Developing a productivity model to management the construction equipment- using simulation approach

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Abstract:

machinery has the main role in the development of the construction activities, enhancing the productivity of the machinery plays a crucial role in the reduction of destructions, their downtime and the delays of project delivery and its final effects. The objective of the present research is to develop machinery productivity and identify the most effective factor of machinery`s productivity in urban project through data collection of the by interviewing the experts, great constructors, managers, and machinery supervisors. Then, the data analysis has been done by dynamic modeling system by which the effective factors of the decrease and increase of the machinery`s productivity was identified to enhance the machinery`s productivity by taking suitable approaches and correct decisions.

After identifying and classifying the effective factors of machinery productivity, and then analyzing the data and dynamic modeling system and also by taking the important role of the human being in productivity into consideration, it is concluded that management and taking the manager`s policies are the main reasons of dynamicity of the machinery productivity. Then, from among the two most effective management subcategories (for experts and in articles), the policy of renting and purchasing machinery and its maintenance were selected. Therefore, results have shown that in comparison with the other factors, the maintenance policy had the most effective correlation; then it is tried to develop this model based on simulation model (cause and effect relationship).

Keywords: Construction equipment,Downtime , maintenance, Management

Introduction

Gaining benefit of the machineries in civil projects is of great importance, it is because of the daily progress of technology in different civil fields, specially machineries, technology of project implementation, management, and supervision. Therefore, the expertise consideration toward machinery productivity is one of the helpful approaches to gain benefit and increase productivity and making the civil project implementation cost effective in planning the project management.

Productivity means the maximum usage of the resources, human force, and the scientific approaches in order to decrease the expenses, increase the staff, managers, and consumers satisfaction. One of the most important factors of tangible decrease of productivity and at last rising the final price of the great civil projects is having a scientific view point approach toward project management instead of having a non-scientific and the constructor`s attitude before the managers and supervisors of the companies. Device management approaches are to some extent different for the classification of different constructors, while the normal and lower level constructor`s approaches of machinery management have similar features. Also the methods in which the higher level constructors take is different from the methods that the normal and lower level ones take (Prasertrungruang and Thanapun,2007).

Talking about providing policies to rent or purchase machineries in this article is from among the factors that this article is to make clear the difference. Large contractors almost always replace the defective equipments before they cause trouble. Instead, the small contractors tend to take part in financial affairs of the company and budgets. Generally, in comparison with the small contractors, the large ones take equipment managements approaches to minimize the problems of the equipments like downtime and the other expenses. This article identified the effective factors of machinery productivity by the use of questionnaire and interview and the literature review of the previous articles, as it is shown in Fig. 1. Then by a great and in-detail analysis of the effective factors of machinery productivity, the most important and the most effective factor was identified and their correlation was counted. At last, the maintenance policies have developed through dynamic modeling system.

According to the construction engineering organization of Iran, construction contractors

can be categorised into five classes (i.e first, second, third, forth and five classes)

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

(Prasertrungruang,2007)

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 cycle, leasing approach, which may come as a package with maintenance services from dealers, may be deemed appropriate (Stewart, 2002c)

Contractors have two option in acquiring plant. They may either own their machinery and equipment or hire it. Many contractors prefer to hire only those items of plant,which are required to meet peak demand or specialized activities. The alternative decision to purchase will have important financial consequences for the contractor, since considerable capital sums will be blocked up in the Equipment, which must be operated at an economic utilization level to produce a profitable rate of return of investment.(construction information services,2012)

table 1 shows Summary Equipment acquisition feedback in the literature articles .

Table1: Summary Equipment acquisition feedback in the literature articles:

Equipment acquisition feedback	Reference
Purchase equipment outright by cash,Financing	Tavakoli et al. (1989)
Acquiring rental equipment	Tavakoli et al. (1989)
Acquiring leased equipment	Tavakoli et al. (1989)
Purchase equipment in used condition,new condition,based on personal judgments,based on current and future workload,based on life cycle cost (LCC) of equipment,based on company Financial status or based on internal rate of return (IRR) of investment	Prasertrungruang Hadikusumo(2007),schexnayder and Hancher (1981),tavakoli et al(1989)
Make decision on acquiring or disposing equipment by president /CEO,by board of directors ,by equipment managers or by project managers	Hinze and Ashton (1979),Schexnayder and Hancher(1981), Tavakoli et al (1989)
Purchase equipment based on brand popularity and spare parts availability, function and its usage	Hinze and Ashton (1979),Prasertrungruang and Hadikusumo(2007)
Purchase the same brand that is being used regularly	Hinze and Ashton (1979)
Purchase equipment from familiar dealers	Prasertrungruang and Hadikusumo(2007)

Purchase equipment based on its price	Hinze and Ashton (1979)
Buy new or used machine based on budget availability	Prasertrungruang and Hadikusumo(2007)
Buy used machines because of cheaper price but still in good condition or need in function and advanced technology	Prasertrungruang and Hadikusumo(2007)
Buy used machines only the ones that do not have complicated system,ones that render expensive repair cost once failure,ones that do not have high repair cost once failure ,ones that are not frequently utilized or ones that are frequently utilized for a long time .	Prasertrungruang and Hadikusumo(2007)
Use rental or leasing strategy for the infrequent utilized equipment , to avoid equipment obsolescence,to avoid uncertainty of spare part cost, to avoid initially financial burden to the company, to test a newly launched machine ,to save spare parts cost ,to benefit from mechanics learning curve , to lower operator /labour costs of machaines or to enhance safety as operator uses similar machines .	Hinze and Ashton (1979),Prasertrungruang and Hadikusumo(2007) ,tavakoli et al(1989)
Use standardization policy for better relationship with dealers or for easier equipment administration	Tavakoli et al. (1989)
Acquiring rental equipmentc	Thanapun Prasertrungruang and B.H.W. Hadikusumo(2007)
Equipment acquisition feedback	Reference
Purchase equipment in used condition	Thanapun Prasertrungruang and B.H.W. Hadikusumo(2007)
Buy new or used machine based on budget availability	Thanapun Prasertrungruang and B.H.W. Hadikusumo(2007)
Differences in equipment management practices among large, medium and small contractors, shows three equipment acquisition practices that are statistically different among different contractor sizes	Thanapun Prasertrungruang and B.H.W. Hadikusumo(2007)
After a consensus among all five large highway contractors cases was made regarding the dynamic behaviors of equipment management practices and downtime ,the generic feedback structures could be delivered which are categorized in to five components as follows: 1-Equipment Acquisition Feedback structure 2-Equipment operational FeedBack structure 3-Equipment Maintenance Feedback structure 4- Equipment disposal Feedback structure 5- Equipment Downtime Feedback structure	Thanapun prasertrungruang and B.H.W. Hadikusumo (2009) Thanapun prasertrungruang and B.H.W. Hadikusumo Por Rungruang concrete ltd,Khonkaen.Thailand (2008)

Best practices for Equipment Acquisition by interviewing the experts:

EAP-01: Acquiring rental equipmentc

EAP-02: Purchase equipment in used condition

EAP-03: Buy new or used machine based on budget availability

Table 1 shows three equipment acquisition practices that are statistically different among different contractor sizes, concluding that their null hypotheses are rejected.

Equipment maintenance practice (EMP)

Maintenance of equipment is essential to contractorِ 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 companyِ future revenue growth (Sutton, 2001).

Table2 shows Summary equipment maintenance feedback in the literature articles .

Maintenance of construction equipment is crucial as this preserve them for future construction jobs, accident and save contractors from unnecessary expenses and time (mavelous,2012)

Table2: Summary equipment maintenance feedback in the literature articles:

Provide maintenance by equipment operators	Hinze and Ashton (1979),Tavakoli et al.(1989)
Provide maintenance by in-house equipment department	Hinze and Ashton (1979),Tavakoli et al.(1989)
Provide maintenance by equipment dealers	Hinze and Ashton (1979)
Provide maintenance by other external mechanics	Hinze and Ashton (1979)
Provide preventive maintenance programs to equipment	Tavakoli et al (1989)
Seek for substitute equipment once machine suddenly breakdowns	Tavakoli et al (1989)
Wait until the failed machine is completely repaired and ready for use	Hinze and Ashton (1979),Tavakoli et al.(1989)
Transfer crews to other works once machine suddenly breakdowns	Tavakoli et al (1989)
Accelerate speed of works once machine suddenly breakdowns	Hinze and Ashton (1979),Tavakoli et al.(1989)
Modify project activity and schedule once machine suddenly breakdowns	Hinze and Ashton (1979),Tavakoli et al.(1989)
Consider poor operating procedures as a main cause of machine failure	Hinze and Ashton (1979),Tavakoli et al.(1989)
Consider poor maintenance and use of non-original parts as a main cause of machine failure during use	Tavakoli et al (1989)

Table 2 illustrates three practices which are statistically different among the three contractor sizes, concluding that their null hypotheses are rejected.

Best practices for Equipment meintenance by interviewing the experts:

EMP-01: Provide maintenance by in-house equipment department

EMP-02: Provide maintenance by equipment dealers

EMP-03: Transfer crews to other works once machine suddenly breakdown

Methodology

By analyzing the productivity of the machineries by considering the literature review of the previous articles and also by giving the questionnaires of the effective factors of productivity and also interviewing, the data collection has been done. Then the most important and effective factor was identified by a great and in-detail analysis between the effective factors on machineryِ productivity; then the subsystem policies of maintenance and simulation have been developed through system dynamic modeling (simulating). One hundred questionnaires were given, 30 of which were answered by the constructors, almost two third of the experienced constructors were between 10 to 29 and over half of them were manager or directing manager of the companies.

sample Characteristics

Among a total of 100 distributed questionnaires, 30 contractors replied, constituting an overall response rate of 30%. There are ten questionnaires discarded as unused due to incomplete data.Table 3 shows the sample profile of contractors categorized by company size and experience, and respondentِ position and work experience. The majority of businesses were medium-size and small contractors. Approximately two thirds of the contractors

have experience in construction of between 10 and 29 years. More than half of the respondents are president or CEO of the company _51.3%_, followed by equipment manager

_27.2%_. The majority of the informants have work experience of between 10 and 19 years.

Table 3. Sample Characteristics _*N*=30 construction Contractors

Company profile	Experience years	
Size company		N
Large	□10	10(33.3%)
Medium	10-19	10(33.3%)
Small	20-29	10(33.3%)
	□29	

Large = Extra-first-class contractors.

Medium = First- and second-class contractors.

Small = Third- fourth and five-class contractors _DOH 2004.

Findings

The effective factors of the machinery`s productivity:

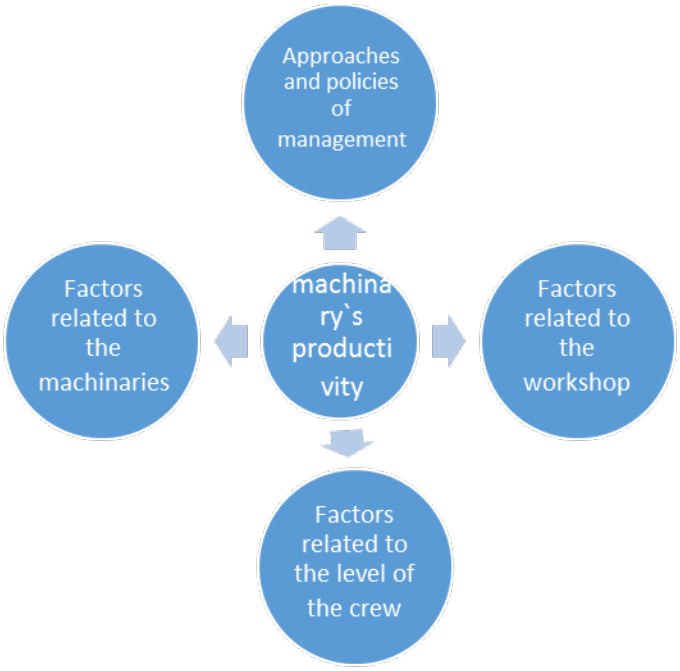


Fig.1.Hypothesized model of Equipment productivity

Identifying and classifying the effective factors of machinery`s productivity based on

Figure 1, management approaches and policies were selected as the most important factor, from among the four effective factors of productivity. management approaches and policies categorize into a multiple subsystem (these variables are the clear or observed variables and the management approaches and policies are the hidden variable) that their important ones were selected by taking the expertise, professionals, the correlation between the factors. They are as:

-Management approaches and policy observed variables:

-The financial conditions of the machinery market

-Declaring the equipments and facilities or their replacement

-The way of buying the equipments (renting or buying the machines)

-Work schedule (doing the work overtime or its repetition)

-The correct selection of the machineries

-The financial status of the projects

-Employing the small contractors

-Managerial commitment in machine maintenance and trouble shooting

-Lack of information of the supervisors and the managers

-The negative effects of time delays on the project

-The constructor`s degree and level

-Incorrect control of source division

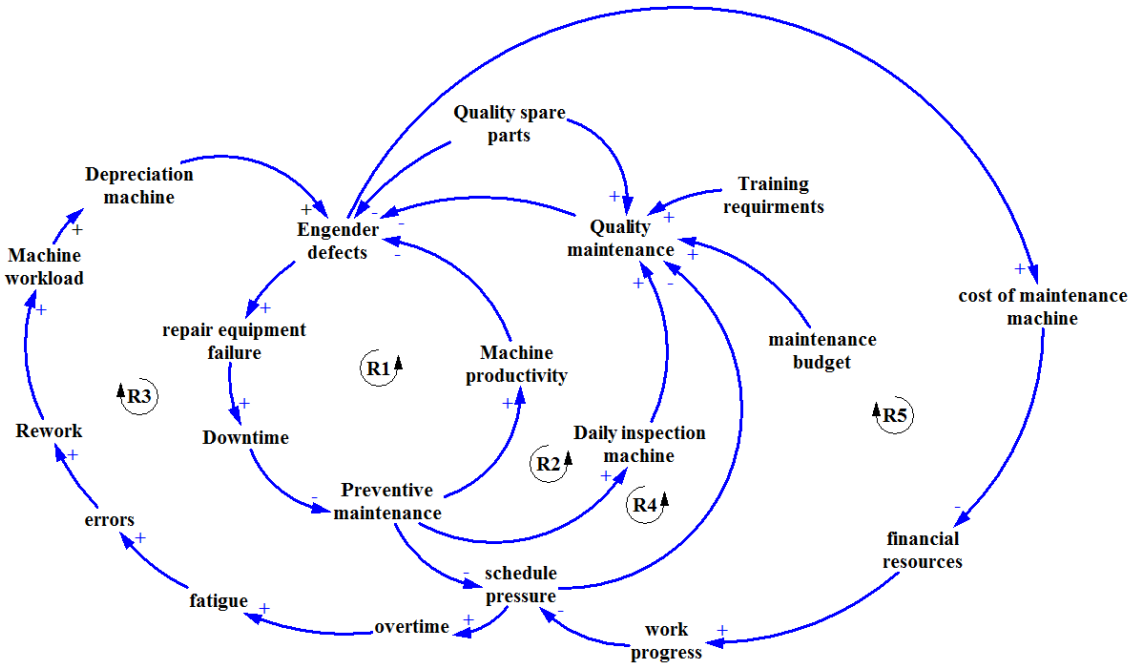
-Taking correct approaches of safety

-Using the standardization policies (installing operator on similar machineries and providing a stronger relationship between the constructors and the sellers)

Equipment Maintenance Feedback Structure :

For Equipment maintenance feedback structure (Fig.2), main focus on this is on the preventive maintenance (PM).However ,PM effort is enhanced by the effect of daily inspection machine and schedule pressure in preventive maintenance reinforcing loop (R2 and R3 in Fig.2). According to the Fig.2,(lop R4)when preventive maintenance increases leads to reduced schedule pressure and quality maintenance increases , thus reduced engender defects leads to repair equipment failure reduced.

Consequently,downtime reduced and preventive maintenance increases.



Legend:

R:reinforcing loop

+(-): positive(negative) relationship between cause and effect

: A causal relationship

Fig.2. Equipment maintenance Feedback Structure

Discussion and conclusion

To some extent, heavy equipment management practices vary considerably among different construction contractor sizes. Large firmپ practices tend to be much different from those of the smaller firms, whereas medium and small contractorsپpractices are more likely to be similar. Large contractorپ 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 companyپ core competency.moreover,equipment should be disposed of or replaced once it becomes inefficient or generates less productivity with high repair cost.

Machinery`s productivity has had a great effect on the costs, time, and the quality of the constructions and the civil projects. One of the effective and important results of decreasing the Machinery`s productivity is the downtime of the machineries in the projects. Almost all of the previous articles have analyzed the outcome of these projects, but this project tries to analyze and develop the machinery`s productivity which is the main source of all of the outcomes of the downtime and then by an in-detail analysis, from among the diverse factors, the most important factor which caused the reduction of the machinery`s productivity was separated; next, the simulation of the dynamic model of machinery`s productivity was developed to solve all of the downtime problems of machineries, their resulted outcome, delays of project delivery, time and cost reduction of the civil projects.

After giving the questionnaires to the managers and the supervisors of the workshop, the highest percentage of the correlations on the machinery`s productivity among the people was of the management policy and procedure`s subsystem, in-detail analysis of the factors, The other effective factors are as follows:

1. Maintenance policies
2. Policies for renting or buying the machines
3. Work schedule
4. Declaring the equipments and facilities or their replacement

After identifying the most effective and important factor of machinery`s productivity, this article tries to analyze machinery maintenance and also its effect on the productivity of constructive machineries and civil projects, then by the use of cause and effect relations, this model was developed through Vensim Simulation Software. Therefore, construction companies need to have a professional planning for management and maintenance to prevent the accidental effects on the function of the construction projects.

Introducing this productive model gives us a great help in the following conditions

First: this model identified the factors resulted when machineries ruin

Second: this model emphasizes the importance of preventive maintenance policies

Third: this model has the capability of identifying the importance of program schedule which happens by reactive construction through managerial decisions and measurements.

Fourth: this model shows the role of the contractors and also the company`s budget

At last, the final model provides a model to uncover the reason of decrease or increase of machinery`s productivity and also the reason of machinery`s downtime and their effect on the activity of project.

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