Heavy equipment management practices and problems in Thai highway contractors

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Abstract

Purpose – This study is intended to investigate the current practices and problems in heavy equipment management as well as to identify practices capable of alleviating equipment management problems for highway contractors in Thailand.

Design/methodology/approach – Equipment management practices were identified and analysed by SPSS using a questionnaire survey. ANOVA test was used to reveal significant differences in equipment management practices among different contractor sizes. Relationships between equipment management practices and problems were also revealed.

Findings – The equipment management practices vary, to some extent, among different contractor sizes. While practices of medium and small contractors tend to be similar, practices of large contractors are different from those of smaller contractors. Large contractors often put more emphasis on outsourcing strategy for equipment management. Moreover, large contractors frequently dispose of or replace equipment as soon as the equipment becomes inefficient before incurring high repair costs. Conversely, smaller contractors tend to mainly emphasise on the company finance and the budget availability as they often rely on purchasing strategy, especially buying used machines. Overall, equipment practices of large contractors were found to be more successful than smaller contractors in minimising equipment management problems, including long downtime duration and cost.

Originality/value – This research is of value for better understanding practices and problems relating to heavy equipment management among different contractor sizes. The study also highlights practices that are capable of reducing problems relating to heavy equipment management for highway contractors.

Keywords Construction equipment, Construction industry, Thailand

Paper type Research paper

Introduction

Highway construction business is a sector that relies primarily on high utilisation of machinery. Equipment is thus one of the key factors for improving contractor's capability in performing their work more effectively and efficiently (Day and Benjamin, 1991). By utilising machinery, an extensive volume of work can be completed in a shorter period of time and within the project schedule. However, in managing construction equipment, contractors are invariably plagued with several difficulties such as huge capital investment in the acquisition phase, which usually constitutes a major financial burden. Procurement of major construction equipment not only costs as high as 36 per cent of the total construction project cost, but also causes a high delivery time uncertainty, which may disrupt the construction schedule (Yeo and Ning, 2006). In the operational phase, contractors are often faced with problems relating to high rate of equipment breakdown and accident resulting from unskilled

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operator abuse (Stewart, 2000; Edwards and Holt, 2002; Edwards and Nicholas, 2002). Poor training of equipment operators is often claimed as a major cause of equipment-related accidents (Gann and Senkar, 1998). In the maintenance phase, proper maintenance management of construction equipment is never over-emphasised since the cost and time that exceed the designated budget or schedule on projects are often resulted from poor machine maintenance practices. However, over-maintenance of equipment is undesirable as well (Vorster and De La Garza, 1990; Edwards *et al.*, 1997). In the disposal phase, determining equipment economic life and timing for replacement is often problematic because such decision is influenced by various factors such as machine obsolescence and efficiency (Vorster, 2005).

Effective equipment management practices not only increase production time and equipment availability, but also maximise the company profit by reducing several costs such as those from costly downtime (Edwards *et al.*, 1998a). However, researches in the field of equipment management practice, particularly in the construction context, have been rare (Edwards *et al.*, 1998b). This research was conducted in order to investigate current practices and problems on equipment management as well as to identify practices that are capable of mitigating equipment management problems from Thai highway contractor's perspectives. Since machine weight is one of the major indicators of equipment downtime and maintenance cost (Edwards *et al.*, 2000a, b; Edwards *et al.*, 2002), only five types of heavy construction equipment were selected in this study (refer to Table I). It is believed that a study on heavy equipment management practices would contribute great benefits for highway contractors in helping them manage heavy equipment successfully.

Contractor heavy equipment management practices

In this research, contractor heavy equipment practices have been categorised into four significant stages based on machine lifecycle, i.e. acquisition, operations, maintenance and disposal.

Equipment acquisition practice (EAP)

It is generally accepted that smart acquisition practices fuel company success. Contractors always have vested interest in ensuring that their invested equipment are properly used, maintained and managed (Mitchell, 1998). In practice, capital conservation is a major factor for most companies in deciding to buy, lease, or rent on an instalment plan (Sutton, 2003). Most companies, regardless of size, tend to prefer a purchasing strategy than other alternatives (Stewart, 2002a). To fulfil short-term equipment demand, most contractors realise the importance of rental machine utilisation (Stewart, 2002b). In the case of high workload during a peak construction

No.	Equipment types	Weight (kg)	Examples of model[a]
1	Track-type tractor	$\geq 12,000$	D5N XL
2	Motor grader	$\geq 14,000$	140H
3	Hydraulic excavator	$\geq 19,000$	320C
4	Asphalt paver	$\geq 11,000$	BG-225
5	Vibratory and pneumatic tyre compactor	$\geq 7,000$	CP-433C

Source: [a]Adopted from Caterpillar (2004)

Table I. Equipment types and size in the study cycle, leasing approach, which may come as a package with maintenance services from dealers, may be deemed appropriate (Stewart, 2002c).

Equipment operational practice (EOP)

An equipment operator is the person in the construction organisation who has the most influence on equipment costs (Stewart, 2001). Quality output can be partly achieved through skilful operators working with machines that are in good operational condition, thus educating equipment operators is one of the most important policies and thus holds great cost-saving potential (Wireman, 1999). Better channels of training can be obtained from various sources such as dealers (Stewart, 1998) and external agencies (Edwards and Holt, 2002). Systematic record-keeping is another practice that can generate valuable management guidelines, particularly in equipment planning and maintenance strategy (Marquez and Herguedas, 2004). Contractors must continually evaluate machine records in order to determine what actions are needed.

Equipment maintenance practice (EMP)

Maintenance of equipment is essential to contractor's profitability because it not only extends the useful life of the equipment but also controls the machine availability at a minimum cost. Nevertheless, equipment maintenance is the most neglected aspect. Successful maintenance management can be achieved through well-developed maintenance programs (Tavakoli *et al.*, 1990; Shenoy and Bhadury, 1998). Maintenance programs can be classified into several forms based on their complexity such as corrective maintenance, preventive maintenance and predictive maintenance (Gopalakrishnan and Banerji, 1991). Maintenance should not be viewed as a cost, but as an investment that can be linked to the company's future revenue growth (Sutton, 2001).

Equipment disposal practice (EDP)

The last stage of machine lifecycle is disposal stage, in which two major decisions concerning equipment have to be made, i.e. timing of replacement and equipment economic life expectancy (Douglas, 1975). There are various factors affecting the timing of replacement: machine efficiency, capital availability, investment costs, commencement of new projects, profits accrued from use, tax expense, depreciation, economic analysis, obsolescence costs, and downtime cost (Hinze and Ashton, 1979; Schexnayder and Hancher, 1981; Tavakoli *et al.*, 1989).

Table II shows 73 factors for heavy equipment management practices of highway contractors derived from not only a review of related literatures but also the expert opinions during a pilot test stage. The factors have been categorised into four groups as follows.

Research method

Data collection

This research involves a questionnaire survey by mail to collect the necessary data on equipment management practices and problems of highway contractors in Thailand. According to the Department of Highways (DOHs) of Thailand, highway contractors can be categorised into five classes (i.e. extra first, first, second, third, and forth classes) based on construction experience and company resources (i.e. equipment, finance and workforce). For the sake of data analysis, it was decided to reclassify contractors into three groups (i.e. large, medium and small). Large contractor group represents the

Table II. Heavy equipment management practices of highway contractors

Equipment acquisition practice (EAP)
EAP-01: purchase equipment outright by cash[c]
EAP-02: Purchase equipment by financing[c]
EAP-03: Acquiring rental equipment[c]
EAP-04: Acquiring leased equipment[c]
EAP-05: Purchase equipment in used condition
EAP-06: Purchase equipment in new condition
EAP-07: Purchase equipment based on personal judgments
EAP-08: Purchase equipment based on current and future workload
EAP-09: Purchase equipment based on internal rate of return (IRR) of investment[bc]
EAP-10: Purchase equipment based on life cycle cost (LCC) of equipment
EAP-11: Purchase equipment based on company financial status
EAP-12: Purchase equipment based on discount or special options from dealers
EAP-13: Make decision on acquiring or disposing equipment by president/CEO[abc]
EAP-14: Make decision on acquiring or disposing equipment by board of directors [abc]
EAP-15: Make decision on acquiring or disposing equipment by equipment managers[abc]
EAP-16: Make decision on acquiring or disposing equipment by project managers[ac]
EAP-17: Purchase equipment based on brand popularity and spare parts availability[a]
EAP-18: Purchase equipment based on functions and its usage
EAP-19: Purchase the same brand that is being used regularly[a]
EAP-20: Purchase equipment from familiar dealers
EAP-21: Purchase equipment based on its price[a]
EAP-22: Buy new or used machine based on budget availability
EAP-23: Buy used machines because of cheaper price but still in good condition
EAP-24: Buy new machines because of a need in functions and advanced technology
EAP-25: Buy used machines only the ones that do not have complicated systems
EAP-26: Buy new machines only the ones that render expensive repair cost once failure
EAP-27: Buy used machines only the ones that do not have high repair cost once failure
EAP-28: Buy new machines only the ones that are frequently utilized for a long time
EAP-29: Buy used machines only the ones that are not frequently utilized
EAP-30: Use rental or leasing strategy for the infrequent utilized equipment[a]
EAP-31: Use rental or leasing strategy to avoid equipment obsolescence[a]
EAP-32: Use rental or leasing strategy to avoid uncertainty of spare part cost
EAP-33: Use rental or leasing strategy to avoid initially financial burden to the company
EAP-34: Use rental or leasing strategy to test a newly launched machine[a]
EAP-35: Use standardization policy to save spare parts cost[c]
EAP-36: Use standardization policy to benefit from mechanics' learning curve[c]
EAP-37: Use standardization policy to lower operator/labour costs of machines[c]
EAP-38: Use standardization policy for better relationship with dealers[c]
EAP-39: Use standardization policy to enhance safety as operator uses similar machines[c]
EAP-40: Use standardization policy for easier equipment administration[c]
Equipment operational practice (EOP)
EOP-01: allow an equipment operator to work with more than one machine[ac]
EOP-02: Provide training by in-house equipment department
EOP-03: Provide training by equipment dealers[d]
EOP-04: Provide training by external agencies
EOP-05: Consider poor operating procedures as a main cause of equipment accident[c]
EOP-06: Consider poor maintenance as a main cause of equipment accident
Equipment maintenance practice (EMP)
EMP-01: Provide maintenance by equipment operators[ac]
EMP-02: Provide maintenance by in-house equipment department[ac]

(*continued*)

EMP-03: Provide maintenance by equipment dealers[abc]
EMP-04: Provide maintenance by other external mechanics[ac]
EMP-05: Provide preventive maintenance programs to equipment[c]
EMP-06: Seek for substitute equipment once machine suddenly breakdowns[f]
EMP-07: Wait until the failed machine is completely repaired and ready for use[f]
EMP-08: Transfer crews to other works once machine suddenly breakdowns[f]
EMP-09: Accelerate speed of works once machine suddenly breakdowns[f]
EMP-10: Modify project activity and schedule once machine suddenly breakdowns[f]
EMP-11: Consider poor operating procedures as a main cause of machine failure[e]
EMP-12: Consider poor maintenance as a main cause of machine failure during use[e]
EMP-13: Consider the use of non-original parts as a main cause of machine failure[e]
Equipment disposal practice (EDP)
EDP-01: Dispose or replace equipment based on intuition and rules of thumb[b]
EDP-02: Dispose or replace equipment based on equipment economic analysis [abc]
EDP-03: Dispose or replace equipment when it becomes technologically obsolete[a]
EDP-04: Dispose or replace equipment when it becomes inefficient[a]
EDP-05: Dispose or replace equipment when the company financial status is good[a]
EDP-06: Dispose or replace equipment before commencing a new job or project[a]
EDP-07: Dispose or replace equipment before major overhaul with high repair cost[ac]
EDP-08: Determine equipment economic life based on investment cost[a]
EDP-09: Determine equipment economic life based on downtime cost[ac]
EDP-10: Determine equipment economic life based on obsolescence cost[ac]
EDP-11: Determine equipment economic life based on tax advantage[ac]
EDP-12: Determine equipment economic life based on depreciation cost[ac]
EDP-13: Determine equipment economic life based on maintenance and repair cost[a]
EDP-14: Determine equipment economic life based on profit accrued from use[a]

Sources: [a]Hinze and Ashton (1979); [b]Schexnayder and Hancher (1981); [c]Tavakoli *et al.* (1989); [d]Stewart (1998); [e]Nepal (2001); [f]Nepal and Park (2004)

Table II.

companies registered in the extra first class, medium contractor group includes those registered in the first and second classes and small contractor group comprises of companies registered in the third and forth classes.

At the fist stage of the questionnaire development, a pilot test, using a semi-structured questionnaire, was conducted to test for the applicability of the tool. The selected samples for the pilot test comprise of equipment managers from ten different companies (i.e. four large, three medium, and three small contractors). Once the pilot test was completed, a valid questionnaire was then prepared and data collection was started. The questionnaire has been divided into three parts. The first part is an introductory section that includes questions related to the respondents and their company profile. In the second part, the respondents were asked to give a score on the frequency level for each of the 73 variables concerning equipment management practices (see Table I). Responses are on a four-point scale (never = 0, seldom = 1, often = 2 and always = 3). In the third part, the respondents were asked to specify the impact/significant level for each of the 20 equipment management problems that actually affect their companies on a five-point scale (not significant = 0, somewhat significant = 1, moderate significant = 2, significant = 3 and very significant = 4). Questionnaires were mailed to the respondents on a basis of random stratified sampling technique.

Data analysis
Data collected from the questionnaire survey was processed and analysed, using the SPSS software to test the research hypotheses. The research null hypothesis is stated that equipment management practices among large, medium and small contractors are the same, while the alternative hypothesis is given that they are different, as shown in the formula below:

$$H_o : \mu_L = \mu_M = \mu_S$$

$$H_a : \mu_L \neq \mu_M \neq \mu_S$$

Where μ_L, μ_M and μ_S are mean scores on heavy equipment management practices of large, medium and small contractors, respectively.

To test the stated hypotheses, one-way ANOVA test was utilised to examine the likely variation among responses from different contractor sizes. Further, post-hoc test using LSD method was also employed to investigate the variation of practices under each pair of contractor sizes (i.e. large VS medium, large VS small and medium VS small).

Pearson correlation was used to test the correlations between the practices and problems of equipment management. Only practices that are statistically different among different contractor sizes were considered and only the top-three most significant equipment problems were also incorporated into the test.

Sample profile
Among the total of 522 distributed questionnaires, 162 contractors replied, which constituted an overall response rate of 31.03 per cent. However, it was found that 152 out of 162 returned questionnaires were useful for data analysis, thus leaving ten questionnaires discarded as unused due to incompletion. A high response rate of the questionnaire survey is probably due to several reasons. First, not only the aim and rationale of this study were stated in the cover letter, but a number of phone calls were also randomly made to contractors in order to encourage survey participation. Further, the questionnaire could be returned anonymously using a self-addressed envelope enclosed. This is an assurance that the rendered data are to be kept confidential.

Table III summarises the frequency of contractors categorised by size, experience and participant position. The results of the survey show that the majority of the firms are medium and small contractors. Most of the companies have between 10 and 19 years experience in highway construction, followed by those with between 20 and 29 years experience. More than half of participants who completed the questionnaire are presidents/CEOs of the companies.

Differences in equipment management practices among large, medium and small contractors

The followings are the results of hypothesis testing using ANOVA and post-hoc test (LSD method) for equipment management practices that are statistically different among different highway contractor sizes.

Equipment acquisition practice (EAP)
Table IV shows three equipment acquisition practices that are statistically different among different contractor sizes, concluding that their null hypotheses are rejected.

Table III.
Sample profile

	n	%
Firm size		
Large	15	9.9
Medium	69	45.4
Small	68	44.7
Firm experience (years)		
<10	24	15.8
10-19	54	35.5
20-29	48	31.6
>29	26	17.1
Participant position		
President/CEO	78	51.3
Equipment manager	41	27.2
Project manager	25	16.4
Others	8	5.1

Note: $n = 152$ highway contractors

Table IV.
Mean scores and *p*-values (ANOVA test) of equipment acquisition practices that are statistically different among different contractor sizes

EAP no.	Equipment acquisition practices (EAP)	Overall mean	Mean score of firm sizes			P-value (two-tailed)
			Large	Medium	Small	
3	Acquire rental equipment	0.90	1.29	0.72	1.00	0.019*
5	Purchase equipment in used condition	1.60	1.21	1.61	1.72	0.031*
22	Buy new or used machine based on budget availability	2.06	1.46	2.10	2.09	0.027*

Note: *Denotes that the difference is significant at 0.05 level (two-tailed)

Results from Table V exhibit that large firms tend to utilise rental equipment more frequently than smaller firms (EAP-03). This is because smaller contractors often prefer to purchase equipment for long-term use. Large contractors, in contrast, are those who have much more jobs that take longer project duration and require a greater number of equipment resources. Thus, utilizing some rental machines, instead of purchasing all equipments, would be the right decision.

For equipment purchasing decision, small and medium contractors tend to purchase equipment in used condition more often than large firms (EAP-05). The difference in financial status among the three contractor groups could possibly explain the above finding as small and medium contractors are much more constrained by the availability of fund than the large contractors (EAP-22).

Equipment operational practice (EOP)

Table VI shows two equipment operational practices that are statistically different among the three contractor sizes, concluding that their null hypotheses are rejected.

According to Table VII, it was found that practice on providing training by external agencies is statistically different between large and medium contractors as well as between large and small firms (EOP-04), concluding that large contractors are far more likely to outsource their training tasks to external agencies than the smaller contractors. It was also discovered that small contractors tend to blame poor maintenance practice as the main cause of equipment-related accidents more often than the larger contractors (EOP-06). This infers that the maintenance quality of small contractors is inferior to that of the larger firms.

Equipment maintenance practice (EMP)

Table VIII illustrates three practices which are statistically different among the three contractor sizes, concluding that their null hypotheses are rejected.

EAP no.	Equipment acquisition practices (EAP)	(I) Size	(J) Size	Mean diff (I-J)	*P*-value (2-tailed)
3	Acquire rental equipment	Medium	Large	−0.57	0.014*
		Medium	Small	−0.28	0.041*
		Large	Small	0.29	0.211
5	Purchase equipment in used condition	Large	Medium	−0.40	0.037*
		Large	Small	−0.51	0.009*
		Medium	Small	−0.11	0.348
22	Purchase equipment based on budget availability	Large	Medium	−0.64	0.009*
		Large	Small	−0.63	0.011*
		Medium	Small	0.01	0.931

Note: *Denotes that the difference is significant at 0.05 level (two-tailed)

Table V. Difference of mean scores and *p*-value (post-hoc test by LSD method) on equipment acquisition practices between a particular pair of contractor sizes

EOP no.	Equipment operational practices (EOP)	Overall mean	Mean score of firm sizes Large	Medium	Small	*P*-value (2-tailed)
4	Provide training by external agencies	0.54	1.08	0.47	0.54	0.013*
6	Consider poor maintenance as a main cause of equipment-related accidents	1.77	1.43	1.70	1.91	0.040*

Note: *Denotes that the difference is significant at 0.05 level (two-tailed)

Table VI. Mean scores and p-values (ANOVA test) of equipment operational practices that are statistically different among different contractor sizes

EOP no.	Equipment operational practices (EOP)	(I) Size	(J) Size	Mean diff (I-J)	*P*-value (2-tailed)
4	Provide training by external agencies	Large	Medium	0.61	0.003*
		Large	Small	0.54	0.010*
		Medium	Small	−0.07	0.556
6	Consider poor maintenance as a main cause of equipment-related accidents	Large	Medium	−0.27	0.197
		Large	Small	−0.48	0.022*
		Medium	Small	−0.21	0.086**

Notes: *Denotes that the difference is significant at 0.05 level (two-tailed); **Denote that the difference is significant at 0.10 level (two-tailed)

Table VII. Mean score difference and *p*-value (*post hoc* test by LSD method) on equipment operational practices between a particular pair of contractor sizes

Results in Table IX show that the practice on providing maintenance by in-house equipment department (EMP-02) is statistically different between medium and small contractors. Small firms are less likely to provide maintenance services by their in-house equipment department than the larger firms. This might be because small contractors have lower number of construction equipment than larger firms. And thus, being fully equipped with human resources and facilities for maintenance services may not be the right decision.

Based on Table IX, large firms tend to acquire maintenance services from equipment dealers more often than small firms (EMP-03). This result confirms the aforementioned finding that large contractors tend to favour outsourcing strategy in managing their equipment.

In the aspect of machine failure during operations, small contractors tend to assign their crews to other jobs more often than large contractors (EMP-08). Equipment ownership of contractors probably explains this finding. Since large firms are more likely to utilise rental machines (EAP-03), they would receive a substitute machine from their dealers if the equipment fails during operations without having to reassign their crews. Smaller firms, in contrast, have to reassign their crews more frequent in order to avoid crew idleness since they tend to acquire equipment using a purchasing strategy.

Table VIII. Mean scores and p-values (ANOVA test) of equipment maintenance practices that are statistically different among different contractor sizes

EMP no.	Equipment maintenance practices (EMP)	Overall mean	Mean score of firm sizes Large	Medium	Small	*P*-value (two-tailed)
2	Provide maintenance by in-house equipment department	2.43	2.53	2.57	2.27	0.036*
3	Provide maintenance by equipment dealers	1.39	1.71	1.45	1.28	0.098**
8	Transfer crews to other works once machine suddenly breakdowns	2.04	1.79	1.99	2.18	0.087**

Notes: *Denotes that the difference is significant at 0.05 level (two-tailed); **Denotes that the difference is significant at 0.10 level (two-tailed)

Table IX. Mean score difference and p-value (*post hoc* test by LSD method) on equipment maintenance practices between a particular pair of contractor sizes

EMP no.	Equipment maintenance practices (EMP)	(I) Size	(J) Size	Mean diff (I-J)	*P*-value (2-tailed)
2	Provide maintenance by in-house equipment department	Large	Medium	−0.04	0.867
		Large	Small	0.26	0.175
		Medium	Small	0.30	0.012*
3	Provide maintenance by equipment dealers	Large	Medium	0.26	0.233
		Large	Small	0.43	0.046*
		Medium	Small	−0.17	0.172
8	Transfer crews to other works once machine suddenly breakdowns	Large	Medium	−0.20	0.328
		Large	Small	−0.39	0.055**
		Medium	Small	−0.19	0.106

Notes: *Denotes that the difference is significant at 0.05 level (2-tailed); **Denotes that the difference is significant at 0.10 level (2-tailed)

Equipment disposal practice (EDP)

Table X illustrates two equipment disposal practices that are statistically different among the three contractor groups, concluding that their null hypotheses are rejected.

From Table XI, it was found that large contractors dispose or replace equipment when it becomes inefficient (EDP-04) more frequently than medium and small contractors. Large firms also tend to dispose or replace equipment before incurring major overhaul and high repair cost (EDP-07) more frequently than small firms. This infers that, in making equipment disposing or replacing decision, large companies tend to put more emphasis on the consideration of equipment operational factors (e.g. repair cost, maintenance cost, and equipment efficiency) than the smaller firms.

Problems caused by practices in heavy equipment management

In order to explore the practices that lead to the problems in equipment management of large heavy machines, it was decided to employ a correlation technique in this study. Therefore, this section is intended to identify the correlations between equipment management practices that are statistically different among different contractor sizes and the top-three most significant problems in equipment management. The top-three most significant problems in equipment management, ranked by the overall mean score, are illustrated in Table XII.

Results reveal that some practices are correlated with equipment management problems (see Table XIII). The first three significant relationships are positive correlations between the practice on considering poor maintenance as the main cause of equipment-related accidents (EOP-06) and all three equipment problems (i.e. high

EDP No.	Equipment disposal practices (EDP)	Overall mean	Mean score of firm sizes Large	Medium	Small	*P*-value (2-tailed)
4	Dispose or replace equipment when it becomes inefficient	1.81	2.46	1.87	1.64	0.001*
7	Dispose or replace equipment before overhaul as repair cost seems to be high	1.48	1.93	1.49	1.33	0.028*

Note: *Denotes that the difference is significant at 0.05 level (2-tailed)

Table X. Mean scores and p-values (ANOVA test) of equipment disposal practices that are statistically different among different contractor sizes

EDP no.	Equipment disposal practices (EDP)	(I) Size	(J) Size	Mean diff (I-J)	*P*-value (2-tailed)
4	Dispose or replace equipment when it becomes inefficient	Large	Medium	0.59	0.009*
		Large	Small	0.82	0.000*
		Medium	Small	0.23	0.072**
7	Dispose or replace equipment before major overhaul as repair cost seems to be high	Large	Medium	0.44	0.052**
		Large	Small	0.60	0.008*
		Medium	Small	0.16	0.227

Notes: *Denotes that the difference is significant at 0.05 level (2-tailed); **Denotes that the difference is significant at 0.10 level (2-tailed)

Table XI. Mean score difference and *p*-value (*post hoc* test by LSD method) on equipment disposal practices between a particular pair of contractor sizes

Table XII.
Top-three most significant problems on equipment management

Rank no.	Equipment management problems	Mean scores by firm sizes: Large	Medium	Small	Overall mean	Significant level of the problems*
1	High equipment downtime duration and cost (Vorster and De La Garza, 1990; Tsimberdonis and Murphree, 1994; Elazouni and Basha, 1996)	2.80	2.75	2.88	2.82	Significant
2	Low equipment availability rate (Pathmanathan, 1980; Vorster and De La Garza, 1990)	2.43	2.54	2.46	2.46	Moderate significant
3	High rate of breakdown and repair cost (Nepal, 2001; Nepal and Park, 2004)	2.43	2.45	2.57	2.45	Moderate significant

Notes: *Mean score (0.00-0.50) = not significant, (0.51-1.50) = somewhat significant, (1.51-2.50) = moderate significant, (2.51-3.50) = significant, and (3.51-4.00) = very significant

Table XIII.
Pearson correlation matrix between practices and problems on equipment management

No.	Equipment management practices (which are statistically different among different contractor sizes)	Top-three equipment management problems: (1) High equipment downtime duration and cost	(2) Low equipment availability rate	(3) High rate of breakdown and repair cost
EAP-03	Acquire rental equipment	0.102	0.120	0.106
EAP-05	Purchase equipment in used condition	0.080	−0.011	0.055
EAP-22	Purchase equipment based on budget availability	−0.025	0.058	−0.035
EOP-04	Provide training by external agencies	−0.058	−0.077	−0.064
EOP-06	Consider poor maintenance as a main cause of equipment-related accidents	0.167*	0.144**	0.267*
EMP-02	Provide maintenance by in-house equipment department	0.006	0.019	0.015
EMP-03	Provide maintenance by equipment dealers	−0.157**	−0.235*	−0.080
EMP-08	Transfer crews to other activities when machine breakdowns during use	0.025	−0.031	−0.064
EDP-04	Dispose or replace equipment when it becomes inefficient	−0.133**	−0.100	0.108
EDP-07	Dispose or replace equipment before major overhaul as repair cost seems to be high	−0.046	−0.032	0.005

Notes: *Denotes that the correlation is significant at 0.05 level (2-tailed); **Denotes that the correlation is significant at 0.10 level (2-tailed) equipment downtime duration and cost, low equipment availability rate, and high rate of breakdown and repair cost), signifying that contractors who invariably have poor maintenance practice are more likely to face these three problems. Besides, small contractors tend to have poorer maintenance practice than the larger contractors (see Table VI). This infers that small contractors, who often have poor maintenance practice, are far more likely to encounter problems relating to high equipment downtime duration and cost (2.88, Table XII), low equipment availability rate (2.46, Table XII) and high rate of breakdown and repair cost (2.57, Table XII) than larger contractors (2.80, 2.43 and 2.43, respectively in Table XII).

Further, Table XIII shows that the practice on acquiring maintenance service from equipment dealers (EMP-03) is negatively correlated with the problems on high equipment downtime duration and cost and low equipment availability rate. This indicates that acquiring maintenance services from equipment dealers could possibly reduce these two problems. In fact, it was found that large contractors tend to utilise maintenance services from dealers more frequent than small contractors (see Table IX). This concludes that large contractors, whose maintenance services are often provided by their dealers, tend to face less problems relating to high downtime duration and cost (2.80, Table XII) and low rate of machine availability (2.43, Table XII) than small contractors (2.88 and 2.46, respectively in Table XII).

Finally, it was found that the practice concerning disposing or replacing equipment when it becomes inefficient (EDP-04) is negatively correlated with the problem relating to high downtime duration and cost. Indeed, it was found that large contractors perform this practice more often than small contractors (see Table XI). This infers that large contractors, who frequently dispose or replace equipment when it becomes inefficient, tend to encounter fewer problems relating to high downtime duration and cost (2.80, Table XII) than small contractors (2.88, Table XII).

Conclusion

To some extent, heavy equipment management practices vary considerably among different highway contractor sizes. Large firm's practices tend to be much different from those of the smaller firms, whereas medium and small contractors' practices are more likely to be similar. Large contractor's practices tend to be more successful in minimising equipment management problems. In order to diminish equipment problems, particularly downtime, the importance of performing preventive maintenance should be strictly emphasised. Adoption of professional services (e.g. maintenance and training) from external agencies such as dealers is also recommended if such tasks are not the company's core competency. Moreover, equipment should be disposed of or replaced once it becomes inefficient or generates less productivity with high repair cost.

The foregoing practices could be considered effective because it significantly reduces major equipment management problems. Therefore, adaptation and implementation of such practices by contractors are strongly suggested. Nevertheless, this research focuses only on equipment management practices and problems of several types of large heavy machines for highway construction. Practices and problems relating to small machines or even equipment utilised in other industries are probably different from this study and thus could be the area for future research.

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