed stone using any of the three Hoa Phat mobile crushers (Figure 19).

**Table 25: Cost of breaking stone manually**

| Activity                            | Rate (m <sup>3</sup> /day/person) | Required person days for 1 m <sup>3</sup> | Wage rate (US\$/day) | Cost US\$/m <sup>3</sup> |
|-------------------------------------|-----------------------------------|-------------------------------------------|----------------------|--------------------------|
| Excavating stone                    | 0.8                               | 1.3                                       | 1.50                 | 1.88                     |
| Breaking stone <sup>33</sup>        | 0.036                             | 27.8                                      | 1.50                 | 41.67                    |
| <b>Total cost per m<sup>3</sup></b> |                                   |                                           |                      | <b>43.54</b>             |

Source: Mitchell and Mwanza (2005), Stiedl (1998) and consultant's estimates

Hand knapping can be more cost effective than mobile crushers when the volume of crushed stone required is low and in situations where it is difficult or costly to mobilise a mobile crusher (e.g. very remote locations). In order to estimate the approximate volume of stone below which hand knapping might be competitive, a comparative analysis of the costs between hand knapping and using a medium sized Hoa Phat mobile crusher (NHHP-PEX 175) was carried out. The results are shown in Figure 22<sup>34</sup>. For volumes of stone under 15 cubic metres, it was calculated to be more cost effective to crush stones manually.

## D2.3 Purchasing from Commercial Quarry

The cost of purchasing crushed material from a quarry includes a fixed component (the cost of the material at the quarry gate) and a variable component (haulage distance). In Vietnam, the cost of crushed stone was found to vary from US\$3.74 per cubic metre (for limestone) to US\$7.16 (for "hard" stone) from an official quarry and the cost of haulage was US\$6.91 per m<sup>3</sup>/km for distances less than 30km<sup>35</sup>. The immediate observation is that the cost of haulage is significant.

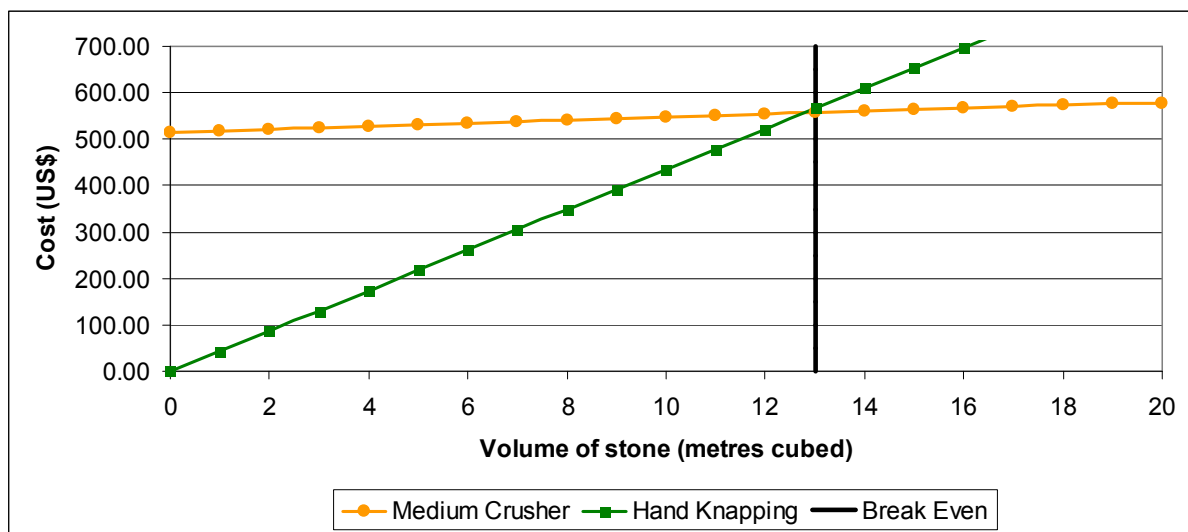
Using the lowest quarry price for stone and assuming one kilometre haulage, the total delivered cost would be US\$3.74+ US\$6.91 = US\$10.65 per cubic metre. This is far in excess of the calculated cost per cubic metre using a mobile crusher of around US\$1.4-2.2 per cubic metre (see Table 25 and the associated figure above). Further analysis was carried out to calculate the 'break-even haulage distance' for quarry stone compared to mobile crusher costs at different annual utilisation rates. This was found to vary from 300-150 metres

<sup>33</sup> It is assumed that stones will be broken to a diameter of 20 mm

<sup>34</sup> It was assumed that the cost of mobilisation (transporting the mobile crusher to the remote site) and demobilisation is equal to US\$513. This is based on one day transportation for mobilisation and demobilisation. 5 tonne flat trucks (Fuso EF639) can be hired for US\$3,000 per month and skilled construction workers are paid US\$130. The cost of fuel is assumed to equal US\$100 each way. Therefore, the cost of 2 days hire of a typical truck, fuel and a skilled worker costs US\$513. The analysis also took into consideration the cost of excavation.

<sup>35</sup> US\$2.16 per tonne/km, as in decision No. 89/2000/QD-VGCP by Cost Norm Office under the Government, 13 November 2000

from the quarry for mobile crusher utilisation rates between 250 and 2,000 hours per year i.e. mobile crushers are more competitive in cost than quarries for production of crushed stone.



Source: Mobile crusher interviews, equipment supplier interviews, equipment manufacturers, Mitchell and Mwanza (2005), Stiedl (1998) and consultant’s estimates

**Figure 22: Cost of crushing stone manually and with a medium sized crusher (Hoa Phat, NHHP-PEX 175)**

These costs do not take into account the fact that a contractor requires a government permit to mine natural resources. This will act as a significant cost burden to contractors, which suggests why the diffusion of mobile crushers is not as wide as the cost effectiveness benefits suggest. Also purchasing from a commercial quarry is more convenient for an SSC and the crushed product is likely to be of a higher quality and a wider range of minerals will be on offer.

### D2.4 Chapter Summary

The estimated cost of producing broken stone by hand knapping was found to be approximately US\$42 per cubic metre. This unit cost is substantially higher than producing crushed stone using a mobile crusher, which ranges between US\$1.3 to US\$4.5 per cubic metre. However, hand knapping can be cost effective where the required volume of broken stone is low (under 15 cubic metres) and in remote areas.

In general, the medium and large Hoa Phat mobile crushers are more cost effective than their smaller counterpart. If the utilisation rate of a mobile crusher is more than 1,000 hours per annum then it is more cost effective to purchase a mobile crusher. Below 1,000 hours per year, hiring was estimated to be more cost effective.

The cost of purchasing crushed material from a commercial quarry is significantly more expensive than using a mobile crusher. However, this option may be the only option available to a contractor if unable to organise the required resources (manpower or machines). Additionally, the quality of commercial quarry product is often better and there could be a wider option of material sizes available. Therefore in situations where high product quality or specific material is required, purchasing from a commercial quarry might be the optimal choice. Table 26, below, summarises the optimal crushing strategies.

**Table 26: Optimum crushing strategies**

| Option                                                                | Hand Knapping | Mobile Crusher |          | Quarry Purchase |
|-----------------------------------------------------------------------|---------------|----------------|----------|-----------------|
|                                                                       |               | Hire           | Purchase |                 |
| Volumes of crushed material under 15 cubic metres 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   |               |                |          | ✓               |

### D3. MOBILE CRUSHER DEMAND AND SUPPLY

This chapter deals with the demand and supply situation linked to mobile crushers. The evidence is mainly drawn from the contractor surveys.

#### D3.1 Demand

##### D3.1.1 Assessment of current demand

Chapter B1 explained the difficulties linked to the estimation of current market demand. The current market demand of crushers is also assessed using the information on the contractors' ownership and hiring level (contractor surveys generated such information). Table 27 summarises the stone crusher ownership and hiring related information.

The ownership level of mobile crushers was considerable among the Vietnamese contractors – 33% owned them. However, no Cambodian contractor owned a mobile crusher. Only 5% of Vietnamese and no Cambodian contractors hired a mobile crusher in the 12 months prior to the interviews.

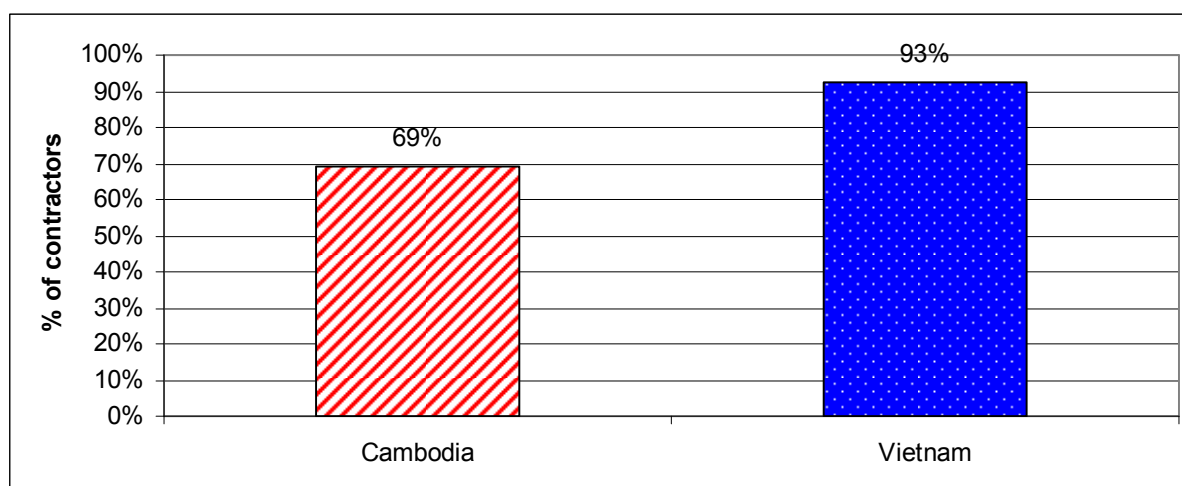
**Table 27: Contractors that own or have hired a mobile crusher in the last 12 months**

| Equipment      | Percentage of contractors that own/hire[a] |       |          |       |          |       |
|----------------|--------------------------------------------|-------|----------|-------|----------|-------|
|                | Total                                      |       | Cambodia |       | Vietnam  |       |
|                | Own                                        | Hire  | Own      | Hire  | Own      | Hire  |
| Mobile Crusher | 16 (1.8)                                   | 3 (1) | 0 (0)    | 0 (0) | 33 (1.8) | 5 (1) |

Source: Contractor surveys

Note: [a] Within bracket values refer to the average number of equipment owned/hired per owning/hiring contractor

Most of the contractors were aware of mobile crushers: approximately 70% of the Cambodian contractors and 90% of the Vietnamese contractors were aware of the mobile crusher (Figure 23). All the contractors that claimed to know about mobile crushers were correctly able to articulate its main functions.

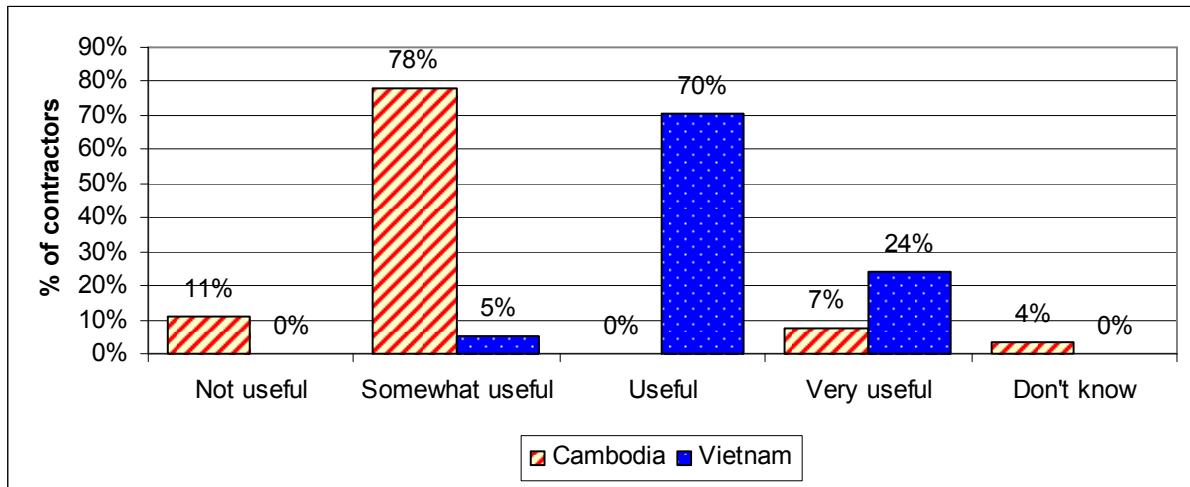


Source: Contractor surveys

**Figure 23: Mobile crusher awareness (% aware)**

The contractors who were aware of mobile crushers were also asked questions on their usefulness. Contractor perception regarding mobile crusher usefulness was high (Figure 24).

All of the Vietnamese contractors and 89% of Cambodian contractors thought that the mobile crusher was a useful item of equipment.

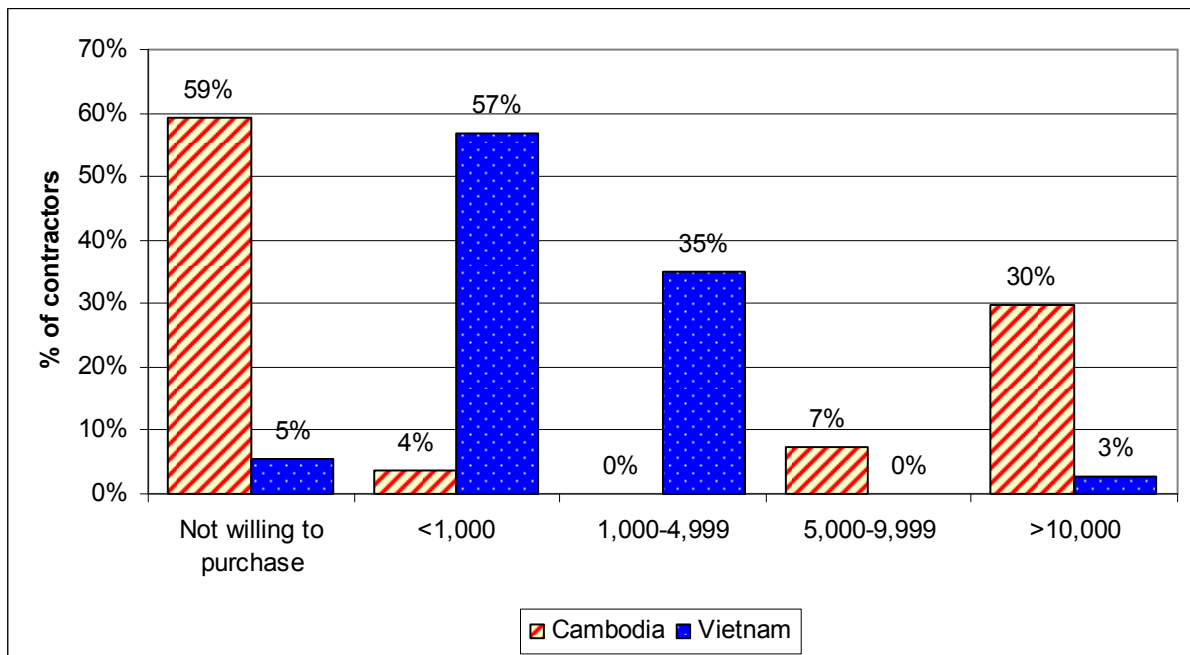


Source: Contractor surveys

**Figure 24: Mobile crusher usefulness**

Contractors, who were aware of the mobile crusher, were also asked whether they would purchase one and, if so, how much they would be willing to pay for one (Figure 25). 59% of the Cambodian contractors said that they would not be willing to purchase a mobile crusher. 30% of the Cambodian contractors would be willing to pay more than US\$10,000 for one. This is twice the price of the largest Hoa Phat crusher. This suggests that the Cambodian contractors have little knowledge of the financial viability of mobile crushers.

An overwhelming majority of the Vietnamese contractors (95%) who were aware of mobile crushers would be willing to buy one. However, 57% of them would only buy a mobile crusher if the purchase price was less than US\$ 1,000. This price is lower than the price of the cheapest Hoa Phat mobile crusher (the NHHP-PEX15 which costs approximately US\$1,420). However, 35% of the Vietnamese contractors were willing to pay between US\$1,000 and 4,999, the typical price of new Hoa Phat crushers.



**Figure 25: Contractors willing to purchase a mobile crusher and at what price (US\$)**

### D3.1.2 Assessment of future demand

The future equipment demand was estimated using the projected amount of rural road linked roadworks in Cambodia, Vietnam and Laos and the productivity rates of the equipment<sup>36</sup> (details available in Section B1.3.2). Table 28 presents the projected future demand (the number that will be required to carry out the planned roadworks) for mobile crushers<sup>37</sup>.

**Table 28: Annual requirement of equipment, number of units (2007/8-2011/12)**

| Equipment                            | Cambodia | Vietnam | Laos |
|--------------------------------------|----------|---------|------|
| Small Crusher, Hoa Phat NHHP-PEX15   | 321      | 6618    | 222  |
| Medium Crusher, Hoa Phat NHHP-PEX175 | 143      | 2941    | 99   |
| Large Crusher, Hoa Phat NHHP-PEX215  | 107      | 2206    | 74   |

Source: Contractor surveys

Table 28 shows that the potential future demand for mobile crushers for rural roadworks is less than 200 units for Laos and Cambodia combined (for medium sized crusher) per year. Given the low demand it would not be worthwhile to pursue a mainstreaming strategy in Cambodia or Laos.

By contrast, the demand for mobile crushers is substantial in Vietnam: it is estimated that over 2,900 (for medium sized crusher) per year will be required to execute the rural road strategy. This is a significant number of units and, therefore, there is a justification for devising a mainstreaming strategy in Vietnam. The objective of the mainstreaming activity will not be to enhance the supply of mobile crushers, but instead to disseminate the information to contractors and equipment suppliers on cost advantages of mobile crushers in sourcing crushed aggregate over other alternatives. This may result in increase in demand for mobile crushers.

In general, there was a level of enthusiasm among contractors and key informants about mobile crushers. Cambodian interviewees were aware of the potential surge of paved road related roadworks, as evident from the conversations. In all three countries, many contractors were also aware that the mobile crusher could be used to recycle building construction rubble and this could also provide income outside the rural roads sub-sector. However, such enthusiasm was felt mainly in booming areas (e.g. Siem Reap). Many of the contractors stated that the requirement for a permit to extract materials was a major constraint. Many interviewees in Cambodia felt that the availability of rock and stone for crushing was far more limited in Cambodia than in Vietnam and Laos. Some of the Cambodian contractors also stated that quarry based crushers were more effective than mobile crushers and could produce higher quality products. Appendix XXX and XXXI provides further anecdotal information on contractor and key informant opinions towards mobile crusher.

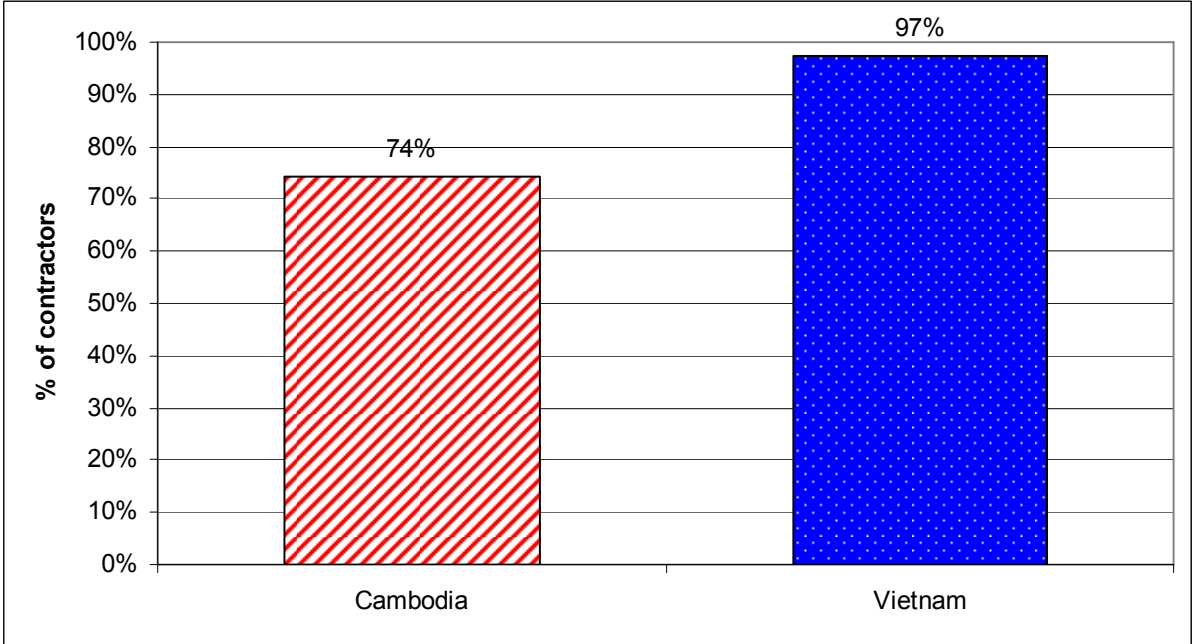
### D3.2 Supply

Contractors who were aware of the mobile crusher were asked if they had adequate access if required. The results are provided in Figure 26. 97% of Vietnamese contractors and 74% of the Cambodian contractors believed that there would be no supply constraints. However, the figures for Cambodia should be treated with caution as none of the contractors actively sought

<sup>36</sup> Productivity rates of 6 m<sup>3</sup>/hour, 4.5 m<sup>3</sup>/hour, 2 m<sup>3</sup>/hour respectively for large, medium and small Hoa Phat mobile crushers. Please note that mobile crusher demand values were not subjected to an efficiency down-scale of 80%. Because the productivity values stated are regarded as being accurate (see Appendix XXIII). Please refer to Section B1.3.2 for further details

<sup>37</sup> The following assumptions apply in the assessment of the demand: roadworks are timed and managed perfectly so that the equipment runs to its full potential and the demand from non-rural road sub-sector is excluded.

to acquire a mobile crusher, therefore, this only reflects the contractors' perceptions on mobile crusher availability. However, all key informants in Cambodia as well as Laos stated that there are no supply constraints to mobile crushers in their respective countries.



Source: Contractor's survey

**Figure 26: Contractor's who state they have adequate access to the mobile crusher**

There are no manufacturers of mobile crushers in Cambodia or Laos. The main manufacturer of crushers in Vietnam is Hoa Phat producing 200 units annually (see Figure 27). The Manager of Hoa Phat's Sales Department stated that the mobile crusher sales volume had been increasing on average 40% per annum, and this trend was expected to continue for the foreseeable future. In spite of this huge surge, the company claims to be able to meet the projected demand. Hoa Phat has also exported their mobile crushers abroad. Since the year 2000, Hoa Phat exported crushers to Sri Lanka and Ukraine. The company began exporting to Cambodia and Laos recently. It can be concluded that Hoa Phat has a strong manufacturing potential and are able to meet regional crusher demand.



**Figure 27: Mobile crusher under assembly, Hoa Phat, Ho Chi Minh City**

### **D3.3 Chapter Summary**

The vast majority of contractors in Cambodia and Vietnam were aware of mobile crushers and its functions. Mobile crusher ownership level is considerable among Vietnamese contractors (33%). However, none of the Cambodia contractors interviewed owned a mobile crusher. While most Cambodian contractors, who were aware of mobile crushers, would not be willing to purchase a mobile crusher, an overwhelming majority of the Vietnamese contractors (95%) would be willing to buy one. The conclusion is that the current demand for mobile crushers is high amongst Vietnamese contractors but low among Cambodian contractors.

The potential future demand for mobile crushers is less than 250 units annually in Laos and Cambodia (combined). However, potential demand is over 2,900 units in Vietnam. This is mainly due to the anticipated high level of paved road work activities. Therefore it is concluded that a mainstreaming strategy needs to be pursued with an objective of dissemination of information on the cost advantages of mobile crushers.

There were no current constraints to mobile crusher supply in the region. Hoa Phat is currently producing approximately 200 units annually and has been exporting to Asian and European countries. No outside intervention is needed to boost Hoa Phat's production capacity as they seem to be adequately satisfying national and regional demand.

## **D4. MOBILE CRUSHER COMPARATIVE ASSESSMENT**

### **D4.1 Viability**

Contractors can obtain crushed/broken stone or rock by hand knapping, using a mobile crusher or purchasing from a commercial quarry. Mobile crushers appear to have a wide application in the three study countries. However, in isolated areas the only option may be to hand knap and certain contracts may require quality crushed material that may only be obtainable from a commercial quarry. In addition, contractors require a permit to extract natural resources. Without such a permit hand knapping and using a mobile crusher are technically illegal activities. However, for small scale excavation, this is often not enforced.

### **D4.2 Cost**

Mobile crushers cost between US\$1,400 (less than 0.5 tonnes) to US\$12,000 (over 6 tonnes). Equipment suppliers in the region rarely hire out mobile crushers.

The most cost effective method of acquiring broken/crushed stone was calculated to be by using a mobile crusher, except in the following cases:

- when the required volume of broken stone is low (less than 15 m<sup>3</sup>) and/or when the construction site is located in isolated areas that makes the mobilisation and demobilisation costs of the mobile crusher considerable. In such cases hand knapping is the most cost effective option; and
- when high quality of the crushed material is required and when the contractor is unable to organise the required resources (man power or machines) due to time restraints. In such cases purchasing from a commercial quarry may be the only option.

The most cost effective Hoa Phat mobile crushers are the medium (NHHP-PEX175) and large (NHHP-PEX215) models. If a contractor is able to utilise a crusher for more than 1,000 hours per year, it is more cost effective to purchase a mobile crusher. Otherwise, hiring is the more cost-effective option.

### **D4.3 Demand and Supply**

Less than 200 units per year of the medium sized Hoa Phat crusher is estimated to be required in Cambodia and Laos (combined) in order to implement the roadworks within the rural roads sub-sector over the next 5 years. However, over 2,900 units will be required in Vietnam due to the anticipated expansion of paved road related activities. Evidence shows that there is no constraint to the supply of mobile crushers in the region.

### **D4.4 Recommendations**

Mobile crushers provide contractors with considerable cost advantages in terms of sourcing crushed material and it is recommended that this information is disseminated by the appropriate authority in the respective countries among contractors and equipment suppliers. An objective of this dissemination process should be to encourage equipment suppliers to make mobile crushers available for hire, particularly in Vietnam.

Despite the high anticipated demand of mobile crushers in Vietnam, no external intervention is required to increase market supply as it appears that the only supplier in Vietnam, Hoa Phat, has the capacity to meet the projected demand.

## REFERENCES

- Deelen L and Bonsu K O (2002), *Equipment Finance for Small Contractors in Public Work Programmes, Social Finance Programme, Employment Intensive Branch, Working Paper No. 28*, ILO, Geneva
- Gongera K and Petts R C (2003), *A Tractor and Labour Based Routine Maintenance System*, LCS Working Paper No. 5
- Hine J L, Ebden J H and Swan P (1997), *A Comparison of Freight Transport Operations in Tanzania and Indonesia (TRL Report 267)*, Transport Research Laboratory, Crowthorne
- Intech Associates (2004), *Introducing the DTW "Cam-Grader", A Low Cost Rural Road Grader*, LCS Working Paper No. 19
- Intech Associates Roads (2000), *A Programme for Labour and Tractor Based Maintenance of the Classified Road Network Pilot Project*, Final Report, MoPWH, Kenya (unpublished)
- IT Transport (2003), *Cost Comparison Study: Mozambique Regional Roads (Final Report)*, IT Transport, np (also available online at: <http://www.ittransport.co.uk/index.php?page=publications>)
- IT Transport (2003), *Cost Comparison Study: Mozambique Regional Roads (Final Report)*, IT Transport, np (also available online at: <http://www.ittransport.co.uk/index.php?page=publications>)
- Jones T E and Robinson R (1996), *A Study of the Cost Effectiveness of Grading Unpaved Roads in Developing Countries*, Research Report No 91, Transport Research Laboratory, Crowthorne
- Klerx G and Lay C (2001), *Small Contractor Survey Report (Draft Final)*, United Nations Development Programme, Phnom Penh
- Larcher P (1997), *Tools and Equipment – Design, Development and Specifications*, Regional Seminar Papers, ASIST, np
- Lebo J and Shelling D (2001), *Design of Rural Transport Infrastructure: Ensuring Basic Access for Rural Communities*, World Bank Technical Paper 496, 2001
- 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
- Mekong Economics (2005), *Research into the Role of the Private Sector in Transport*, SEACAP 014, May 2005
- Ministry of Communication Transport Post and Construction (2007), *National Strategy on Accelerated Provision of Rural Transport Infrastructure*, Ministry of Communication Transport Post and Construction, Vientiane
- Ministry of Transport (2007), *Rural Road Surfacing Research: SEACAP 1 Final Report*, Intech Associates and TRL Limited, np
- Ministry of Rural Development (2007), *Strategic Plan for Rural Roads*, Ministry of Rural Development, np.
- Mitchell C J & Mwanza M (2005), *Farmlime Manual for Mobile Production of Agricultural Lime* British Geological Survey Report CR/05/092N, Keyworth
- Pemberton-Pigott C (1997), *Crushing Stony Silence* MART, ASIST Bulletin No. 6, September, np

Petts R C (1997), *Agricultural Tractors in Roadworks*, MART Working Paper No 7, Regional Seminar Papers 1997, ASSIST

Petts R C (2004), *Evaluation of Mark 2 Cambodia Light Grader (LCS Working Paper No 19)*, Intech Associates, np

Petts R C and Jones T E (1991), *Mobile crushers and Tractor-Based Maintenance of Low Volume Roads*, Transport Research Laboratory, Crowthorne

Petts R C and Jones T E (1991), *Towed Graders and Tractor-Based Maintenance of Low Volume Roads*, Transport Research Laboratory, Berkshire, UK

Stiedl D (1998), *Productivity Norms for Labour-based Construction*, ILO-ASIST Technical Brief No.2, Harare

TDSI and WSP International (2005), *Institutional, Incentive and Capacity Study of the Local Transport Network*, SEACAP 016, July 2005

The Economist (2008), "Half Way from Rags to Riches, A Special Report on Vietnam (April 26<sup>th</sup>, 2008", *The Economist*, Vol. 397 Number 8577

World Bank (2006), *Project Appraisal Document on a Proposed Credit\ to the Socialist Republic of Vietnam for a Third Rural Transport Project*, World Bank, Washington DC

## **APPENDICES**

## Contractor Survey (FORM 1)

|                           |  |                                 |  |
|---------------------------|--|---------------------------------|--|
| <b>Company Name:</b>      |  | <b>Interviewee's Name:</b>      |  |
| <b>Interviewee ID No:</b> |  | <b>Position in the Company:</b> |  |
| <b>Address:</b>           |  | <b>Operating Region:</b>        |  |
|                           |  | <b>Telephone No.:</b>           |  |
| <b>Name of surveyor:</b>  |  | <b>Surveyor ID No:</b>          |  |
| <b>Date:</b>              |  | <b>Location:</b>                |  |

### SECTION 1: Company details

**1.1a) What is the annual turnover of your company? (approximate average over the last 3 years, US\$)**

|                    |                          |                    |                          |
|--------------------|--------------------------|--------------------|--------------------------|
| Less than 5,000    | <input type="checkbox"/> | 5,000 to 9,999     | <input type="checkbox"/> |
| 10,000 to 19,999   | <input type="checkbox"/> | 20,000 to 39,999   | <input type="checkbox"/> |
| 40,000 to 80,000   | <input type="checkbox"/> | 80,000 to 199,999  | <input type="checkbox"/> |
| 200,000 to 499,999 | <input type="checkbox"/> | 500,000 to 999,999 | <input type="checkbox"/> |
| Over 1,000,000     | <input type="checkbox"/> | No data available  | <input type="checkbox"/> |
| Not stated         |                          |                    | <input type="checkbox"/> |

**1.1b) What is the annual turnover of your company from rural road projects only? (approximate average over the last 3 years, US\$)**

|                    |                          |                    |                          |
|--------------------|--------------------------|--------------------|--------------------------|
| Less than 5,000    | <input type="checkbox"/> | 5,000 to 9,999     | <input type="checkbox"/> |
| 10,000 to 19,999   | <input type="checkbox"/> | 20,000 to 39,999   | <input type="checkbox"/> |
| 40,000 to 80,000   | <input type="checkbox"/> | 80,000 to 199,999  | <input type="checkbox"/> |
| 200,000 to 499,999 | <input type="checkbox"/> | 500,000 to 999,999 | <input type="checkbox"/> |
| Over 1,000,000     | <input type="checkbox"/> | No data available  | <input type="checkbox"/> |
| Not stated         |                          |                    | <input type="checkbox"/> |

**1.2 How many permanent (full time) staff your company has?**

|        |                          |               |                          |            |                          |
|--------|--------------------------|---------------|--------------------------|------------|--------------------------|
| 0      | <input type="checkbox"/> | 1 – 2         | <input type="checkbox"/> | 3-5        | <input type="checkbox"/> |
| 6 – 10 | <input type="checkbox"/> | 11 – 15       | <input type="checkbox"/> | 16-50      | <input type="checkbox"/> |
| 51-100 | <input type="checkbox"/> | More than 100 | <input type="checkbox"/> | Not Stated | <input type="checkbox"/> |

**1.3 What organisations are the company enlisted with/ has worked for?**

|                                 |                          |                                      |                          |
|---------------------------------|--------------------------|--------------------------------------|--------------------------|
| MOT                             | <input type="checkbox"/> | PDOT                                 | <input type="checkbox"/> |
| Other public sector             | <input type="checkbox"/> | Other contractor                     | <input type="checkbox"/> |
| Other private sector (national) | <input type="checkbox"/> | Other private sector (international) | <input type="checkbox"/> |
| Aid agency                      | <input type="checkbox"/> | RT2 or RT3 only                      | <input type="checkbox"/> |

## SECTION 2: Equipment

**2.1 Has the company used any of the following equipment in the last 12 months? (Y/N)**

**If so, please tick (√) the appropriate box**

| Equipment                               | (√) | Type (where applicable) | Equipment                           | (√) | Type (where applicable) |
|-----------------------------------------|-----|-------------------------|-------------------------------------|-----|-------------------------|
| Truck (flat truck, tipper truck, itean) |     |                         | Concrete Vibrator                   |     |                         |
| Tractor (type 4WD; 2WD) & Trailer       |     |                         | Mobile Small-Scale Stone Crusher    |     |                         |
| Wheelbarrow                             |     |                         | Grader (motor grader; towed grader) |     |                         |
| Roller/compactor [a]                    |     |                         | Bitumen Heater                      |     |                         |
| Water Bowser (self propelled, towed)    |     |                         | Bitumen Hand Sprayer                |     |                         |
| Concrete Mixer                          |     |                         |                                     |     |                         |

Note: [a] type: Ride on vibratory, towed vibratory, deadweight, towed deadweight, pedestrian vibratory, plate compactor, hand drawn

**2.2 Does your company own any equipment? (Y/N)**

**If yes, please indicate what equipment, how many and how it was purchased**

| Equipment                               | (√) | Number (and type) | Method of Purchase (use code) | Purchase from? (use code) | Comment |
|-----------------------------------------|-----|-------------------|-------------------------------|---------------------------|---------|
| Truck (flat truck, tipper truck, itean) |     |                   |                               |                           |         |
| Tractor (type 4WD; 2WD) & Trailer       |     |                   |                               |                           |         |
| Wheelbarrow                             |     |                   |                               |                           |         |
| Roller/compactor [a]                    |     |                   |                               |                           |         |
| Water Bowser (self propelled, towed)    |     |                   |                               |                           |         |
| Concrete Mixer                          |     |                   |                               |                           |         |
| Concrete Vibrator                       |     |                   |                               |                           |         |
| Mobile Small-Scale Stone Crusher        |     |                   |                               |                           |         |
| Grader (motor grader; towed grader)     |     |                   |                               |                           |         |
| Bitumen Heater                          |     |                   |                               |                           |         |
| Bitumen Hand Sprayer                    |     |                   |                               |                           |         |

Note: [a] type: Ride on vibratory, towed vibratory, deadweight, towed deadweight, pedestrian vibratory, plate compactor, hand drawn

**2.3 Has your company thought about purchasing any additional equipment? (Y/N)**

**If yes, please indicate what equipment**

| Equipment                               | (√) purchase considered | Type | Reason not purchased (use code) | Comment |
|-----------------------------------------|-------------------------|------|---------------------------------|---------|
| Truck (flat truck, tipper truck, itean) |                         |      |                                 |         |
| Tractor (type 4WD; 2WD) & Trailer       |                         |      |                                 |         |
| Wheelbarrow                             |                         |      |                                 |         |
| Roller/compactor [a]                    |                         |      |                                 |         |
| Water Bowser (self propelled, towed)    |                         |      |                                 |         |
| Concrete Mixer                          |                         |      |                                 |         |
| Concrete Vibrator                       |                         |      |                                 |         |
| Mobile Small-Scale Stone Crusher        |                         |      |                                 |         |
| Grader (motor grader; towed grader)     |                         |      |                                 |         |
| Bitumen Heater                          |                         |      |                                 |         |
| Bitumen Hand Sprayer                    |                         |      |                                 |         |

Note: [a] type: Ride on vibratory, towed vibratory, deadweight, towed deadweight, pedestrian vibratory, plate compactor, hand drawn

**If no, please indicate why you never considered purchasing additional equipment**

The reason why I have never considered purchasing additional equipment is.....

**2.4 Has the company ever faced any problems in financing the purchase of equipment? (Y/N)**

**If yes, what problems did you face?**

|                                              |                          |
|----------------------------------------------|--------------------------|
| Unable to raise private capital              | <input type="checkbox"/> |
| Unable to obtain credit                      | <input type="checkbox"/> |
| Credit available, but large deposit required | <input type="checkbox"/> |
| Credit available, but at high interest rate  | <input type="checkbox"/> |
| Other, please specify.....                   |                          |

**2.5a Has the company ever imported or thought about importing equipment? (Y/N)**

**If no, the please go to question 2.6**

**If yes, what equipment did you think about importing?**

| Equipment                               | (√) if considered importing | Type | Equipment                           | (√) if considered importing | Type |
|-----------------------------------------|-----------------------------|------|-------------------------------------|-----------------------------|------|
| Truck (flat truck, tipper truck, itean) |                             |      | Concrete Vibrator                   |                             |      |
| Tractor (type 4WD; 2WD) & Trailer       |                             |      | Mobile Small-Scale Stone Crusher    |                             |      |
| Wheelbarrow                             |                             |      | Grader (motor grader; towed grader) |                             |      |
| Roller/compactor [a]                    |                             |      | Bitumen Heater                      |                             |      |
| Water Bowser (self propelled, towed)    |                             |      | Bitumen Hand Sprayer                |                             |      |
| Concrete Mixer                          |                             |      |                                     |                             |      |

Note: [a] type: Ride on vibratory, towed vibratory, deadweight, towed deadweight, pedestrian vibratory, plate compactor, hand drawn

**2.5b Why did you feel you needed to import such equipment?**

|                                    |                          |
|------------------------------------|--------------------------|
| Not available when required        | <input type="checkbox"/> |
| Not available locally              | <input type="checkbox"/> |
| Quality of local equipment too low | <input type="checkbox"/> |
| Local equipment too expensive      | <input type="checkbox"/> |
| Other, please specify.....         |                          |

**2.5c Did you encounter any problems importing? (Y/N)**

**If yes, please specify such problems**

|                                                                        |                          |
|------------------------------------------------------------------------|--------------------------|
| Did not know how to import                                             | <input type="checkbox"/> |
| Equipment not available to import                                      | <input type="checkbox"/> |
| Importation tax too high                                               | <input type="checkbox"/> |
| Foreign equipment too expensive                                        | <input type="checkbox"/> |
| Lengthy/complicated process (please provide further information below) | <input type="checkbox"/> |
| Other, please specify below.....                                       |                          |

Further information on importation.....

**2.6 Has your company hired any equipment in the last 12 months? (Y/N)**

**If yes, please indicate what equipment, how many and from which source**

| Equipment                               | (√) if hired | Number and Type | Source (use code) | Comment |
|-----------------------------------------|--------------|-----------------|-------------------|---------|
| Truck (flat truck, tipper truck, itean) |              |                 |                   |         |
| Tractor (type 4WD; 2WD) & Trailer       |              |                 |                   |         |
| Wheelbarrow                             |              |                 |                   |         |
| Roller/compactor [a]                    |              |                 |                   |         |
| Water Bowser (self propelled, towed)    |              |                 |                   |         |
| Concrete Mixer                          |              |                 |                   |         |
| Concrete Vibrator                       |              |                 |                   |         |
| Mobile Small-Scale Stone Crusher        |              |                 |                   |         |
| Grader (motor grader; towed grader)     |              |                 |                   |         |
| Bitumen Heater                          |              |                 |                   |         |
| Bitumen Hand Sprayer                    |              |                 |                   |         |

Note: [a] type: Ride on vibratory, towed vibratory, deadweight, towed deadweight, pedestrian vibratory, plate compactor, hand drawn

**2.7 Has your company ever had any difficulty obtaining the following equipment? (Y/N)**

**If yes, please indicate which equipment and why**

| Equipment                               | (√) if difficulty obtaining | Type | Reason (use code) | Comment |
|-----------------------------------------|-----------------------------|------|-------------------|---------|
| Truck (flat truck, tipper truck, itean) |                             |      |                   |         |
| Tractor (type 4WD; 2WD) & Trailer       |                             |      |                   |         |
| Wheelbarrow                             |                             |      |                   |         |
| Roller/compactor [a]                    |                             |      |                   |         |
| Water Bowser (self propelled, towed)    |                             |      |                   |         |
| Concrete Mixer                          |                             |      |                   |         |
| Concrete Vibrator                       |                             |      |                   |         |
| Mobile Small-Scale Stone Crusher        |                             |      |                   |         |
| Grader (motor grader; towed grader)     |                             |      |                   |         |
| Bitumen Heater                          |                             |      |                   |         |
| Bitumen Hand Sprayer                    |                             |      |                   |         |

Note: [a] type: Ride on vibratory, towed vibratory, deadweight, towed deadweight, pedestrian vibratory, plate compactor, hand drawn

**2.8 Are there any potential institutions that can help your company in procuring equipment? (Y/N)**

**If yes, please indicate which institution(s) can help?**

|                          |                          |                        |                          |
|--------------------------|--------------------------|------------------------|--------------------------|
| MOT                      | <input type="checkbox"/> | PDOT                   | <input type="checkbox"/> |
| Other public institution | <input type="checkbox"/> | Please provide example | .....                    |
| Bank                     | <input type="checkbox"/> | Please provide example | .....                    |
| Charity/NGO              | <input type="checkbox"/> | Please provide example | .....                    |
| Other                    | <input type="checkbox"/> | Please provide example | .....                    |

**Please indicate how such institution(s) can help?**

**SECTION 3: Towed Grader**

**3.1 Are you aware of the towed grader? (Y/N)**

If no, please go to question 4

**3.2 Do you know what it does? (Y/N)**

If yes, please state its function

**3.3 Have you seen a towed grader? (Y/N)**

If yes, please go to question 3.4; If no, please go to question 3.5

**3.4 Has your company used a towed grader? (Y/N)**

**3.5 Does your company have adequate access to the towed grader when required? (Y/N)**

If yes, please go to question 3.7; If no, please go to question 3.6

**3.6 Why do you feel that your company has restricted access to the towed grader?**

|                                     |                          |
|-------------------------------------|--------------------------|
| Cannot find equipment to purchase   | <input type="checkbox"/> |
| Cannot find equipment to hire       | <input type="checkbox"/> |
| Equipment too expensive             | <input type="checkbox"/> |
| Other, please specify.....<br>..... |                          |

**3.7 Do you own a towed grader? (Y/N)**

**3.8 Do you think that the towed grader is a useful item of equipment? (Y/N)**

If yes, please indicate how useful

|                 |                          |
|-----------------|--------------------------|
| Somewhat useful | <input type="checkbox"/> |
| Useful          | <input type="checkbox"/> |
| Very useful     | <input type="checkbox"/> |
| Essential       | <input type="checkbox"/> |
| Don't know      | <input type="checkbox"/> |

**3.9 How much are you be willing to pay for a towed grader (US\$)?**

|                  |                          |                             |                          |
|------------------|--------------------------|-----------------------------|--------------------------|
| less than 1,000  | <input type="checkbox"/> | 1,000-1,999                 | <input type="checkbox"/> |
| 2,000-2,999      | <input type="checkbox"/> | 3,000-3,999                 | <input type="checkbox"/> |
| 4,000-4,999      | <input type="checkbox"/> | 5,000-6,999                 | <input type="checkbox"/> |
| 7,000-9,999      | <input type="checkbox"/> | 10,000-20,000               | <input type="checkbox"/> |
| more than 20,000 | <input type="checkbox"/> | Not willing to purchase one | <input type="checkbox"/> |

**3.10) If you had a towed grader, would you have adequate access to a tractor? (Y/N)**

**SECTION 4: Mobile small-scale stone crusher**

**4.1 Are you aware of the mobile small-scale stone crusher? (Y/N)**

If no, you have now completed the questionnaire

**4.2 Do you know what it does? (Y/N)**

If yes, please state its function

**4.3 Have you seen a mobile small-scale stone crusher? (Y/N)**

If yes, please go to question 4.4; If no, please go to question 4.5

**4.4 Has your company used a mobile small-scale stone crusher? (Y/N)**

**4.5 Does your company have adequate access to the mobile small-scale stone crusher when required? (Y/N)**

If yes, please go to question 4.7; If no, please go to question 4.6

**4.6 Why do you feel that your company has restricted access to the mobile small-scale stone crusher?**

|                                   |                          |
|-----------------------------------|--------------------------|
| Cannot find equipment to purchase | <input type="checkbox"/> |
| Cannot find equipment to hire     | <input type="checkbox"/> |
| Equipment too expensive           | <input type="checkbox"/> |
| Other, please specify.....        |                          |
| .....                             |                          |

**4.7 Does your company own a mobile small-scale stone crusher? (Y/N)**

**4.8 Do you think that the mobile small-scale stone crusher is a useful item of equipment? (Y/N)**

If yes, please indicate how useful

|                 |                          |
|-----------------|--------------------------|
| Somewhat useful | <input type="checkbox"/> |
| Useful          | <input type="checkbox"/> |
| Very useful     | <input type="checkbox"/> |
| Essential       | <input type="checkbox"/> |
| Don't know      | <input type="checkbox"/> |

**4.9) How much are you be willing to pay for a mobile small-scale stone crusher (US\$)?**

|                  |                          |                             |                          |
|------------------|--------------------------|-----------------------------|--------------------------|
| less than 1,000  | <input type="checkbox"/> | 1,000-1,999                 | <input type="checkbox"/> |
| 2,000-2,999      | <input type="checkbox"/> | 3,000-3,999                 | <input type="checkbox"/> |
| 4,000-4,999      | <input type="checkbox"/> | 5,000-6,999                 | <input type="checkbox"/> |
| 7,000-9,999      | <input type="checkbox"/> | 10,000-20,000               | <input type="checkbox"/> |
| more than 20,000 | <input type="checkbox"/> | Not willing to purchase one | <input type="checkbox"/> |

Thank you! You have now completed the questionnaire! We appreciate your help

**List of Key Informants**

**Cambodia**

- HE Suos Kong, Secretary of State, MRD
- HE Yoeun Sophal, Director, Department of Rural Roads, MRD
- Ngoun Dara, Deputy Director, Department of Rural Roads, MRD
- Var Synarong, Engineer, MRD
- Sam Ny, Deputy Director, Provincial Department of Rural Roads, Kampot
- Veasna Bun, Infrastructure Operations Officer, The World Bank
- Paul Van Im, Programs Officer, Asian Development Bank
- Phibal Chao, Lecturer, Norton University, Cambodian Mekong University
- Ros Sar, Director, Department of Rural Development, MRD, Siem Reap
- Sereyreatama Dit, Director, PDWT
- Chem Salin, Engineer, Ministry of Rural Development
- Heng Kackada, Secretary, CNCTP
- Suo Sadim, Vice Chairman Undersecretary, Electric Authority of Cambodia

**Vietnam**

- Chun Su, Rural Transport Expert, MOT
- Choi Sun, Director of Rural Transport, Ministry of Transport
- Dr. Nguyen Huu Tri, Director General, Science and Technology Department, ITST
- Dr. Jasper Cook, Regional Manager, Intech Associates
- Simon Lucas, Infrastructure Specialist, The World Bank
- Hury Bui Ngoc, Highway Engineer, ITST
- Mr. Thang, Manager of Rural Transport Project
- Tran Quoc Thang, Deputy Director, IMUIS
- Ta Van Giang, Deputy Director of R&D Department, ITST

**Laos**

- Mr. Sengdarith, Director, Local Roads Division
- Mr. Somnak, Deputy Director, Local Roads Division
- Belal Hussein, Basiv Access Component, Lao-Swedish Road Sector Project III
- Per Oluf, Team Leader, Maintenance Component, Lao-Swedish Road Sector Project III
- Khamvieng Nantholid, Deputy Director, ARI Co. Ltd.

|                 |  |
|-----------------|--|
| <b>Date</b>     |  |
| <b>Location</b> |  |

**Interview with Equipment Supplier (FORM 2)**

**SECTION 1: Interviewee's details**

**1.1) Name:**

**1.2) Employer:**

**1.3) Position:**

**1.4) Work address:**

**1.5) Telephone No:**

## SECTION 2) Equipment

### 2.1) Which of these equipment do you supply?

| Equipment                     | Tick if supply (√) | Equipment                        | Tick if supply (√) |
|-------------------------------|--------------------|----------------------------------|--------------------|
| Tractor (2WD)                 |                    | Roller (Hand drawn)              |                    |
| Tractor (4WD)                 |                    | Plate compactor                  |                    |
| Tipper truck                  |                    | Towed bowser                     |                    |
| Flat truck                    |                    | Concrete mixer                   |                    |
| Trailer                       |                    | Concrete vibrator                |                    |
| Wheelbarrow                   |                    | Motor grader                     |                    |
| Roller (Ride on vibratory)    |                    | Towed Grader                     |                    |
| Roller (Towed vibratory)      |                    | Mobile small-scale stone crusher |                    |
| Roller (Towed deadweight)     |                    | Bitumen heater                   |                    |
| Roller (Pedestrian vibratory) |                    | Bitumen hand sprayer             |                    |
| Roller (Deadweight)           |                    |                                  |                    |

### 2.2) What are the top 4 most typical models? How much does each model cost (new and second hand)? How many do you sell of each model?

| Typical model |       |                           | New          |                 | 2 <sup>nd</sup> Hand |               |                 |
|---------------|-------|---------------------------|--------------|-----------------|----------------------|---------------|-----------------|
| Brand         | Model | Power, Volume, Weight [a] | Price (US\$) | Number per year | Av. Price (US\$)     | Av. age (yrs) | Number per year |
|               |       |                           |              |                 |                      |               |                 |
|               |       |                           |              |                 |                      |               |                 |
|               |       |                           |              |                 |                      |               |                 |

[a] For tipper trucks, flat trucks, trailer, water bowser, wheel barrow, concrete mixer, bitumen heater, bitumen hand sprayer (please provide volume, cubic metres).

For rollers please provide weight, (kg, tones)

For tractors and motor graders please provide power (e.g. 100 hp).

For concrete vibrator please provide diameter (E.g. 3 inch)

### 2.3) Do you hire this equipment out? (Y/N)

If yes, please provide details on the model, hire out rate and the number you hire out per year?

| Typical model |       |                           | Hire out rate (\$/month) | Number hire out per year |
|---------------|-------|---------------------------|--------------------------|--------------------------|
| Brand         | Model | Volume, Power, Weight [a] |                          |                          |
|               |       |                           |                          |                          |
|               |       |                           |                          |                          |
|               |       |                           |                          |                          |

[a] For tipper trucks, flat trucks, trailer, water bowser, wheel barrow, concrete mixer, volume, bitumen heater, bitumen hand sprayer please provide (cubic metres).

For rollers please provide weight.

For tractors and motor graders please provide power (e.g. 35 hp).

For concrete vibrator please provide diameter (E.g. 3 inch)

**2.4) Do you feel that there is insufficient demand for the equipment that you sell? (Y/N)**

**If yes, please indicate why**

**2.5) Is there excess demand for the equipment you supply (i.e. cannot meet demand)? (Y/N)**

**If yes, which periods of the year? (E.g. throughout the year, months, wet season, dry season etc.)**

**2.6) Do you import the equipment? (Y/N)**

**If yes, from which country(s)?**

**2.7a) What are the typical importation procedures?**

**2.7b) What are common barriers to importation?**

**2.7c) Is there any potential for this equipment to be manufactured locally? (Y/N/Don't know)**

APPENDIX IV

Required Equipment for Various Road Surfacing Technologies

| Equipment                   | Engineered Natural Surface | Soil Stabilisation | Natural Gravel / Laterite | Water Bound Macadam | Dry Bound Macadam | Crushed Stone Macadam | Hand Packed Stone | Telford Paving | Cobble Stones | Stone Setts or Pavement | Dressed Stone | Mortared Stone | Stone Chippings | Slurry Bound Macadam | Bituminous Sand Seal | Bituminous Chip Seal | Slurry Seal | Ottaseal <sup>38</sup> | Penetration Macadam (Bitumen) | Pre-Mix Macadam (Bitumen) | Burnt Clay Brick | Concrete Brick | Un-Reinforced Concrete | Steel Reinforced Concrete | Bamboo Reinforced Concrete | Geo-Cell Paving | Stone Chipping Binding |   |  |
|-----------------------------|----------------------------|--------------------|---------------------------|---------------------|-------------------|-----------------------|-------------------|----------------|---------------|-------------------------|---------------|----------------|-----------------|----------------------|----------------------|----------------------|-------------|------------------------|-------------------------------|---------------------------|------------------|----------------|------------------------|---------------------------|----------------------------|-----------------|------------------------|---|--|
| Tractor (2WD)               | ✓                          | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      |   |  |
| Tractor (4WD)               | ✓                          | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      |   |  |
| Tipper Truck                |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Flat Truck                  |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Dumpers                     |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Power Tiller                |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Itan                        |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Trailer                     | ✓                          | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      | ✓ |  |
| Wheelbarrow                 | ✓                          | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      | ✓ |  |
| Pedestrian Vibrating Roller | ✓                          |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Towed Deadweight Roller     |                            |                    |                           | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      | ✓ |  |
| Ride On Vibrating Roller    |                            |                    |                           | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      | ✓ |  |
| Towed Vibrating Roller      | ✓                          | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      | ✓ |  |
| Towed Bowser                | ✓                          | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                       | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                      | ✓ |  |
| Hand Drawn Roller           |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Laden Truck / Traffic       |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Vibrating Plate             |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |
| Concrete Mixer              |                            |                    |                           |                     |                   |                       |                   |                |               |                         |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                        |   |  |

<sup>38</sup> Needs pneumatic tyred roller

| Equipment                    | Engineered Natural Surface | Soil Stabilisation | Natural Gravel / Latelite | Water Bound Macadam | Dry Bound Macadam | Crushed Stone Macadam | Hand Packed Stone | Telford Paving | Cobble Stones | Stone Sets or Pave' | Dressed Stone | Mortared Stone | Stone Chippings | Slurry Bound Macadam | Bituminous Sand Seal | Bituminous Chip Seal | Slurry Seal | Ottaseal <sup>13</sup> | Penetration Macadam (Bitumen) | Pre-Mix Macadam (Bitumen) | Burnt Clay Brick | Concrete Brick | Un-Reinforced Concrete | Steel Reinforced Concrete | Bamboo Reinforced Concrete | Geo-Cell Paving | Stone Chipping Blinding |   |
|------------------------------|----------------------------|--------------------|---------------------------|---------------------|-------------------|-----------------------|-------------------|----------------|---------------|---------------------|---------------|----------------|-----------------|----------------------|----------------------|----------------------|-------------|------------------------|-------------------------------|---------------------------|------------------|----------------|------------------------|---------------------------|----------------------------|-----------------|-------------------------|---|
| Concrete Vibrator            | ✓                          |                    |                           |                     |                   |                       |                   |                |               |                     |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |
| Concrete Dumper              |                            |                    |                           |                     |                   |                       |                   |                |               |                     |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |
| Concrete Paver Press         |                            |                    |                           |                     |                   |                       |                   |                |               |                     |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |
| Hand Operated Mobile Crusher |                            |                    |                           | ✓                   | ✓                 | ✓                     |                   | ✓              |               |                     |               |                | ✓               |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |
| Towed Grader                 |                            | ✓                  | ✓                         | ✓                   | ✓                 | ✓                     | ✓                 | ✓              | ✓             | ✓                   | ✓             | ✓              | ✓               | ✓                    | ✓                    | ✓                    | ✓           | ✓                      | ✓                             | ✓                         | ✓                | ✓              | ✓                      | ✓                         | ✓                          | ✓               | ✓                       | ✓ |
| Bitumen Heater               |                            |                    |                           |                     |                   |                       |                   |                |               |                     |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |
| Bitumen Hand Sprayer         |                            |                    |                           |                     |                   |                       |                   |                |               |                     |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |
| Fuel Bowser                  |                            |                    |                           |                     |                   |                       |                   |                |               |                     |               |                |                 |                      |                      |                      |             |                        |                               |                           |                  |                |                        |                           |                            |                 |                         |   |

Note: It is assumed that the construction would start from the re-shaping of the sub-grade. Sub-base and base (where applicable) would subsequently be constructed.

>6T – greater than 6 tonnes; 1-3T – between 1 to 3 tonnes; 3Tm – minimum 3 tonnes; >60kg – greater than 60 kg; >80l – would require greater than 80 litres

Analysis based on the minimum equipment requirements.

Main equipment from the analysis:

- (i) Tractor (2WD) and Tractor (4WD) –for towing a trailer in order to transport maintenance materials and for towing grader
  - (ii) Trailer – for transporting construction materials (< 10km)
  - (iii) Tipper truck, Flat truck and Itean – for transporting construction materials (> 10km)
  - (iv) Wheelbarrow – for transporting construction material for a short-distance during construction and maintenance.
  - (v) Pedestrian vibratory roller, Towed deadweight roller (>6T and 1-3 tonnes ), Towed vibratory roller (>3T, >1T), Vibrating plate (>60kg) - for compaction
  - (vi) Towed Bowser – watering equipment
  - (vii) Concreting equipment: concrete mixer (>80l and 250l) and vibrator
  - (viii) Hand operated mobile crusher – for crushing of rock and stone
  - (ix) Towed grader – to shape road surface
- Bitumen related equipment: bitumen heater and bitumen hand sprayer.

APPENDIX V

Equipment Operating Costs

| Equipment/Vehicle             | Make              | Model      | Depreciation | Interest | Maintenance costs | Cost of tyres | Fuel & lub. costs | Operators wages | Overhead | Total Operating Costs |
|-------------------------------|-------------------|------------|--------------|----------|-------------------|---------------|-------------------|-----------------|----------|-----------------------|
| Tipper Truck                  | Hyundai           | HD 72      | 2.19         | 2.93     | 0.63              | 0.38          | 11.11             | 1.13            | 0.18     | 18.54                 |
| Flat Truck                    | Isuzu             | FRR33H4    | 1.56         | 2.10     | 0.45              | 0.38          | 7.96              | 1.13            | 0.14     | 13.70                 |
| Tractor (2WD)                 | Kobuta            | MX 500     | 1.56         | 2.10     | 0.37              | 0.25          | 4.64              | 1.13            | 0.10     | 10.14                 |
| Tractor (4WD)                 | Kobuta            | 9570       | 2.63         | 3.52     | 0.48              | 0.25          | 4.64              | 1.13            | 0.13     | 12.76                 |
| Trailer                       | Local manufacture |            | 0.11         | 0.14     | 0.08              | 0.07          | -                 | -               | 0.00     | 0.41                  |
| Wheelbarrow                   | Local manufacture |            | 0.01         | 0.00     | -                 | -             | -                 | 0.30            | 0.00     | 0.31                  |
| Roller (ride on vibratory)    | Komatsu           | 100 JVA    | 13.00        | 17.44    | 1.18              | 0.20          | 10.13             | 1.02            | 0.43     | 43.39                 |
| Roller (pedestrian vibratory) | Komatsu           | JV08HM     | 0.78         | 1.05     | 0.11              | 0.13          | 4.02              | 0.64            | 0.07     | 6.79                  |
| Roller (towed vibratory)      | XCMG              | YZ12JC     | 1.84         | 2.47     | 0.27              | 0.25          | 2.54              | -               | 0.07     | 7.45                  |
| Roller (deadweight)           | Bomag             | BW 154AD-2 | 2.40         | 3.22     | 0.50              | 0.40          | 7.63              | 1.02            | 0.15     | 15.32                 |
| Roller (hand drawn)           | Sakai             | TS 10 H    | 0.44         | 0.59     | 0.15              | 0.06          | 0.01              | 0.64            | 0.02     | 1.90                  |
| Roller (towed deadweight)     | Bitelli           |            | 0.06         | 0.08     | 0.02              | 0.13          | 0.01              | -               | 0.00     | 0.31                  |
| Plate Compactor               | Mikasa            | MVH-120    | 0.51         | 0.34     | 0.10              | -             | 2.01              | 1.02            | 0.04     | 4.02                  |
| Water Bowser (self propelled) | Unkown            |            | 11.67        | 15.65    | 0.63              | 0.38          | 11.11             | 6.00            | 0.45     | 45.87                 |
| Water Bowser (towed)          | Herculano         | RT 4000    | 0.83         | 1.12     | 0.24              | 0.17          | -                 | -               | 0.02     | 2.38                  |
| Concrete Mixer                | Local manufacture |            | 0.37         | 0.24     | 0.03              | 0.09          | 1.51              | 0.64            | 0.03     | 2.90                  |
| Concrete Vibrator             | Mikasa            | MSX-28     | 0.10         | 0.04     | 0.02              | -             | 1.01              | 1.02            | 0.02     | 2.22                  |
| Bitumen Heater                | Vina Bima         | NBT-100    | 0.39         | 0.42     | 0.05              | -             | -                 | 0.85            | 0.02     | 1.73                  |
| Bitumen Hand sprayer          | Vina Bima         | PBT-100    | 0.65         | 0.70     | 0.03              | 0.17          | -                 | 0.85            | 0.02     | 2.42                  |

Source: Contractor surveys; Equipment supplier surveys; IT Transport (2003); Larcher (1997)

**Financial Operating, Productivity and Utilisation Rates of Costs of Typical Equipment**

| Equipment                       | Typical Model / Brand | Productivity |             |             | Utilisation rate (hrs/year) | Financial operating cost (US\$/hr) |
|---------------------------------|-----------------------|--------------|-------------|-------------|-----------------------------|------------------------------------|
|                                 |                       | Activity     | Value       | Unit        |                             |                                    |
| Tipper Truck                    | Hyundai HD 72         | Haulage      | 71.11       | tonne.km/hr | 1,600                       | 18.54                              |
| Flat Truck                      | Isuzu FRR33H4         | Haulage      | 30.44       | tonne.km/hr | 1,600                       | 13.70                              |
| Tractor 2WD                     | Kobuta MX 500         | Haulage      | 13.09       | tonne.km/hr | 1,600                       | 10.14                              |
| Tractor 4WD                     | Kobuta 9570           | Haulage      | 25.71       | tonne.km/hr | 1,600                       | 12.76                              |
| Trailer                         | Local manufacture     | Haulage      | see tractor |             | 1,400                       | 0.41                               |
| Wheelbarrow                     | Local manufacture     | Haulage      | 0.24        | tonne.km/hr | 1,200                       | 0.31                               |
| Roller (ride on vibratory)      | Komatsu 100 JVA       | Compaction   | 1,365.00    | m2/hr       | 1,000                       | 43.39                              |
| Roller (pedestrian vibratory)   | Komatsu JV08HM        | Compaction   | 80.76       | m2/hr       | 1,600                       | 6.79                               |
| Roller (towed vibratory)        | XCMG YZ121C           | Compaction   | 1,365.00    | m2/hr       | 1,600                       | 7.45                               |
| Roller (ride on deadweight)     | Bomag BW 154AD-2      | Compaction   | 270.00      | m2/hr       | 1,000                       | 15.32                              |
| Roller (deadweight, hand drawn) | Sakai TS 10 H         | Compaction   | 30.00       | m2/hr       | 1,600                       | 1.90                               |
| Roller (towed deadweight)       | Bitelli               | Compaction   | 63.00       | m2/hr       | 1,600                       | 0.31                               |
| Vibrating Plate                 | Mikasa MVH-120        | Compaction   | 1.73        | m2/hr       | 1,000                       | 4.02                               |
| Water Bowser (self-propelled)   | Unknown               | Watering     | 457.14      | m2/hr       | 300                         | 45.87                              |
| Water Bowser (towed)            | Herculano RT 4000     | Watering     | 194.29      | m2/hr       | 600                         | 2.38                               |
| Concrete Mixer                  | Local manufacture     | Concreting   | 6.72        | m3/hr       | 1,600                       | 2.90                               |
| Concrete Vibrator               | Mikasa MSX-28         | Concreting   | 6.72        | m3/hr       | 1,000                       | 2.22                               |
| Bitumen Heater                  | Vina Bima NBT-100     | Bitumen      | 252.95      | m2/hr       | 1,600                       | 1.73                               |
| Bitumen Hand Sprayer            | Vina Bima PBT-100     | Bitumen      | 252.95      | m2/hr       | 1,600                       | 2.42                               |

Source: Contractor surveys, Equipment supplier surveys, Equipment manufacturers, 'Cost Comparison Study', Mozambique, ILO, 2003' and 'Tools and Equipment-Design, Development and Specifications', Regional Seminar Papers, ASIST, 1997.

## APPENDIX VII

### Rural Road Work Activities in Cambodia, Vietnam and Laos

#### Cambodia

The Cambodian Rural Road Strategic Plan (Ministry of Rural Development, 2007) was used as the main source to ascertain the programme for the rural road network.

Three scenarios are proposed (see table below), however, all three options aim to bring all Tertiary Roads to a maintainable standard in 7 years and all Sub-Tertiary 1 Roads to a maintainable standard in 10 years. The scenarios differ in their proposed strategy for Sub-Tertiary 2 and Sub-Tertiary 3 Roads. The consultant's of this report have been advised by the authors of the Cambodian Rural Transport Strategy that Scenario 3 is the most likely.

#### Cambodian Rural Transport Strategy (Criteria)

| Criteria                                             | Scenario 1 | Scenario 2 | Scenario 3 |
|------------------------------------------------------|------------|------------|------------|
| Bring all T roads to a maintainable standard (yrs)   | 7          | 7          | 7          |
| Bring all ST1 roads to a maintainable standard (yrs) | 10         | 10         | 10         |
| Bring all ST2 roads to a maintainable standard (yrs) | 10         | 10         | 15         |
| Bring all ST3 roads to a maintainable standard (yrs) | 10         | 15         | 20         |

Source: Ministry of Rural Development (2007),

The table below provides the development, periodic and routine maintenance of paved, gravel and earth roads.

#### Cambodian Rural Transport Strategy, Rural road work activities (km/year, 2007/8-2011/12)

| Activity             | Surface | Tertiary | Tertiary 1 | Tertiary 2&3 | Total |
|----------------------|---------|----------|------------|--------------|-------|
| Construction         | Paved   | 103      | -          | -            | 103   |
| Construction         | Gravel  | 103      | 232        | 1,046        | 1,381 |
| Periodic Maintenance | Paved   | -        | -          | -            | -     |
| Periodic Maintenance | Gravel  | 325      | 349        | 1,408        | 2,081 |
| Routine Maintenance  | Paved   | 103      |            |              | 103   |
| Routine Maintenance  | Gravel  | 933      | 890        | 3,652        | 5,475 |

Source: Ministry of Rural Development (2007),

#### Vietnam

Plans developed by the Ministry of Transport (MOT), Vietnam were used as the main source to obtain planned expansion and maintenance forecasts. The aim of the plans is to pave 55% of the rural network by the 2010 (World Bank, 2006). It assumes no expansion of the total rural network length, only a redistribution of the paved/gravel/earth composition. Gravel and earth roads are assumed to be periodically maintained every 5 years, and paved roads are assumed to require paving and periodic maintenance every seven years (however, newly built roads are not subject to any form of periodic maintenance). All roads are assumed to require routine maintenance once every year unless they have been constructed or are being subjected to periodic maintained, in which case they will be routinely maintained in the following year.

#### Laos

The National Strategy on Accelerated Provision of Rural Transport Infrastructure document was used as the main source to ascertain the planned rural road network strategy for Laos (Ministry of Communication Transport Post and Construction, 2007). It articulates that approximately 11,000 km of rural roads require construction and that 19% of the network is

open all-year round and are therefore eligible for periodic maintenance. All roads are assumed to require routine maintenance once every year unless they have been constructed or are being subjected to periodic maintained, in which case they will be routinely maintained in the following year.

## Appendix VIII

### Contractors that own or have hired equipment in the last 12 months

| Equipment                        | Percentage of contractors that own/hire[a] |          |           |          |           |          |
|----------------------------------|--------------------------------------------|----------|-----------|----------|-----------|----------|
|                                  | Total                                      |          | Cambodia  |          | Vietnam   |          |
|                                  | Own                                        | Hire     | Own       | Hire     | Own       | Hire     |
| Tipper Truck                     | 87 (4.5)                                   | 49 (3.3) | 82 (3.6)  | 49 (2.6) | 93 (5.2)  | 50 (4)   |
| Flat Truck                       | 23 (2.2)                                   | 1 (10)   | 18 (2.6)  | 3 (10)   | 28 (2)    | 0 (0)    |
| Tractor 2WD                      | 3 (1.5)                                    | 0 (0)    | 0 (0)     | 0 (0)    | 5 (1.5)   | 0 (0)    |
| Tractor 4WD                      | 14 (1.4)                                   | 10 (1)   | 21 (1.5)  | 15 (1)   | 8 (1)     | 5 (1)    |
| Trailer                          | 27 (1.3)                                   | 15 (1.1) | 33 (1.3)  | 3 (1)    | 20 (1.4)  | 28 (1.1) |
| Wheelbarrow                      | 76 (15.5)                                  | 1 (2)    | 67 (18.2) | 0 (0)    | 85 (13.4) | 3 (2)    |
| Roller (ride on vibratory)       | 77 (1.8)                                   | 39 (1.1) | 77 (1.5)  | 38 (1.1) | 78 (2.1)  | 40 (1.1) |
| Roller (pedestrian vibratory)    | 9 (2)                                      | 0 (0)    | 18 (2)    | 0 (0)    | 0 (0)     | 0 (0)    |
| Roller (towed vibratory)         | 1 (1)                                      | 0 (0)    | 3 (1)     | 0 (0)    | 0 (0)     | 0 (0)    |
| Roller (ride on deadweight)      | 65 (2.6)                                   | 8 (1.3)  | 36 (1.1)  | 0 (0)    | 93 (3.2)  | 15 (1.3) |
| Roller (deadweight, hand drawn)  | 34 (1.6)                                   | 0 (0)    | 46 (1.5)  | 0 (0)    | 23 (1.9)  | 0 (0)    |
| Roller (towed deadweight)        | 0 (0)                                      | 0 (0)    | 0 (0)     | 0 (0)    | 0 (0)     | 0 (0)    |
| Vibrating Plate                  | 43 (2.3)                                   | 6 (1.2)  | 28 (2.1)  | 8 (1)    | 58 (2.4)  | 5 (1.5)  |
| Water Bowser (self propelled)    | 53 (1.9)                                   | 13 (1.3) | 38 (1.4)  | 15 (1)   | 68 (2.1)  | 10 (1.8) |
| Water Bowser (towed)             | 24 (1.4)                                   | 4 (1)    | 36 (1.4)  | 3 (1)    | 13 (1.2)  | 5 (1)    |
| Concrete Mixer                   | 77 (3.5)                                   | 8 (2.5)  | 56 (2.7)  | 5 (1)    | 98 (3.9)  | 10 (3.3) |
| Concrete Vibrator                | 75 (4.9)                                   | 5 (1.8)  | 54 (2.7)  | 5 (2)    | 95 (6.1)  | 5 (1.5)  |
| Mobile Small-Scale Stone Crusher | 16 (1.8)                                   | 3 (1)    | 0 (0)     | 0 (0)    | 33 (1.8)  | 5 (1)    |
| Motor Grader                     | 61 (1.9)                                   | 37 (1.3) | 44 (1.5)  | 51 (1.3) | 78 (2.1)  | 23 (1.4) |
| Towed Grader                     | 0 (0)                                      | 0 (0)    | 0 (0)     | 0 (0)    | 0 (0)     | 0 (0)    |
| Bitumen Heater                   | 41 (1.6)                                   | 14 (1.4) | 10 (1.8)  | 3 (2)    | 70 (1.6)  | 25 (1.3) |
| Bitumen Hand Sprayer             | 38 (2.1)                                   | 14 (1.3) | 8 (1)     | 3 (2)    | 68 (2.2)  | 25 (1.2) |

Source: Contractor surveys

## Appendix IX

### Total company annual turnover (for rural road sub-sector only) Percentages (total values in brackets)

| Turnover (US\$)     | Total   | Cambodia | Vietnam |
|---------------------|---------|----------|---------|
| Less than 5,000     | 3 (2)   | 5 (2)    | 0 (0)   |
| 5,000 to 9,999      | 3 (2)   | 5 (2)    | 0 (0)   |
| 10,000 to 19,999    | 13 (10) | 23 (9)   | 3 (1)   |
| 20,000 to 39,999    | 18 (14) | 21 (8)   | 15 (6)  |
| 40,000 to 80,000    | 25 (20) | 23 (9)   | 28 (11) |
| 80,000 to 199,999   | 15 (12) | 13 (5)   | 18 (7)  |
| 200,000 to 499,999  | 13 (10) | 0 (0)    | 26 (10) |
| 500,000 to 999,999  | 4 (3)   | 0 (0)    | 8 (3)   |
| more than 1,000,000 | 1 (1)   | 0 (0)    | 3 (1)   |
| No data available   | 6 (5)   | 13 (5)   | 0 (0)   |
| Not stated          | 0 (0)   | 0 (0)    | 0 (0)   |

Source: Contractor surveys

**APPENDIX X****Total company annual turnover (for all commercial sectors). Percentages (total values in brackets)**

| <b>Turnover (US\$)</b> | <b>Total</b> | <b>Cambodia</b> | <b>Vietnam</b> |
|------------------------|--------------|-----------------|----------------|
| Less than 5,000        | 0 (0)        | 0 (0)           | 0 (0)          |
| 5,000 to 9,999         | 0 (0)        | 0 (0)           | 0 (0)          |
| 10,000 to 19,999       | 5 (4)        | 10 (4)          | 0 (0)          |
| 20,000 to 39,999       | 8 (6)        | 15 (6)          | 0 (0)          |
| 40,000 to 80,000       | 11 (9)       | 23 (9)          | 0 (0)          |
| 80,000 to 199,999      | 23 (18)      | 38 (15)         | 8 (3)          |
| 200,000 to 499,999     | 13 (10)      | 0 (0)           | 26 (10)        |
| 500,000 to 999,999     | 25 (20)      | 0 (0)           | 51 (20)        |
| more than 1,000,000    | 9 (7)        | 0 (0)           | 18 (7)         |
| No data available      | 5 (4)        | 10 (4)          | 0 (0)          |
| Not stated             | 1 (1)        | 3 (1)           | 0 (0)          |

Source: Contractor surveys

**Contractors facing difficulty in equipment procurement**

| Equipment                        | Percentage of contractors that have had difficulty acquiring |          |         |
|----------------------------------|--------------------------------------------------------------|----------|---------|
|                                  | Total                                                        | Cambodia | Vietnam |
| Tipper Truck                     | 1                                                            | 0        | 3       |
| Flat Truck                       | 0                                                            | 0        | 0       |
| Tractor 2WD                      | 0                                                            | 0        | 0       |
| Tractor 4WD                      | 1                                                            | 0        | 3       |
| Trailer                          | 1                                                            | 3        | 0       |
| Wheelbarrow                      | 0                                                            | 0        | 0       |
| Roller (ride on vibratory)       | 3                                                            | 0        | 5       |
| Roller (pedestrian vibratory)    | 1                                                            | 0        | 3       |
| Roller (towed vibratory)         | 0                                                            | 0        | 0       |
| Roller (ride on deadweight)      | 1                                                            | 0        | 3       |
| Roller (deadweight, hand drawn)  | 0                                                            | 0        | 0       |
| Roller (towed deadweight)        | 0                                                            | 0        | 0       |
| Vibrating Plate                  | 0                                                            | 0        | 0       |
| Water Bowser (self propelled)    | 4                                                            | 0        | 8       |
| Water Bowser (towed)             | 0                                                            | 0        | 0       |
| Concrete Mixer                   | 1                                                            | 0        | 3       |
| Concrete Vibrator                | 1                                                            | 0        | 3       |
| Mobile Small-Scale Stone Crusher | 4                                                            | 0        | 8       |
| Motor Grader                     | 3                                                            | 0        | 5       |
| Towed Grader                     | 1                                                            | 0        | 3       |
| Bitumen Heater                   | 6                                                            | 0        | 13      |
| Bitumen Hand Sprayer             | 5                                                            | 0        | 10      |

Source: Contractor surveys

**APPENDIX XII**

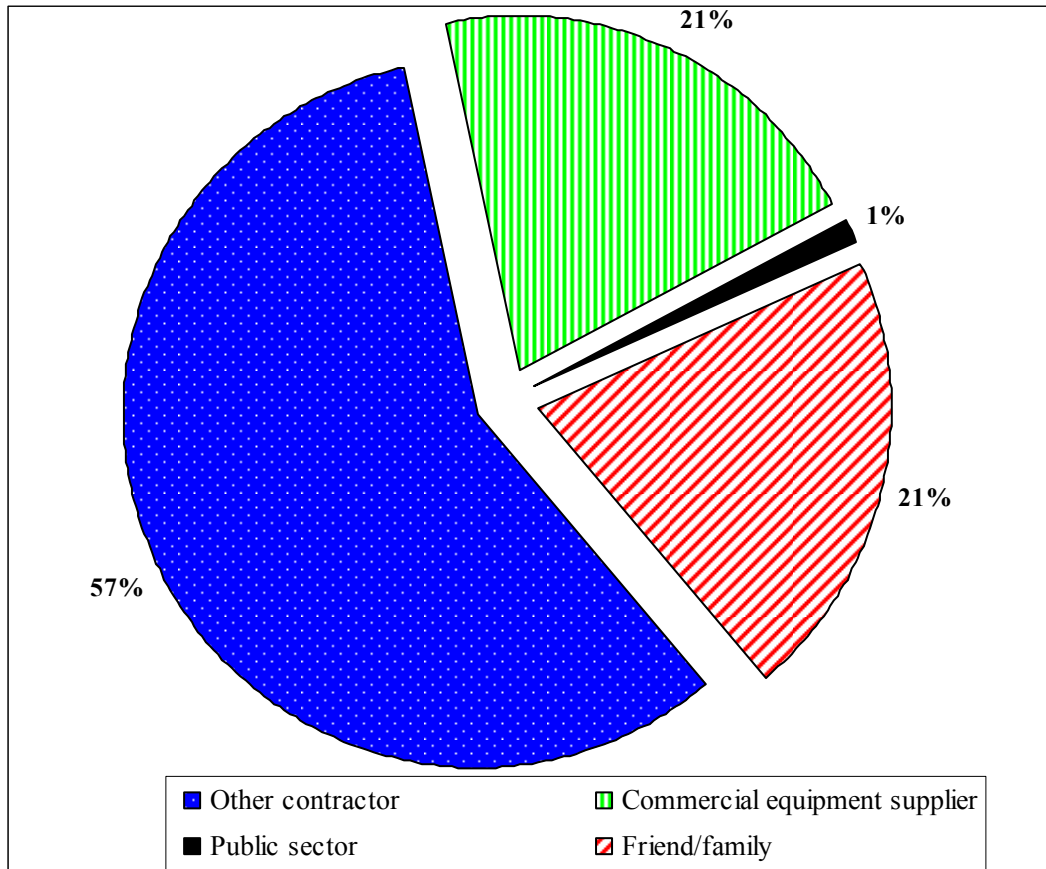
**Equipment suppliers**

| <b>Equipment</b>              | <b>Equipment Supplier</b>                       | <b>Address</b>                                                          | <b>Country</b> |
|-------------------------------|-------------------------------------------------|-------------------------------------------------------------------------|----------------|
| Tipper truck                  | Khounxay Bridge & Road Conatruction Company     | Ban Nongbouathong, Sikot District, Vientiane, Vientiane                 | Laos           |
|                               | Loa Development                                 | Ban Thongkhankham, Chanthabouly District, Vientiane                     | Laos           |
|                               | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
|                               | Vehicle Assemble Factory Company                | Donekoy, T 4 Road, Hatsayphong District, Vientiane                      | Laos           |
|                               | Sovann Yaun Company                             | #271 E0, St Tep Phan, Phnom Penh                                        | Cambodia       |
|                               | V-TRAC                                          | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi  | Vietnam        |
| Flat truck                    | Komatsu Vietnam JSC                             | K2 Office - 14 Thuy Khue Street, Tay Ho District, Hanoi                 | Vietnam        |
|                               | Vehicle Assemble Factory Company                | Donekoy, T 4 Road, Hatsayphong District, Vientiane                      | Laos           |
|                               | Sovann Yaun Company                             | #271 E0, St Tep Phan, Phnom Penh                                        | Cambodia       |
|                               | Xuan Kien Automobile Factory                    | 2 Trieu Quoc Dat Street, Hanoi                                          | Vietnam        |
|                               | Megastar Motor Company                          | No 406 Tran Khat Chan Street - Hanoi                                    | Vietnam        |
|                               | Insithong Motor Company                         | Ban Nongdouang Neau, Samsenethai Road, Sikhottabong District, Vientiane | Laos           |
| Tractor 2WD                   | Agriculture Development Co. Ltd.                | # 117, St 126, Phnom Penh                                               | Cambodia       |
|                               | Vietnam Engine and Agricultural Machinery Corp. | 2 Trieu Quoc Dat Street, Hanoi                                          | Vietnam        |
| Tractor 4WD                   | Insithong Motor Company                         | Ban Nongdouang Neau, Samsenethai Road, Sikhottabong District, Vientiane | Laos           |
|                               | Agriculture Development Co. Ltd.                | # 117, St 126, Phnom Penh                                               | Cambodia       |
| Trailer                       | Vietnam Engine and Agricultural Machinery Corp. | 2 Trieu Quoc Dat Street, Hanoi                                          | Vietnam        |
|                               | Keo Motor Heavy Equipments                      | Nonghai, Hatsayphong District, Vientiane                                | Laos           |
|                               | Khounxay Bridge & Road Conatruction Company     | Ban Nongbouathong, Sikot District, Vientiane                            | Laos           |
|                               | Loa Development                                 | Ban Thongkhankham, Chanthabouly District, Vientiane                     | Laos           |
|                               | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
|                               | Megastar Motor Company                          | No 406 Tran Khat Chan Street - Hanoi                                    | Vietnam        |
| Wheelbarrow                   | Hol Korb Lathes                                 | #66S2, St.163, Toul Tumpong I, Khan Chamcarmon, Phnom Penh              | Cambodia       |
|                               | Pheng Ly Co.                                    | #111, St.155, Sangkat Toul Tompoung I, Khan Chamcarmon, Phnom Penh      | Cambodia       |
|                               | Hoa Phat                                        | 243 Giai Phong Rd., Dong Da District, Hanoi                             | Vietnam        |
|                               | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
| Roller (ride on vibratory)    | Dong Loi Joint Stock Machinery Company          | G7, Lang Quoc te Thang Long – Cau Giay Dist, Hanoi                      | Vietnam        |
|                               | KLLC Ltd Company                                | A22-Lot 9 – Dinh Cong, Hanoi                                            | Vietnam        |
| Roller (pedestrian vibratory) | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
|                               | Seak Ly Co. Ltd.                                | #286, St 182, Phnom Penh                                                | Cambodia       |

| Equipment                        | Equipment Supplier                                      | Address                                                                  | Country  |
|----------------------------------|---------------------------------------------------------|--------------------------------------------------------------------------|----------|
| Roller (towed vibratory)         | Hoa Phat                                                | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
|                                  | Tu Chau Construction Equipment Cooperation (XCMG)       | 24 T2 Building, Trung Hoa-Nhan Chinh New Urban Area, The 17 Floor, Hanoi | Vietnam  |
| Roller (ride on deadweight)      | Seak Ly Co. Ltd.                                        | #286, St 182, Phnom Penh                                                 | Cambodia |
|                                  | Transport Material and Equipment Sharehold Company      | Khuat Duy Tien Road - Thanh Xuan Dist, Hanoi                             | Vietnam  |
| Roller (deadweight, hand drawn)  | V-TRAC                                                  | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi   | Vietnam  |
|                                  | Khounxay Bridge & Road Conatruction Company             | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
| Roller (towed deadweight)        | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
|                                  | Chhim Chiv                                              | #2100A, St 68, Phnom Penh                                                | Cambodia |
| Roller (towed deadweight)        | Loa Development                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                      | Laos     |
|                                  | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
| Vibrating Plate                  | V-TRAC                                                  | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi   | Vietnam  |
|                                  | Keo Motor Heavy Equipments                              | Nonghai, Hatsayphong District, Vientiane                                 | Laos     |
| Vibrating Plate                  | Khounxay Bridge & Road Conatruction Company             | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
|                                  | Loa Development                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                      | Laos     |
| Vibrating Plate                  | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
|                                  | Sam Sokhom                                              | #2058 E0, St 68, Phnom Penh                                              | Cambodia |
| Water Bowser (towed)             | Hoa Phat                                                | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
|                                  | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
| Concrete Mixer                   | Khounxay Bridge & Road Conatruction Company             | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
|                                  | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                                | Laos     |
| Concrete Mixer                   | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
|                                  | Hol Korb Lathes                                         | # 66S2, St 163, Phnom Penh                                               | Cambodia |
| Concrete Vibrator                | Pheng Ly Co.                                            | #111, St.155, Sangkat Toul Tompoung 1, Khan Chamcarmon, Phnom Penh       | Cambodia |
|                                  | Hoa Phat                                                | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
| Concrete Vibrator                | Megastar Motor Company                                  | No 406 Tran Khat Chan Street - Hanoi                                     | Vietnam  |
|                                  | Construction Electrical & Mechanical Equipment Co Ltd., |                                                                          |          |
| Mobile Small-Scale Stone Crusher | Hoa Phat                                                | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                                 | Vietnam  |
|                                  | Thien Hoa An                                            | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
| Motor Grader                     | Keo Motor Heavy Equipments                              | 146 Truong Chinh Str., Dong Da, Hanoi                                    | Vietnam  |
|                                  | Khounxay Bridge & Road Conatruction Company             | Nonghai, Hatsayphong District, Vientiane                                 | Laos     |
| Motor Grader                     | Loa Development                                         | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
|                                  |                                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                      | Laos     |

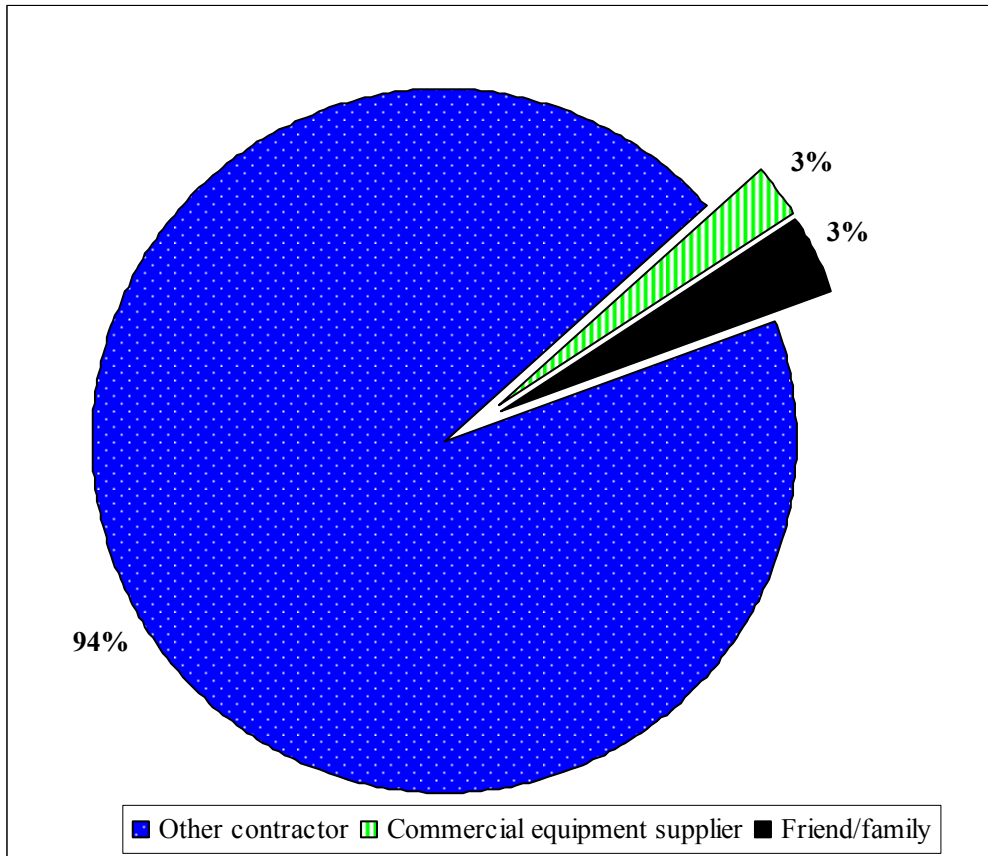
| <b>Equipment</b>     | <b>Equipment Supplier</b>                               | <b>Address</b>                                                         | <b>Country</b> |
|----------------------|---------------------------------------------------------|------------------------------------------------------------------------|----------------|
| Towed Grader         | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                             | Laos           |
|                      | Metro Group Fo Cambodia Co Ltd.                         | #1778, St 5, Phnom Penh                                                | Cambodia       |
|                      | Dong Loi Joint Stock Machinery Company                  | G7, Lang Quoc te Thang Long – Cau Giay Dist, Hanoi                     | Vietnam        |
|                      | V-TRAC                                                  | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi | Vietnam        |
|                      | Komatsu Vietnam JSC                                     | K2 Office - 14 Thuy Khue Street, Tay Ho District, Hanoi                | Vietnam        |
|                      | DTW                                                     | Unit 17ab&c, Street 528, Phnom Penh                                    | Cambodia       |
|                      | Keo Motor Heavy Equipments                              | Nonghai, Hatsayphong District, Vientiane                               | Laos           |
|                      | Khouxay Bridge & Road Conatruction Company              | Ban Nongbouathong, Sikot District, Vientiane                           | Laos           |
|                      | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                              | Laos           |
|                      | Loa Development                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                    | Laos           |
| Bitumen Heater       | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                             | Laos           |
|                      | Construction Electrical & Mechanical Equipment Co Ltd., | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                               | Vietnam        |
|                      | Khouxay Bridge & Road Conatruction Company              | Ban Nongbouathong, Sikot District, Vientiane                           | Laos           |
|                      | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                              | Laos           |
| Bitumen Hand Sprayer | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                             | Laos           |
|                      | Construction Electrical & Mechanical Equipment Co Ltd., | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                               | Vietnam        |
|                      | Khouxay Bridge & Road Conatruction Company              | Ban Nongbouathong, Sikot District, Vientiane                           | Laos           |
|                      | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                              | Laos           |

Source of equipment hire (Cambodia)



Source: Contractor surveys

Source of equipment hire (Vietnam)



Source: Contractor surveys

**APPENDIX XV**

**Contractors that imported or considered importing equipment**

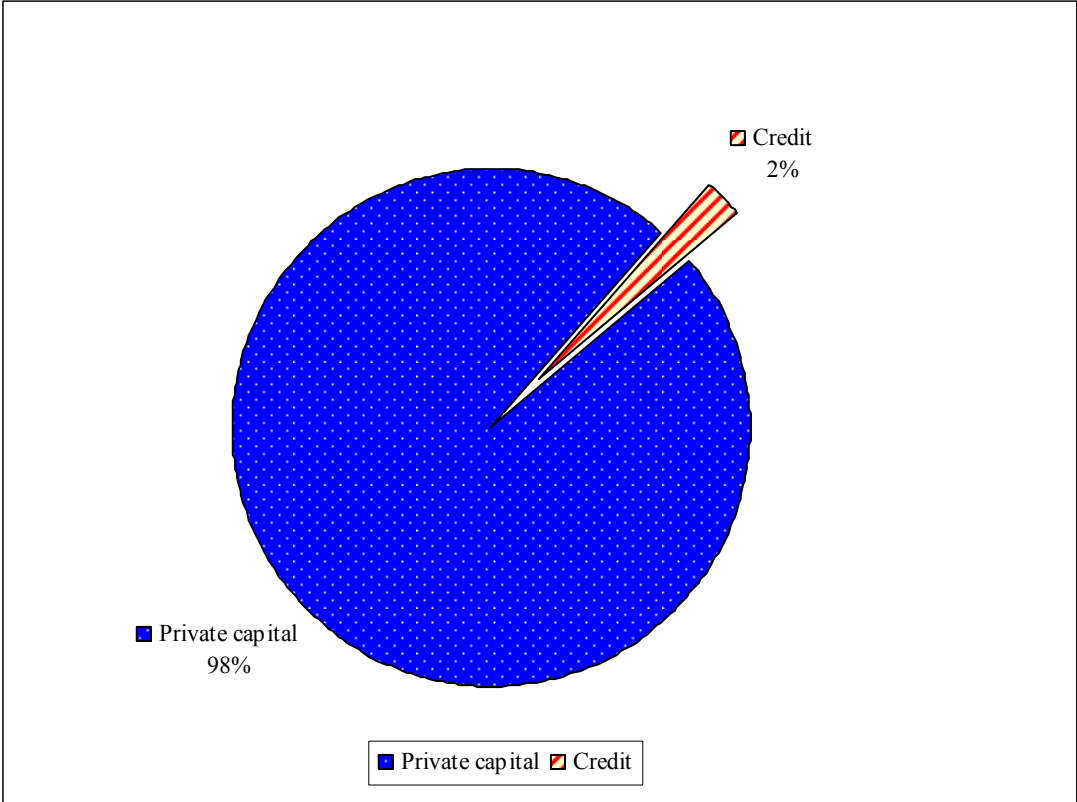
| Equipment                        | Percentage of contractors imported/considered importing |          |         |
|----------------------------------|---------------------------------------------------------|----------|---------|
|                                  | Total                                                   | Cambodia | Vietnam |
| Tipper Truck                     | 4                                                       | 3        | 5       |
| Flat Truck                       | 0                                                       | 0        | 0       |
| Tractor 2WD                      | 0                                                       | 0        | 0       |
| Tractor 4WD                      | 0                                                       | 0        | 0       |
| Trailer                          | 1                                                       | 0        | 3       |
| Wheelbarrow                      | 0                                                       | 0        | 0       |
| Roller (ride on vibratory)       | 5                                                       | 5        | 5       |
| Roller (pedestrian vibratory)    | 0                                                       | 0        | 0       |
| Roller (towed vibratory)         | 1                                                       | 0        | 3       |
| Roller (ride on deadweight)      | 1                                                       | 0        | 3       |
| Roller (deadweight, hand drawn)  | 0                                                       | 0        | 0       |
| Roller (towed deadweight)        | 0                                                       | 0        | 0       |
| Vibrating Plate                  | 0                                                       | 0        | 0       |
| Water Bowser (self propelled)    | 1                                                       | 0        | 3       |
| Water Bowser (towed)             | 0                                                       | 0        | 0       |
| Concrete Mixer                   | 1                                                       | 0        | 3       |
| Concrete Vibrator                | 1                                                       | 0        | 3       |
| Mobile Small-Scale Stone Crusher | 0                                                       | 0        | 0       |
| Motor Grader                     | 3                                                       | 0        | 5       |
| Towed Grader                     | 0                                                       | 0        | 0       |
| Bitumen Heater                   | 4                                                       | 0        | 8       |
| Bitumen Hand Sprayer             | 4                                                       | 0        | 8       |

**APPENDIX XVI**

**Equipment manufacturers**

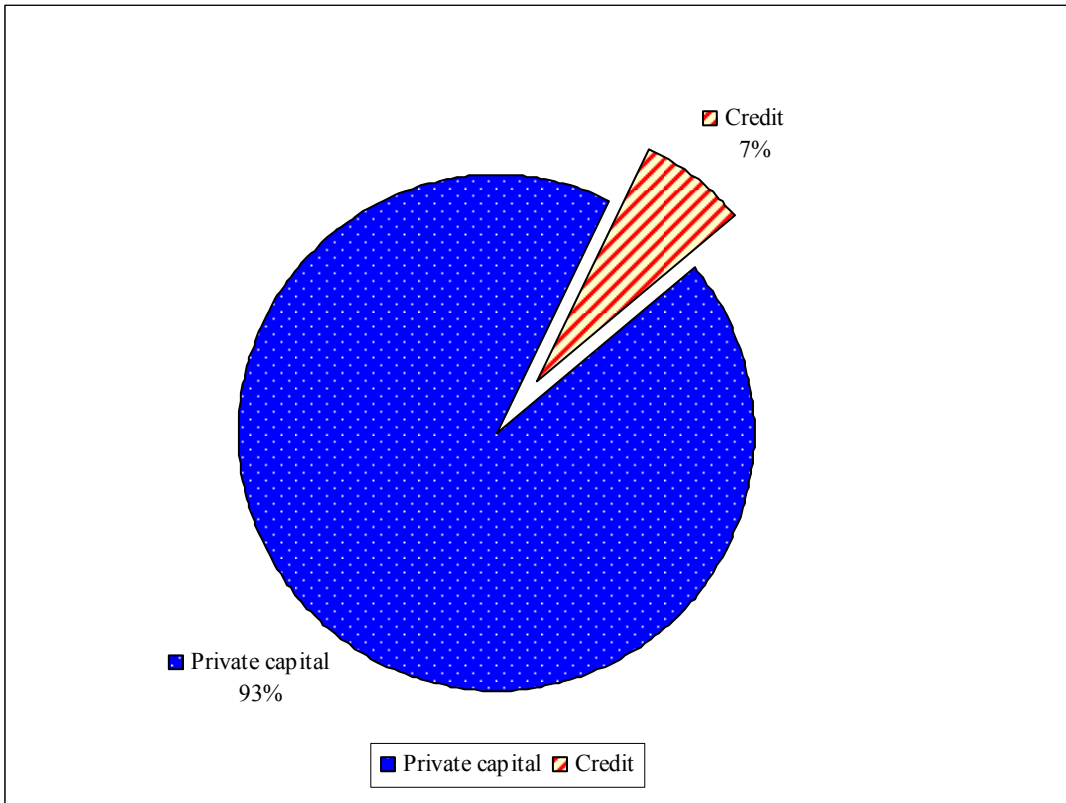
| <b>Equipment</b>                 | <b>Equipment Supplier</b>                              | <b>Address</b>                                                     | <b>Country</b> |
|----------------------------------|--------------------------------------------------------|--------------------------------------------------------------------|----------------|
| Tipper truck                     | Construction Electrical & Mechanical Equipment Co Ltd. | 145 Duc Giang- Long Bien- Gia Lam, Hanoi                           | Vietnam        |
| Flat truck                       | Truong Hai Company                                     | 2 Ngo Gia Tu - Long Bien, Hanoi                                    | Vietnam        |
|                                  | Cuu Long Motor                                         | 500 Hung Trac, Van Lam, Hung Yen                                   | Vietnam        |
|                                  | Xuan Kien Automobile Company                           | Tien Phong commune-Me Linh district, Vinh Phuc Province            | Vietnam        |
| Tractor 2WD                      | Truong Hai Group                                       | Tam Hiep industrial zone, Nui Thanh, Quang Nam                     | Vietnam        |
|                                  | Vietnam Engine and Agricultural Machinery Corp.        | Trieu Quoc Dat Street, Hanoi                                       | Vietnam        |
| Tractor 4WD                      | 1-5 Machinery Company                                  | Dong Anh Town, Hanoi                                               | Vietnam        |
|                                  | Vietnam Engine and Agricultural Machinery Corp.        | Trieu Quoc Dat Street, Hanoi                                       | Vietnam        |
| Trailer                          | Cuu Long Motor                                         | 500 Hung Trac, Van Lam, Hung Yen                                   | Vietnam        |
| Wheelbarrow                      | Hol Korb Lathes                                        | #66S2, St.163, Toul Tumpoung I, Khan Chamcarmon, Phnom Penh        | Cambodia       |
|                                  | Pheng Ly Co.                                           | #111, St.155, Sangkat Toul Tompoung 1, Khan Chamcarmon, Phnom Penh | Cambodia       |
|                                  | 3-2 Machinery Company                                  | 18 Giai Phong Str., Dong Da Dist., Hanoi                           | Vietnam        |
| Vibrating Plate                  | Rong Riet                                              | 109, Highway 1A, Thanh Xuan Precinct, District 12                  | Vietnam        |
|                                  | Hol Korb Lathes                                        | #66S2, St.163, Toul Tumpoung I, Khan Chamcarmon, Phnom Penh        | Cambodia       |
| Concrete mixer                   | Pheng Ly Co.                                           | #111, St.155, Sangkat Toul Tompoung 1, Khan Chamcarmon, Phnom Penh | Cambodia       |
|                                  | Hoa Phat                                               | Pho Noo Industrial Zone, Hung Yen                                  | Vietnam        |
|                                  | 1-5 Machinery Company                                  | Dong Anh Town, Hanoi                                               | Vietnam        |
|                                  | 3-2 Machinery Company                                  | 18 Giai Phong Str., Dong Da Dist., Hanoi                           | Vietnam        |
|                                  | IMI Institute                                          | 34 Lang Ha Str., Dong Da Dist., Hanoi                              | Vietnam        |
| Mobile Small-Scale Stone Crusher | Rong Riet                                              | 109, Highway 1A, Thanh Xuan Precinct, District 12                  | Vietnam        |
|                                  | Hoa Phat                                               | Pho Noo Industrial Zone, Hung Yen                                  | Vietnam        |
| Bitumen heaters                  | Construction Electrical & Mechanical Equipment Co Ltd. | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                           | Vietnam        |
| Bitumen handsprayers             | Construction Electrical & Mechanical Equipment Co Ltd. | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                           | Vietnam        |

Method of equipment finance (Cambodia)



Source: Contractor surveys

Method of equipment finance (Vietnam)



Source: Contractor surveys

## APPENDIX XIX

### Grader unit operating costs for equipment purchase (US\$ per hour) when the motor grader is being utilised at 900 hours per annum

| New/Second hand | Model & Brand             | Technology             | Size   | Depreciation (US\$/hour) | Interest (US\$/hour) | Maintenance costs (US\$/hour) | Cost of tyres (US\$/hour) | Fuel & lub. Costs (US\$/hour) | Operators wages (US\$/hour) | Overhead (US\$/hour) | Total Operating Costs (US\$/hour) |
|-----------------|---------------------------|------------------------|--------|--------------------------|----------------------|-------------------------------|---------------------------|-------------------------------|-----------------------------|----------------------|-----------------------------------|
| New             | CAT 120H                  | Motor Grader           | Medium | 15.56                    | 20.86                | 1.11                          | 0.67                      | 9.79                          | 2.00                        | 0.50                 | 50.49                             |
| New             | Lee Boy 635               | Motor Grader           | Small  | 6.69                     | 8.97                 | 0.48                          | 0.67                      | 3.29                          | 2.00                        | 0.22                 | 22.31                             |
| New             | Simba & Kobuta 9570       | Towed Grader & Tractor | Medium | 5.10                     | 6.84                 | 0.84                          | 1.20                      | 5.58                          | 2.82                        | 0.22                 | 22.60                             |
| New             | Cam Grader & Kobuta MX500 | Towed Grader & Tractor | Small  | 2.75                     | 3.69                 | 0.62                          | 0.45                      | 5.12                          | 2.82                        | 0.15                 | 15.60                             |
| Second hand     | CAT 120H                  | Motor Grader           | Medium | 21.11                    | 14.16                | 1.11                          | 0.67                      | 9.79                          | 2.00                        | 0.49                 | 49.32                             |
| Second hand     | Lee Boy 635               | Motor Grader           | Small  | 8.89                     | 5.96                 | 0.48                          | 0.67                      | 3.29                          | 2.00                        | 0.21                 | 21.49                             |
| Second hand [a] | Simba & Kobuta 9570       | Towed Grader & Tractor | Medium | 4.30                     | 3.49                 | 0.84                          | 1.20                      | 5.58                          | 2.82                        | 0.22                 | 18.44                             |
| Second hand     | Cam Grader & Kobuta MX500 | Towed Grader & Tractor | Small  | 2.25                     | 1.68                 | 0.62                          | 0.45                      | 5.12                          | 2.82                        | 0.15                 | 13.09                             |

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

[a] For second hand options, the towed graders are purchased new with a second hand tractor.

**APPENDIX XX**

**Grader unit operating costs for equipment hire (US\$ per hour) when the motor grader is being utilised at 900 hours per annum**

| <b>Model &amp; Brand</b>  | <b>Technology</b>      | <b>Size</b> | <b>Hire cost (US\$/hour)</b> | <b>Cost of tyres (US\$/hour)</b> | <b>Fuel &amp; lub. Costs (US\$/hour)</b> | <b>Operators wages (US\$/hour)</b> | <b>Overhead (US\$/hour)</b> | <b>Total Operating Costs (US\$/hour)</b> | <b>Cost per km (US\$)</b> |
|---------------------------|------------------------|-------------|------------------------------|----------------------------------|------------------------------------------|------------------------------------|-----------------------------|------------------------------------------|---------------------------|
| CAT 120H                  | Motor Grader           | Medium      | 21.00                        | 0.30                             | 9.63                                     | 0.90                               | 0.32                        | 32.15                                    | 80.37                     |
| Lee Boy 635               | Motor Grader           | Small       | 9.06                         | 0.30                             | 3.23                                     | 0.90                               | 0.13                        | 13.63                                    | 34.07                     |
| Simba & Kobuta 9570       | Towed Grader & Tractor | Medium      | 11.88                        | 0.54                             | 5.53                                     | 1.27                               | 0.19                        | 19.41                                    | 53.93                     |
| Cam Grader & Kobuta MX500 | Towed Grader & Tractor | Small       | 8.42                         | 0.20                             | 5.07                                     | 1.27                               | 0.15                        | 15.12                                    | 42.00                     |

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

[a] For second hand options, the towed graders are purchased new with a second hand tractor.

### Grading Equivalent Cost Using Manual Labourers

Grading activities can be executed using manual labourers. Instead of using grading machines, the following procedures can be followed:

- prepare formation of work area;
- gravel/soil loaded into wheelbarrows using shovels;
- gravel/soil hauled to desired area and unloaded;
- gravel/soil spread over desired area using rakes; and
- gravel/soil compacted to the required standards and specifications using levelling devices such as hand rammers

Empirical evidence from published sources (ILO/ASIST, 1998) and ITT experience provides the productivity levels for the above activities which are presented in the table below.

#### Productivity levels of labourers

| Activity           | Budget Productivity (man days/m <sup>3</sup> ) |
|--------------------|------------------------------------------------|
| Prepare formation  | 0.2                                            |
| Load, haul, unload | 0.3                                            |
| Spread, compact    | 0.2                                            |
| Total              | 0.7                                            |

Source: ILO/ASIST (1998) and ITT experience

The cost of grading related activities using manual labourers is presented in the table below. It costs approximately US\$120 to grade soil/gravel using labourers.

#### Estimated costs of grading using labourers

| Variable                                     | Unit           | Value |
|----------------------------------------------|----------------|-------|
| Road width                                   | m              | 6     |
| Surface thickness                            | m              | 0.15  |
| Proportion of surface requiring maintenance  | %              | 10%   |
| Total volume of grading required             | m <sup>3</sup> | 90    |
| Total man days required                      | days           | 63    |
| Total cost including overheads and equipment | US\$/km        | 118   |

Source: ILO/ASIST (1998), ITT experience and consultants' estimates

**APPENDIX XXII**

**Equipment suppliers**

| <b>Equipment</b>              | <b>Equipment Supplier</b>                       | <b>Address</b>                                                          | <b>Country</b> |
|-------------------------------|-------------------------------------------------|-------------------------------------------------------------------------|----------------|
| Tipper truck                  | Khouxay Bridge & Road Conatruction Company      | Ban Nongbouathong, Sikot District, Vientiane, Vientiane                 | Laos           |
|                               | Loa Development                                 | Ban Thongkhankham, Chanthabouly District, Vientiane                     | Laos           |
|                               | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
|                               | Vehicle Assemble Factory Company                | Donekoy, T 4 Road, Hatsayphong District, Vientiane                      | Laos           |
|                               | Sovann Yaun Company                             | #271 E0, St Tep Phan, Phnom Penh                                        | Cambodia       |
|                               | V-TRAC                                          | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi  | Vietnam        |
| Flat truck                    | Komatsu Vietnam JSC                             | K2 Office - 14 Thuy Khue Street, Tay Ho District, Hanoi                 | Vietnam        |
|                               | Vehicle Assemble Factory Company                | Donekoy, T 4 Road, Hatsayphong District, Vientiane                      | Laos           |
|                               | Sovann Yaun Company                             | #271 E0, St Tep Phan, Phnom Penh                                        | Cambodia       |
|                               | Xuan Kien Automobile Factory                    | 2 Trieu Quoc Dat Street, Hanoi                                          | Vietnam        |
|                               | Megastar Motor Company                          | No 406 Tran Khat Chan Street - Hanoi                                    | Vietnam        |
|                               | Insithong Motor Company                         | Ban Nongdouang Neau, Samsenethai Road, Sikhottabong District, Vientiane | Laos           |
| Tractor 2WD                   | Agriculture Development Co. Ltd.                | # 117, St 126, Phnom Penh                                               | Cambodia       |
|                               | Vietnam Engine and Agricultural Machinery Corp. | 2 Trieu Quoc Dat Street, Hanoi                                          | Vietnam        |
|                               | Insithong Motor Company                         | Ban Nongdouang Neau, Samsenethai Road, Sikhottabong District, Vientiane | Laos           |
| Tractor 4WD                   | Agriculture Development Co. Ltd.                | # 117, St 126, Phnom Penh                                               | Cambodia       |
|                               | Vietnam Engine and Agricultural Machinery Corp. | 2 Trieu Quoc Dat Street, Hanoi                                          | Vietnam        |
| Trailer                       | Keo Motor Heavy Equipments                      | Nonghai, Hatsayphong District, Vientiane                                | Laos           |
|                               | Khouxay Bridge & Road Conatruction Company      | Ban Nongbouathong, Sikot District, Vientiane                            | Laos           |
|                               | Loa Development                                 | Ban Thongkhankham, Chanthabouly District, Vientiane                     | Laos           |
|                               | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
|                               | Megastar Motor Company                          | No 406 Tran Khat Chan Street - Hanoi                                    | Vietnam        |
|                               | Hol Korb Lathes                                 | #66S2, St.163, Toul Tompoung I, Khan Chamcarmon, Phnom Penh             | Cambodia       |
| Wheelbarrow                   | Pheng Ly Co.                                    | #111, St.155, Sangkat Toul Tompoung I, Khan Chamcarmon, Phnom Penh      | Cambodia       |
|                               | Hoa Phat                                        | 243 Giai Phong Rd., Dong Da District, Hanoi                             | Vietnam        |
|                               | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
| Roller (ride on vibratory)    | Dong Loi Joint Stock Machinery Company          | G7, Lang Quoc te Thang Long – Cau Giay Dist, Hanoi                      | Vietnam        |
|                               | KLLC Ltd Company                                | A22-Lot 9 – Dinh Cong, Hanoi                                            | Vietnam        |
| Roller (pedestrian vibratory) | Loa - Singapore Construction Ltd                | Ban Vatnak, Sisattanak District, Vientiane                              | Laos           |
|                               | Seak Ly Co. Ltd.                                | #286, St 182, Phnom Penh                                                | Cambodia       |

| Equipment                        | Equipment Supplier                                      | Address                                                                  | Country  |
|----------------------------------|---------------------------------------------------------|--------------------------------------------------------------------------|----------|
| Roller (towed vibratory)         | Hoa Phat                                                | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
|                                  | Tu Chau Construction Equipment Cooperation (XCMG)       | 24 T2 Building, Trung Hoa-Nhan Chinh New Urban Area, The 17 Floor, Hanoi | Vietnam  |
| Roller (ride on deadweight)      | Seak Ly Co. Ltd.                                        | #286, St 182, Phnom Penh                                                 | Cambodia |
|                                  | Transport Material and Equipment Sharehold Company      | Khuat Duy Tien Road - Thanh Xuan Dist, Hanoi                             | Vietnam  |
| Roller (deadweight, hand drawn)  | V-TRAC                                                  | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi   | Vietnam  |
|                                  | Khounxay Bridge & Road Conatruction Company             | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
| Roller (towed deadweight)        | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
|                                  | Chhim Chiv                                              | #2100A, St 68, Phnom Penh                                                | Cambodia |
| Roller (towed deadweight)        | Loa Development                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                      | Laos     |
|                                  | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
| Vibrating Plate                  | V-TRAC                                                  | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi   | Vietnam  |
|                                  | Keo Motor Heavy Equipments                              | Nonghai, Hatsayphong District, Vientiane                                 | Laos     |
| Water Bowser (towed)             | Khounxay Bridge & Road Conatruction Company             | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
|                                  | Loa Development                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                      | Laos     |
| Concrete Mixer                   | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
|                                  | Sam Sokhom                                              | #2058 E0, St 68, Phnom Penh                                              | Cambodia |
| Concrete Vibrator                | Hoa Phat                                                | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
|                                  | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
| Concrete Vibrator                | Khounxay Bridge & Road Conatruction Company             | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
|                                  | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                                | Laos     |
| Mobile Small-Scale Stone Crusher | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                               | Laos     |
|                                  | Hol Korb Lathes                                         | # 66S2, St 163, Phnom Penh                                               | Cambodia |
| Motor Grader                     | Pheng Ly Co.                                            | #111, St.155, Sangkat Toul Tompoung 1, Khan Chamcarmon, Phnom Penh       | Cambodia |
|                                  | Hoa Phat                                                | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
| Motor Grader                     | Megastar Motor Company                                  | No 406 Tran Khat Chan Street - Hanoi                                     | Vietnam  |
|                                  | Construction Electrical & Mechanical Equipment Co Ltd., |                                                                          | Vietnam  |
| Motor Grader                     | Hoa Phat                                                | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                                 | Vietnam  |
|                                  | Thien Hoa An                                            | 243 Giai Phong Rd., Dong Da District, Hanoi                              | Vietnam  |
| Motor Grader                     | Keo Motor Heavy Equipments                              | 146 Truong Chinh Str., Dong Da, Hanoi                                    | Vietnam  |
|                                  | Khounxay Bridge & Road Conatruction Company             | Nonghai, Hatsayphong District, Vientiane                                 | Laos     |
| Motor Grader                     | Loa Development                                         | Ban Nongbouathong, Sikot District, Vientiane                             | Laos     |
|                                  |                                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                      | Laos     |

| Equipment            | Equipment Supplier                                      | Address                                                                | Country  |
|----------------------|---------------------------------------------------------|------------------------------------------------------------------------|----------|
| Towed Grader         | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                             | Laos     |
|                      | Metro Group Fo Cambodia Co Ltd.                         | #1778, St 5, Phnom Penh                                                | Cambodia |
|                      | Dong Loi Joint Stock Machinery Company                  | G7, Lang Quoc te Thang Long – Cau Giay Dist, Hanoi                     | Vietnam  |
|                      | V-TRAC                                                  | 16th Floor, Hoa Binh Tower - 106 Hoang Quoc Viet, Cau Giay Dist, Hanoi | Vietnam  |
|                      | Komatsu Vietnam JSC                                     | K2 Office - 14 Thuy Khue Street, Tay Ho District, Hanoi                | Vietnam  |
|                      | DTW                                                     | Unit 17ab&c, Street 528, Phnom Penh                                    | Cambodia |
|                      | Keo Motor Heavy Equipments                              | Nonghai, Hatsayphong District, Vientiane                               | Laos     |
|                      | Khouxay Bridge & Road Conatruction Company              | Ban Nongbouathong, Sikot District, Vientiane                           | Laos     |
|                      | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                              | Laos     |
|                      | Loa Development                                         | Ban Thongkhankham, Chanthabouly District, Vientiane                    | Laos     |
| Bitumen Heater       | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                             | Laos     |
|                      | Construction Electrical & Mechanical Equipment Co Ltd., | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                               | Vietnam  |
|                      | Khouxay Bridge & Road Conatruction Company              | Ban Nongbouathong, Sikot District, Vientiane                           | Laos     |
|                      | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                              | Laos     |
| Bitumen Hand Sprayer | Loa - Singapore Construction Ltd                        | Ban Vatnak, Sisattanak District, Vientiane                             | Laos     |
|                      | Construction Electrical & Mechanical Equipment Co Ltd., | 144 Duc Giang- Long Bien- Gia Lam, Hanoi                               | Vietnam  |
|                      | Khouxay Bridge & Road Conatruction Company              | Ban Nongbouathong, Sikot District, Vientiane                           | Laos     |
|                      | Kongchai Spare Parts and Heavy Equipments               | Ban Phakhao, Saithany District, Vientiane                              | Laos     |

Source: Equipment supplier interviews

### Mobile Crusher Interview Summary Report

SSCs were identified and subjected to a ‘Mobile Crusher Interview’. The SSC were asked questions over the phone and the SEACAP 020 team managed to acquire a sample size of 14, all Vietnamese based. The findings of the mobile crusher interviews are presented below.

Out of the 14 respondents, 7 of the respondents owned mobile crushers produced in China and 7 owned versions made in Vietnam (5 of which were produced by Hoa Phat). All Chinese versions were purchased second hand, their ages range between 5 to 12 years, and prices ranged between \$1,000 and \$1,500. The vast majority of the Vietnamese versions were purchased new, typically costing the contractor between \$1500 and \$4000. Vietnamese (or new) crushers are currently between 1 and 4 years of age and Chinese (or second hand) crusher are over 10 years of age.

#### Overview of the crushers in the Mobile Crusher Questionnaires

| Model        | Country | New/Second Hand |             | Current Age (years) | Purchase Price (2007 US\$) <sup>39</sup> |
|--------------|---------|-----------------|-------------|---------------------|------------------------------------------|
|              |         | Status          | Age (years) |                     |                                          |
| -            | Vietnam | Second Hand     | 8           | 16                  | 1968                                     |
| KA C-1A      | Vietnam | New             | N/A         | 11                  | 1655                                     |
| NHHP-PEX-175 | Vietnam | New             | N/A         | 3                   | 2765                                     |
| NHHP-PEX-175 | Vietnam | New             | N/A         | 2                   | 2622                                     |
| NHHP-PEX-215 | Vietnam | New             | N/A         | 4                   | 3937                                     |
| NHHP-PEX-215 | Vietnam | New             | N/A         | 1                   | 3985                                     |
| NHHP-PEX-215 | Vietnam | New             | N/A         | 1                   | 4051                                     |
| -            | China   | Second Hand     | 5           | 12                  | 1565                                     |
| -            | China   | Second Hand     | 12          | 16                  | 1338                                     |
| -            | China   | Second Hand     | 8           | 15                  | 1173                                     |
| -            | China   | Second Hand     | 8           | 15                  | 1173                                     |
| -            | China   | Second Hand     | 9           | 15                  | 1232                                     |
| -            | China   | Second Hand     | 12          | 15                  | 1345                                     |
| -            | China   | Second Hand     | 6           | 9                   | 1494                                     |

<sup>39</sup> All prices were converted to 2007 prices, by applying Vietnamese inflation rates. Inflation rates were derived from a combination of sources:

Development Data Group, The World Bank. 2007. 2007 World Development Indicators Online. Washington, DC: The World Bank. Available at: <http://go.worldbank.org/3JU2HA60D0> and VietnamNet. Available at <http://english.vietnamnet.vn/biz/2007/02/665915/>

**Pairwise Analysis: Percentage of Small Mobile Crushers From China/Vietnam Purchased Either New/Second Hand**

| Status      | Chinese | Vietnamese |
|-------------|---------|------------|
| Second Hand | 50%     | 7%         |
| New         | 0%      | 43%        |

The average age (when purchased) of the Chinese and second hand models were 8.6 and 8.5 years, respectively, the same figure for Vietnamese models were 1.1 years of age. The average price (when purchased) of the Chinese and second hand models were \$1332 and \$1411, respectively, the same figure for Vietnamese and new models were \$2997 and 3169, respectively.

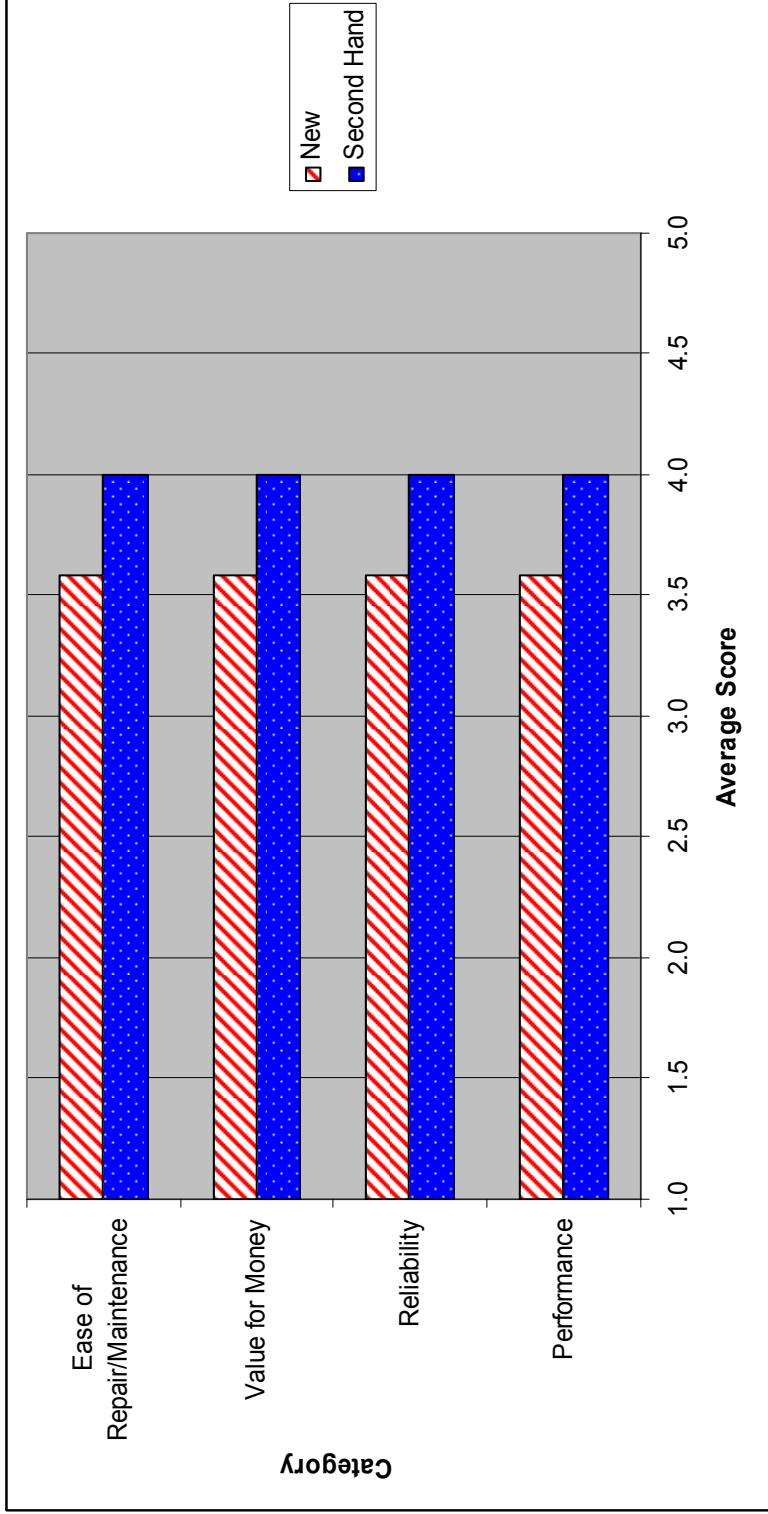
**Average Age and Price of Mobile Crusher at Time Of Purchase**

| Status      | Number | Av. Purchase Age (years) | Av. Purchase Price (2007 US\$) |
|-------------|--------|--------------------------|--------------------------------|
| Second Hand | 8      | 8.5                      | 1411                           |
| New         | 6      | 0                        | 3169                           |
| Chinese     | 7      | 8.6                      | 1332                           |
| Vietnamese  | 7      | 1.1                      | 2997                           |

The responses from the questionnaires revealed that product satisfaction is currently higher amongst owners of second hand mobile crushers. When asked to rate their products between 1 and 5 (higher scores equating to higher satisfaction level) in categories of performance, reliability, value for money and maintenance, second hand crushers scored an average of 4 for every category, and new crushers achieved a score of 3.6 for every category. This would suggest that SSCs are generally satisfied (though not overwhelmingly) satisfied with the crushers they own, but newer crushers less so. There could be many reasons to explain this, such as:

- contractors may opt for a second hand crusher in order to obtain an equipment with superior specification, given a certain price level;
- contractors may have lower expectations with second hand products; and
- superior engineering of small mobile crushers in China

**Product Satisfaction: Average Scores (1-5) For Mobile Crushers. 1 Refers To 'Very Poor' And 5 Refers To 'Excellent'**



Second hand crushers have a slightly higher output rate than new versions (7 and 6 cubic metres per hour, respectively). This suggests that SSCs substitute between equipment and improved technology. Output rates of the NHHP-PEX175 and NHHP-PEX215, as claimed by owners of the equipment (5 and 6 cubic metres per hour, respectively) are within the range stated by the manufacturer, Hoa Phat (4 to 5 and 5 to 7 cubic metres per hour, respectively). The small mobile crushers are used slightly under half of the days of the year, indicating that there is significant work for owners. They are broken down for approximately a period of a month each year; however, product satisfaction scores reveal that this breakdown rate is acceptable for their owners.

### Mobile Crusher Performance

| Status      | Output (m <sup>3</sup> /hour) | Days (per year) In Use | Days (per year) Broken Down |
|-------------|-------------------------------|------------------------|-----------------------------|
| Second Hand | 7.0                           | 155                    | 36                          |
| New         | 6.0                           | 163                    | 35                          |

When contractors were asked to name problems encountered with the mobile crusher, the most common faults cited were the rapid erosion of the crusher jaws and the quick breakdown of their sieves. On average the jaws manage to produce slightly over 1300 cubic metres of crushed rock (table below) before needing replacement. However, such erosion rates are strongly dependent on the properties of the materials which are fed into the crusher, and the information gathered regarding such mineral properties were not sufficient to subject to any form of statistical analysis. Sieves usually need replacing twice every year (table below), replacement rates will be highly dependent on the intensity of equipment usage, which is roughly half the days of the year (table above). Therefore, based on the evidence available, it can be concluded that the crusher sieves will require replacing after 3 months of crusher usage.

### Average Jaw and Sieve Longevity

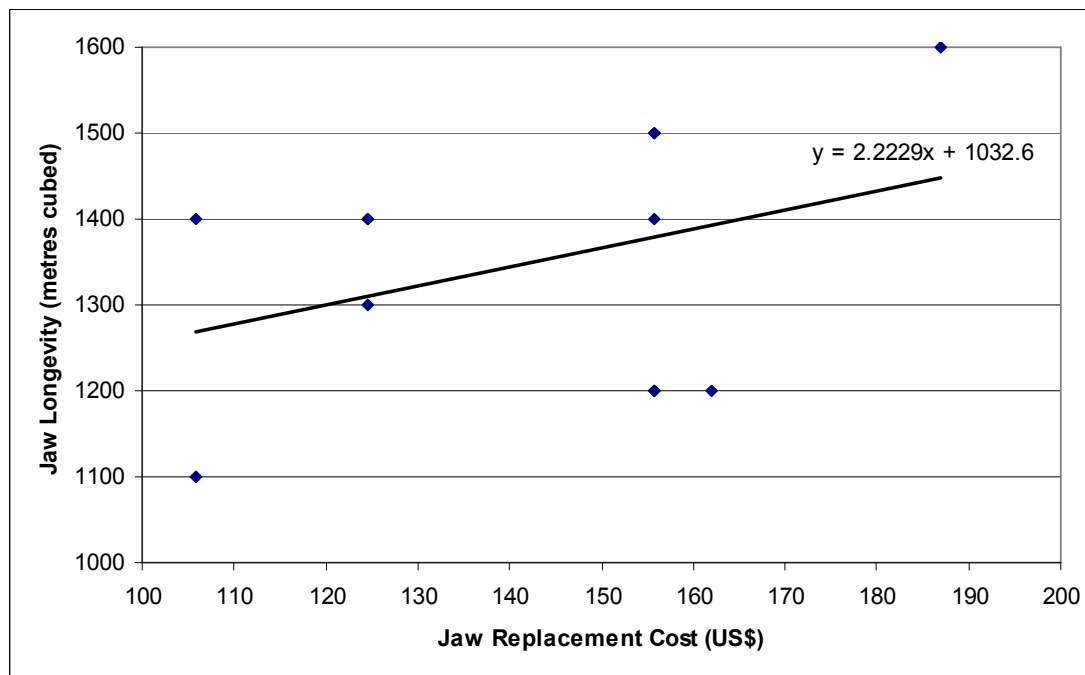
| Status                              | Value |
|-------------------------------------|-------|
| Av. Jaw Longevity (m <sup>3</sup> ) | 1336  |
| Av. Sieve Longevity (months)        | 7     |

Jaw replacement costs varied considerably, in the range of \$100 to \$200; therefore, it was considered sensible to explore the possible relationship between jaw quality and cost. The table below indicates that there is a positive relationship between the cost of the jaws and their longevity. Jaw replacements should manage to crush at least 1000 cubic metres of crushed rock, however, a \$100 and \$200 jaw would typically produce 1250 and 1480 cubic metres of crushed rock, respectively. Therefore, little benefit is derived, in terms of crushed rock volume alone, by acquiring a more expensive crusher jaw. Such an analysis ignores, amongst other factors, the potential improved output quality of more expensive jaws.

The mean average cost of jaw replacement and crusher output is approximately \$150 and 6.5 cubic metres per hour, and a crusher of this output rate best describes the largest of the small mobile crushers produced by Hoa Phat (NHHP-PEX215), Hoa Phat also sells jaw replacement for this crusher for roughly \$150. However, the average life of the jaws estimated by Hoa Phat at 1200 hours is overestimated by a magnitude of almost 6. The average life of the jaws, as claimed by the SSCs is approximately 215 hours<sup>40</sup>.

<sup>40</sup> Derived by dividing the jaw longevity (m<sup>3</sup>) by the crusher output rate (m<sup>3</sup> per hour)

## Relationship between crusher jaw longevity and crusher replacement cost



When contractors and key informants were asked of the potential benefits of low cost equipment, many cite their potential to stimulate the local manufacturing industry of the area. For such a 'second order effect' to materialise, a critical mass of demand is most importantly required, but other factors that need to be considered is the potential engineering and manufacturing capability of the local community and the steady demand for replacements. The SSCs were asked which component, if any, of their small mobile crusher has been locally manufactured. The only components that were mentioned were the frame (93%), the sieve (43%) and the belt (36%).

The frame will very rarely need replacing, as it was not stated as one of the major faults of the crusher, and because the concentration of small mobile crusher in one village would not typically be huge, such local manufacturing capability is unlikely to generate significant revenue for the local community. On a national (or possibly regional) level the ability to manufacture locally fabricated frames may stimulate commercial benefits amongst a handful of companies.

The belts of the crushers were not typically cited as a major source of faults; therefore, this is also unlikely to generate maintenance/production activity.

It is typical to replace a sieve an average of twice a year, consequently, such a replacement rate, may generate work for the local manufacturing industry within the community. But this will require a high concentration of small mobile crusher ownership in a particular area. The potential market for mobile crushers in Cambodia is estimated to be too low to generate significant second order benefits; however, this is not the case in Vietnam, partially as a result of their ambitious paved road programme.

### Recycling Waste Construction Materials

The introduction of mobile crushers provides the opportunity to contractors of producing recycled aggregate from demolished construction materials. There are two approaches to this:

- To transport waste materials to a central processing site where they are crushed by large machines; and
- To crush the materials on site using a mobile crusher.

The second option is preferred in order to reduce handling and transport of the materials.

The two main materials recycled into aggregate are asphalt paving and concrete. In the USA about 10% (200 million tonnes per year) of all aggregates are recycled material<sup>41</sup>, roughly half asphalt and half concrete. They are approved for a number of uses but the main use (around 70%) is for sub-base of paved roads. Their use is increasing and is being encouraged because of the environmental benefits in reducing the use of natural aggregates and also in reducing the disposal of the waste materials in fill sites.

The opportunities to recycle construction materials into aggregate in the region will be much lower than in the USA because of the much lower level of demolition and redevelopment of infrastructure. However, there are good benefits from exploiting the limited opportunities using mobile crushers. Rubble waste from the construction industry can be recycled into crushed aggregate to re-supply to the construction industry, particularly for the base course of paved roads. Concrete, brick and asphalt can be recycled cost-effectively instead of incurring energy, cost and environmental penalties in waste disposal. The recycled concrete can provide good quality and cost effective construction material<sup>42</sup>. A case study of an application of recycled construction rubble in the UK is presented in **APPENDIX XXV**.

### Conclusion

Development brings an increasing demand for crushed stone and rock, particularly in road construction and maintenance. It is estimated that in the USA the demand is 10 tonne per person per year (see footnote 15), in the UK it is estimated to be around 5 tonne per person per year<sup>43</sup>. The demand in the study region is much lower than this but can be expected to grow yearly in line with growth in GDP<sup>44</sup>. This will create increasing opportunities for SSCs to benefit from the acquisition and use of mobile stone crushers. The main benefits have been outline above as:

- They can allow contractors to make use of sources of stone and rock that may be closer to the construction site than commercial quarries therefore saving in transport costs that are a large component of aggregate costs
- Contractors have control over extraction costs and avoid the overhead and profit margins incorporated in the price of purchasing aggregate from the commercial quarries
- Mobile crushers provide opportunities to produce aggregate from recycling waste materials from the demolition of infrastructure which can save costs for the contractor and also benefit the environment. This is likely to be a growing benefit in the future.

---

<sup>41</sup> Encyclopaedia of Earth, [www.eoearth.org/article/Recycled\\_aggregates](http://www.eoearth.org/article/Recycled_aggregates).

<sup>42</sup> From a study conducted by [Rice University](http://www.rice.edu) in 2006.

<sup>43</sup> [www.publicsectorreview.com/transport](http://www.publicsectorreview.com/transport)

<sup>44</sup> Thomas Kelly: Crushed Cement Concrete Substitution for Construction Aggregates – A Materials Flow Analysis; U.S. Geological Survey Circular 1177

**A Case Study in Recycling Rubble**

The subject of the Case Study is a Company that recycles rubble, Shillibier, and supplies the construction industry with concrete and road surfacing aggregate.

The Company has as its base a large compound situated in an industrial estate, strategically located to cater for the recycling needs of two cities and three large towns. These centres lie within a radius of twenty miles from the compound, and they are in a continuous state of industrial and urban commercial development, with the demolition of redundant buildings proceeding apace. The access and exit ramps of an expressway are two miles from the Company's compound and the approach of the contractors' dump trucks is facilitated by the excellent connecting feeder road.



**Stockpile of Mainly Mass Concrete Rubble**

The Company owns one 'EXTEC' large scale mobile crusher and several small-scale mobile crushers. Each of the small-scale crushers is capable of crushing 24 tons of rubble per day (Red Rhino 4000). The 'Red Rhinos' are easily transportable and can be hired out as and when they are available.

The compound is large enough to stockpile the loads of rubble delivered and offloaded by a constant flow of contractors' dump trucks. As the trucks arrive their loads are briefly inspected and, depending on the type of rubble they are carrying, the trucks are directed to one of four stockpiles: mainly reinforced concrete; mainly mass concrete; mainly brick; and mixed rubble. In many cases, the newly dumped rubble will contain contaminated building material such as wood, plastic, tile, aluminium etc., which must be sorted and removed by hand and the Company retains a small labour team for this purpose. Concrete containing a large proportion of heavy rebar is also transferred to a separate stockpile, where the steel is removed as the chunks of concrete are broken by hand with a pavement breaker.

The 'clean' rubble is fed into the crusher with a front end loader.

The recycled aggregate products consist of crushed concrete, crushed brick and crushed 'mixed rubble', and each grade is stored in a separate bin for reuse by the Company in the manufacture of concrete products or for sale to building and construction entrepreneurs.

Every year since April 2001 landfill tax has risen at a rate of £3.00 per ton - currently £21.00 per ton. This will continue on an annual basis - £3 per ton in April 2007 to £24.00 per ton. As a result landfill operators need to recover the extra cost brought about by this Landfill Directive, which makes the disposal of waste uneconomical. It is a financial necessity to segregate waste at source and recycle. The Red Rhino can offer a solution for the conversion of construction waste to a required aggregate; generating significant cost reduction savings in the process.

The extraction of aggregates from the environment (sand, gravel and crushed rock) represents 82% by tonnage of all non-fossil fuel minerals extracted from the land and sea in the UK. The extraction, transport and eventual disposal of these aggregates have significant implications for the environment.

By 2012, if UK demand increases by an expected 1% per annum, 20 million tonnes of extra aggregates will be needed each year. – this will inevitably mean a rise in purchase costs for construction companies in which such costs are likely to be passed onto consumers in the form of a surcharge. A possible solution which will reduce the demand for extra aggregates is to recycle building rubble.

The following points highlight how such a company provides benefits in the UK and how such benefits relate to the situation in the project countries:

- Companies will not need to pay for skip hire to take care of transporting rubble away from original site. In the UK, the average cost for a skip hire is between £80 to 120 per day (depending on size). In the project countries, companies are unlikely to go through the hassle of getting rid of the business rubble. In some case building waste is just left, therefore the cost is transferred (via externalities to the local community)
- Companies have no need to pay landfill tax, in the UK this costs £21 per ton. In the project countries, companies are unlikely to go through the hassle of getting rid of the business rubble. In some case building waste is just left, therefore the cost is transferred (via externalities to the local community)
- No need for haulage costs as vehicles are not required to transport the material. In the case for the project countries is such that if companies do decide to move the rubble, then the economic costs are likely to be higher due to vehicle operating costs and the damage such movements will incur on the nations roads.
- No need to purchase aggregates. Crushed rock costs a minimum of 8 per tonne.
- Save space – crushed material covers one third the space of rubble. However, in the project countries, if all the recycled rubble is re-used within the construction industry, then the space saved is likely to 100%.

### Factors in the Selection of a Mobile Crusher

A number of functional factors need to be considered to select a suitable crusher for the crushing operations to be carried out:

- 1. Compressive Strength of the stone or rock to be crushed** – the most common materials used for aggregate are limestone, granite and basalt. Properties of these rocks are shown in the table below.

#### Compressive Strength of Common Rocks

| Rock type | Bulk Density (Tonne/m <sup>3</sup> ) | Compressive Strength (MPa) |
|-----------|--------------------------------------|----------------------------|
| Limestone | 2.2 – 2.6                            | 30 – 250                   |
| Granite   | 2.6 – 2.9                            | 100 – 250                  |
| Basalt    | 2.8 – 2.9                            | 100 – 300                  |

Jaw crushers are generally rated for crushing rock up to a compressive strength of 320 MPa which adequately covers the rocks included in the table above.

- 2. Capacity** – this relates to the rate at which material can be crushed. The main use of the crusher will be producing aggregate for the base of paved roads. The typical thickness of the sub-base is 25cm. For a 6m wide road the volume of aggregate needed per m length is 1.5m<sup>3</sup> and the volume needed for a work rate of 100m per day is 150m<sup>3</sup>. The largest crusher produced by the local manufacture, Hoa Phat, the NHHP-PEX215 has a rated capacity of around 6 m<sup>3</sup> per day and an equivalent crusher. This indicates that a mobile crusher can produce an upper limit of aggregate for sub-base of a paved road of around a length of 35 to 40m per day. It has to be decided if this meets contract requirements or whether additional crushers may be needed.
- 3. Maximum input size** – the maximum size of lumps that can be fed into the crusher decreases with a lower size and power of the crusher. Methods of breaking and handling of the rock must therefore be matched to the crusher size. Smaller crushers will require greater inputs of labour or machine time to break the rock into smaller lumps. Larger crushers will require consideration to be given to safe handling of the larger lumps that can be fed into the crusher.
- 4. Size of output aggregate** – jaw crushers have a crushing ratio that determines the maximum reduction in size that can be achieved in one throughput of the material through the crusher. If the required output size of aggregate cannot be achieved in a single pass then a secondary pass will be needed. The capacity of the crusher is linked to the crushing ratio, the lower the ratio the higher the rate of crushing.
- 5. Loading and unloading the crusher** – it is essential to integrate the crusher into an overall effective operating system from excavation of the stone or rock through to delivery on the working site if the use of a mobile crusher is to be efficient and cost-effective. The ancillary operations of excavation, breaking the rock and loading and unloading the crusher are likely to be more costly than the operation of the crusher and they need to be carefully worked out to match the crusher and local situation. In particular the addition of a conveyor to load the crushed material directly into trucks is likely to be cost-effective.

## APPENDIX XXVII

### Specifications of Jaw Crushers (Hoa Phat Company, Vietnam)

| Model                               | Unit               | NHHP-PEX15        | NHHP-PEX175 | NHHP-PEX215    |
|-------------------------------------|--------------------|-------------------|-------------|----------------|
| Capacity                            | M <sup>3</sup> /hr | 1 to 3            | 4 to 5      | 5 to 7         |
| Maximum size of input stone         | Mm                 | 150 x 250         | 175 x 300   | 215 x 300      |
| Size of output stone                | Mm                 | 8 to 40           | 8 to 40     | 8 to 60        |
| Diesel engine power                 | Kw                 | 9                 | 13.5        | 18             |
| Size of crusher                     | Mm                 | 860x620x780       | 995x842x970 | 3400x1400x2550 |
| Weight                              | Kg                 | 400               | 900         | 2,000          |
| Cost <sup>45</sup>                  | US\$               | 1,420             | 2,560       | 4,245          |
| Cost <sup>46</sup>                  | US\$               | 1,370 (estimated) | 2,700       | 3,990          |
| Life of crushing jaws <sup>47</sup> | Hours              | 215               | 215         | 215            |
| Cost of replacement jaw             | US\$               | 42.50             | 87.50       | 156.25         |

Source: Hoa Phat and mobile crusher surveys.

---

<sup>45</sup> Prices provided by the supplier

<sup>46</sup> Average prices obtained from the survey of contractors

<sup>47</sup> The average life obtained from the survey of contractors

**APPENDIX XXVIII**

**Mobile crusher unit operating costs for equipment purchase (US\$ per hour) when being utilised at 1,000 hours per annum**

| <b>Model &amp; Brand</b> | <b>Size</b> | <b>Depreciation</b> | <b>Interest</b> | <b>Jaw costs</b> | <b>Maintenance cost (ex Jaws)</b> | <b>Fuel &amp; lub. Costs</b> | <b>Operators wages</b> | <b>Overhead</b> | <b>Total Operating Costs</b> |
|--------------------------|-------------|---------------------|-----------------|------------------|-----------------------------------|------------------------------|------------------------|-----------------|------------------------------|
| NHHP-PEX215, Hoa Phat    | Large       | 0.53                | 0.57            | 0.73             | 0.14                              | 5.52                         | 1.02                   | 0.09            | 8.59                         |
| NHHP-PEX175, Hoa Phat    | Medium      | 0.32                | 0.34            | 0.41             | 0.10                              | 4.14                         | 1.02                   | 0.06            | 6.39                         |
| NHHP-PEX15, Hoa Phat     | Small       | 0.18                | 0.19            | 0.20             | 0.07                              | 2.76                         | 1.02                   | 0.04            | 4.46                         |

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

**APPENDIX XXIX**

**Mobile crusher unit operating costs for equipment hire (US\$ per hour) when being utilised at 2,000 hours per annum**

| <b>Model &amp; Brand</b> | <b>Size</b> | <b>Hire cost<br/>(US\$/hour)</b> | <b>Fuel &amp;<br/>lub. Costs<br/>(US\$/hour)</b> | <b>Operators<br/>wages<br/>(US\$/hour)</b> | <b>Overhead<br/>(US\$/hour)</b> | <b>Total<br/>Operating<br/>Costs<br/>(US\$/hour)</b> |
|--------------------------|-------------|----------------------------------|--------------------------------------------------|--------------------------------------------|---------------------------------|------------------------------------------------------|
| Hoa Phat NHHP-PEX215     | Large       | 2.56                             | 5.52                                             | 0.51                                       | 0.09                            | 8.68                                                 |
| Hoa Phat NHHP-PEX215     | Medium      | 1.54                             | 4.14                                             | 0.51                                       | 0.06                            | 6.26                                                 |
| Hoa Phat NHHP-PEX215     | Small       | 0.86                             | 2.76                                             | 0.51                                       | 0.04                            | 4.17                                                 |

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

**Contractor and Key Informant Opinions on the Mobile Crusher****Cambodia**

Intensive interviews with SSCs revealed that contractors are generally interested in the small mobile crusher, however, not in the transport construction industry. Many SSCs cited the fact that the majority of their roads are earth surfaced and that this situation is unlikely to change. Many SSCs also stated the limited resources available (raw materials) to input into the small mobile crusher, although this was often followed by statements which confirmed their knowledge that such inputs could be purchased from larger quarries. Most SSCs were aware of the potential of the small mobile crusher to recycle building rubble and sell the processed product back to the building construction industry, and for this purpose most of the SSCs interviewed were positive.

Anecdotal evidence in the various regions reflected differing opinions towards the mobile crusher. In Kampot province, the SSCs were generally positive towards purchasing a mobile crusher, even if good quality rock may not be found in sizes small enough to feed into the crusher, they stated that it would still remain economically beneficially to purchase broken rocks, ready to feed into the crushers. They also appreciated the potential that the crusher could be used on 'idle days' by producing crushed rock for the local construction industry and therefore adding contractor profitability. They did, however, state that most roads in the rural provinces are earth roads and the crusher would be effectively useless. They expressed that horizontal packaging of contracts may be beneficial for the diffusion of crushers as crushers could be used extensively by a 'specialised contractor', however, at the moment, vertical contracting is more common. They stated that lack of finance inhibited SSCs to gamble with equipment that is not tried and tested. The SSCs also stated that mobile crushers are generally not a necessary requirement for a successful tender bid.

In Svay Rieng Province, the SSCs were unfamiliar with mobile crushers, they were not particularly keen in purchasing one because there is little available rock in the country and the opportunity to sell rock to the construction industry is limited due to the small size of the sector. SSCs were generally interested in purchasing mobile crushers in Champong Cham Province, and there were no shortage of quarries in the country, however, they lacked the funds to purchase such equipment. In Siem Reap Province, SSC were unfamiliar to mobile crushers and they believed that small-scale crushers are far less effective than large scale quarry based crushers and they doubted the ability of crushers in producing aggregates of quality suitable for structural concrete. They did not anticipate a demand for rural roads other than laterite and earth. Although there appears to be a boom in construction work, probably due to its proximity to the Angkor Wat world heritage site, however, such work seems to be monopolised by large scale contractors and the sites are dominated by their substantial concrete batching plants.

**Vietnam**

Many of the SSCs that were interviewed were pessimistic about using the small mobile crusher for the transport construction industry, mainly because obtaining a permit to mine natural resources require a government permit, which often takes in excess of two years. However, many SSCs were aware of the potential of the small mobile crusher to raise their company's profits by selling recycled building rubble to the building construction industry (such a commercial activity would not require a government permit).

In Yen Bai Province, although there are no quarries in the Province, there was also a general opinion that, should they acquire small-scale mobile crushers they would also be able to put them to good use for the supply of road surfacing, concreting and building construction aggregates.

## **Laos**

Consultants' unofficial conversations with contractors revealed a similar pattern of opinion. Many of the contractors are generally worried by the quality of the crushers currently being imported from China (not very highly regarded in terms of product quality, this view is not corroborated by empirical evidence from the mobile crusher surveys in Vietnam) but nevertheless, a number of SSCs have expressed an interest in purchasing them (high demand) but lack adequate information on where they can be purchased. One particular SSC, who owns his own small mobile crusher, has revealed that the jaws erode far too quickly and he would not be willing to purchase another small mobile crusher once his current one becomes obsolete.

## **Key Informants**

Almost all of the interviewees had heard of the small mobile crusher and the overwhelming majority had seen one. The interviewee's perception of the crusher was more positive than the towed grader. Most of the negative issues that were raised concerned the contractor's ability to access material to insert into the crusher; therefore its viability is very much dependent from region to region. Some highlighted that remote SSC would find crushers more beneficial, in cases where commercial supplies are unreliable. Many stated that due to economies of scale, larger contractors would prefer specialised commercial suppliers and therefore small mobile crushers may of great benefit to SSCs.

Some interviewees stated that SSCs can become more independent if they owned their own crushers; the equipment would provide a form of 'option value', whereby they can use them if they need to or when the financial benefits become greater. The issue of access to spare parts was an issue for some of the clients, especially considering that some of the other interviews had doubts about the durability of some parts of the crushers (especially the jaws). Overall, the general opinions are that they may provide benefits to the local contractor's, provided they prove to be a more cost effective means of acquiring aggregates and the contractor has easy access to a local quarry site.

### Evidence of Mobile Crusher Usage in Laos

The consultants of the SEACAP 020 have first hand experience of seeing two working examples of small mobile crushers in action in Laos:

**Airport runway:** This setup is temporary and much smaller than commercial quarries. The crusher is on a large construction site for a new airstrip in Luang Namtha. River gravel is brought from 10km away and an excavator and screen are used to remove all stones larger than about 100mm diameter. These stones are then crushed and used as the sub-base for the runway. The nearest quarry for crushed stone (which is used on top of the sub-base) is 50km from the airstrip. A significant number of the contractors surveyed reported that they would like to carry out a similar operation, but on a smaller scale. They believe that the use of a mobile crusher would have financial benefits but they do not know where to purchase a crusher of suitable size and reliability.



**Crusher being used at Lung Namtha, Laos**

**Individual contractor:** One contractor interviewed is the owner of two motor graders, several excavators and a fleet of trucks. He has imported a crusher from China and utilised his own workshop to construct a barrel type screen and mounting for the crusher and engine. He testifies that the crusher jaws are wearing quickly and that he would be interested in purchasing another crusher of a higher quality.



**Make shift crusher in Bokel, Laos**