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Utilization of Value Engineering to Optimize Concreting Productivity

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Abstract: This study highlights the topics of productivity monitoring and measurement in constructing sector. To develop the productivity, several measures have been done in some area of construction projects. Concreting process is taken as case study. The finding pointed the relative importance of this activity in terms of time and cost. Three methods of concreting process were examined; manual method, semi-mechanized method and full-mechanized method. For small size works, the manual method was the best for concreting work less than 50 m^3 for work more than 50 m^3 and less than 260 m^3, the Semi Mechanized Method was the best and finally for work size more than 260 m^3, the full mechanized method was the most suitable. A comparative model has been developed to determine the best method of construction, its cost and duration. This model can also be used as a predicting tool for selecting the method during the planning phase of project.

Key words: Productivity measurement, concreting process, value engineering

INTRODUCTION

As organizations have recognized the criticality of projects to their success, project management has become a focal point of improvement efforts. More and more organizations have embraced project management as a key strategy for remaining competitive in today's highly competitive business environment (Amiruddin *et al*., 2007). Value Engineering (VE) or Value Management (VM) is one of the important project management tool, it can be defined as the systematic effort directed at analyzing the functional requirements of systems, equipment, facilities, procedures and supplies for the purpose of achieving the essential function at the lowest total cost, consistent with meeting needed performance, reliability, quality, maintainability, aesthetics, safety and fire resistance. VM as a management style focuses on value system evolution and resolution within projects, or organizational systems for that matter, by bringing the right team of stakeholders together at the right time. Through a structured, challenging, analytical and mediated process it permits value systems to coalesce to the benefit of the commissioning organization, regardless of whether the VM service is offered internally within an organization or is commissioned externally (Male *et al*., 2007). VM also can be defined as a structured and analytical process, the purpose of which is to seek to achieve value for money by providing all of the necessary functions at the lowest cost consistent with required levels of quality and performance (Lin and Shen, 2007).

Implementation of value engineering involves six steps: information, functional analysis, creative, evaluation, planning/proposal and implementation/follow-up. Value Management (VM) studies often face pressure caused by limited time and resources. The identification of key factors for value management success enables appropriate allocation of the limited time and resources in order to achieve better output. Shen distinguishes these factors according to their degrees of importance in relation to success via conducting a questionnaire survey to gather views from experts with experience in value management practice (Shen and Liu, 2003).

Value engineering may be performed in two ways; proactively or reactively. A proactive approach uses value engineering to collect ideas starting at the beginning of design. Thus, multiple design alternatives are considered and the most cost effective selected on a continual basis throughout the design phase. A reactive approach gathers cost effective alternatives through design reviews by other project personnel such as constructors and other designer engineers. This is performed after the entire design or specific component of design is complete. One of the best field to apply value engineering concepts is the productivity. In construction projects; the productivity is the most critical factor to determine the project cost, duration and as a result; the benefit for all parties.

Construction productivity is the ratio between inputs and outputs. It is important to specify that the inputs and outputs to be measured when calculating the productivity

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because there are many inputs such as labours, materials, equipments, tools, capital and design in the construction system. The process of conversion from inputs to outputs associated with construction operations is also complex and influenced by the technology, government regulations, weather, economic conditions and management and by various internal environment components. The change in productivity can be due to one or more internal or external influence including undefined disturbance. In addition, there could be different productivity indices for different purposes and these productivity indices are related to time and place.

A construction project is mostly initiated by the needs of the client. In order to satisfy the client's requirements in terms of time, cost and quality, various procurement methods are recommended for selection to increase the chance of success for the complex sequence of activities. Design-build integrates design and construction to overcome some of the hurdles inherent in the traditional design-bid-build method. An investigation into the determinants of successful design-build projects can therefore help to set a benchmark study for industry practitioners to compare their project performance. Project success index developed for projects in the Hong Kong context to better indicate the success level of projects, which is assessed by the key project performance indicators of time, cost, quality and functionality (Lam *et al*., 2008).

Performance measurements and benchmarking of various construction activities and operations are the best methods that may help to develop the productivity of this industry. Jongeling refer to the needs for quantitative analyses, standardizing the representation of activities and formalizing methods for quantitative analysis of construction concerns. The productivity and therefore the output of crews are strongly dependent on available workspace and affect the progress on projects and ultimately the project cost (Jongeling *et al*., 2008).

Concreting process, which consist of concrete mixing, transporting and placing is a major operation in most of construction project. Study of concreting is of direct value to the productivity improvement and of wider economical interest. Data collected for the research during the period from 2003 up to the end of 2006 via monitor the labour force performance and equipment resources in the concreting field of construction project in Iraq. The study was concerned by completely ready mixed concrete and partially ready mixed for building projects which of value about 0.7 million US Dollars. Some of the objectives were:

- Measuring of the productivity being achieved by site labours, labours with simple mixing equipments and by completely ready mixed concrete with track mixer and concrete pump machines for the concreting of building
- Compare the resources utilization of different concrete placing methods in term of cost and time, besides the producing of performance benchmarks for future
- Compare the cost of one cubic meter of concrete for the three methods
- Find out factors affecting concreting productivity and ways to improve it

This case study was conducted under unsuitable circumstances (political and economical), so the cost index is related to that period but the procedure is valid for other cases taking into account the correction factor for price index.

CONCRETING WORK IN CONSTRUCTION PROJECT

The analysis of data related to projects under study refers that for (6) projects which is shown in Table 1. The weight of concreting work rate is (33.9%) of total projects cost and if it is compared with other civil and architecture works, the rate of concreting work will be (39.4%) for these projects. These rates explain the relative importance of concreting work and means that any change in direction of the improvement in the productivity of concreting work will reduce the time needed for this

Table 1: Rate of the concreting cost in $ US to total project work time rate of the concreting work

	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Total/average
Total project cost $ US	422630	586000	291700	783000	547200	262630	2893160
Civil and arch. Work $ US	389240	498145	247940	665555	465120	223235	2489235
Concreting work cost $ US	163910	200695	98345	247280	186270	84150	980650
Concreting cost to total project cost	38.8%	34.2%	33.7%	31.6%	34.0%	32.0%	33.9%
Concreting cost to civil and arch. work cost	42.1%	40.3%	39.7%	37.2%	40.1%	37.8%	39.4%
Total project working day*	3024	409	435	325	690	540	5423
Concreting working day	886	107	152	77	186	176	1584
Rate of concreting to total project time	29.3%	26.2%	35.0%	23.7%	27.0%	32.6%	29.2%

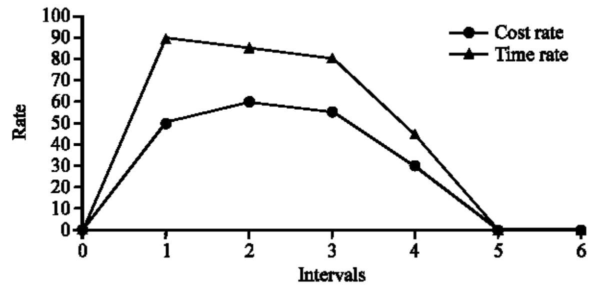

Fig. 1: Relative concreting process duration and cost to total project duration and cost

process. Also that will minimize the cost of this item, which will effect on the total cost of project by rate 1/0.34 (1 unit of concreting equal to 0.34 of total project units). In term of civil and architecture works the rate will be (1/0.40).

The time needed for civil and architectural items is one of the important elements, which govern the total project time that is from one hand and the implementation of other item in the project depend on the completion of the civil and architectural items from other hand. By comparing the time of concreting relative to the total project time. It was found that the rate is (29.2%). So the improve in the concreting process will lead to improve the total performance in the project in direction of reduce the constructing time needed by rate (1/0.29) in term of rate of reduction in concreting time to the total project time. If the projects were divided into equal six intervals in term of time needed and total cost. The concreting processes duration relative to the total project duration will be as shown in Fig. 1. It explain the relative importance of concreting cost across the project life cycle; also it is determine the interval of maximum profit for improving concrete productivity in term of cost.

The area under both curves represents the weight of concreting process in term of time and cost respectively. This will give the ability to determine the best period to improve the cost index when the path of project cost dropdown; in this case the best period is the intervals 2, 3 and 4 of project life cycle which have the large area under curve. Also for time index, if the project exposed to some delay; the best period to correct the project path is interval 2 and 3 and intervals.

OPTIMIZATION OF THE CONCRETING METHODS

The study of available alternatives that can used in the projects will lead to choose the best way in term of cost, time and quality. By assuming that the quality was controlled, so that the two remain factors; time and cost will govern the method of construction. In this study that related with concreting work, three methods were chosen; Manual Method, Semi-Mechanized Method and Full-Mechanized Method. The comparison has been done to find the optimum method for each case according to the size of concreting work and available time and cost.

Manual method: This method uses group (groups) of workers having moderate expert in concrete work with two technicians one of them as concrete specification controller and the other uses his expert to lead the group. The cost was measured for one cubic meter of concrete in $ US from quantity surveying for the cost of concreting works for different sites and the result was listed in Table 2.

So, each working group which includes 15 workers produced 10 m^3 of concrete. The cost of one cubic meter for handling method is 29.50 $ US m^{-3} and the time needed is one working day (8 h). This means that the productivity is 1.25 $m^3\ h^{-1}$ of concrete or 0.8 h for each 1.0 M^3 of concrete. The characteristics of this method are:

- Simple tools needed for implementation
- Low cost of concrete casting
- There is no need for fuel, electrical or mechanical energy
- Imperceptibly effected by the inflation, work law or political regulations
- Used for small work size (less than 10 m^3 for each work group)

Semi mechanized method: The cost and time measurements for this method, which contain mixing, mechanize with labour are developed by work study and monitoring of the concrete casting for all the projects which were under consideration (Table 2). This method characterized by the following:

- Linked between the hand working and mechanize
- Use simple machines for mixing concrete
- Moderate skills workers needed with technicians
- Used for moderate work size (less than 50 m^3 for machine with its working group)

The cost of one cubic meter is 10.40 $ US and the time needed is 0.16 h for 1.0 m^3 of concrete and this will reduce the labour force needed for one cubic meter to 0.28 worker m^{-3} and the productivity for this method is 6.25 m h^{-1}.

Full-mechanized method: This method can be distinguished by the using of machines in wide scale,

Table 2: Detailed cost in $ US of concreting process

		Manual method	Semi mechanized method	Mechanized method
Working group	Workers No.	15.0	10.0	8.0
	Cost/worker	10.0	10.0	10.0
	technicians	2.0	2.0	4.0
	Cost/Tech.	30.0	30.0	30.0
	Overheads/per.	5.0	5.0	5.0
	Total	295.0	220.0	260.0
Mixing machine	No.	-	1.0	-
	Rent rate	-	300.0	-
Shovels	No.	-	-	2.0
	Rent rate	-	-	150.0
Track mixers	No.	-	-	3.0
	Rent rate	-	-	200.0
Concrete pump	No.	-	-	1.0
	Rent rate	-	-	400.0
Total cost in $ US		295.0	520.0	1560.0
Daily productivity (m^3)		10.0	50.0	260.0
Cost of 1.0 m^3		29.5	10.4	6.0

which including concrete pump, three truck mixers and two shovels with suitable cone for withdrawing the mix content into the tracks with 8 workers for managing the process. The details of productivity and cost are listed in Table 2. The main features of full mechanized method can be outlined as below:

- Used of complex mechanical techniques and machines.
- High cost for concrete casting.
- Low labour force demand for produce ready concrete.
- High quality control required for the concreting process.
- Suitable for large scale work (more than 200 m^3 day^{-1}).

The cost of one cubic meter is 6 $ US and the time needed for one cubic meter is 0.03 h or the productivity is 32.5 m^3 h^{-1}. For large-scale projects, this method (full-mechanized method) can be suitable in terms of time and cost.

RESULTS AND DISCUSSION

The summary of the results for the three methods in term of working day (8 h) was listed in Table 3.

In order to simplify the selection of concreting method, daily productivity and daily cost represented by-chart as in Fig. 2. Consider the duration as horizontal axis, productivity as right-vertical axis and the cost of working day as left-vertical axis. (P1,C1), (P2,C2) and (P3,C3) will represent the daily productivity and daily cost of method 1, 2 and 3, respectively. The working days needed could found for the concreting activity depending on the total concrete quantity needed in cubic meter for each method by the horizontal projection on their productivity curves

Table 3: Summary of production and cost for the three methods

Methods	Productivity of one working day (m^3 day^{-1})	Cost of one working day in $ US	Cost $ US/1.0 m^3
Manual	10	295	29.50
Semi mechanized	50	520	10.40
Full mechanized	260	1560	6.00

(each fraction of time needed should be complemented as one day; (e.g., 1.22 days should consider as 2.0 days). The total cost can be found for each method by vertical projection of working days on each curve then from horizontal projection on cost axis.

The relation show that the cost and productivity for the three methods varies linearly with the duration. In another hand the gap between productivity and cost curve for the same duration is directly proportional to the production cost of one cubic meter of concrete. This mean the smallest gap the lowest concreting cost. So the full-mechanized method is considered as the lowest in unit price, followed by semi-mechanized. The manual method was the highest in unit price. The decision of which method should used will not depend only on the least cost, but also study must doing for the availability of resources, site limitation, project schedule and the cost of delay per day. Then the decision could be taken to show which method is the best and most suitable for the concreting activity.

Example of casting 500 m^3 of concrete is given in Fig. 3. To show how to use the chart. Step 1 done by horizontal projection of the concrete quantity needed on the productivity curve of Semi-Mechanized Method (P2). Step 2 draw vertical line to perform two things; the first is vertical projection on the duration axis to determine the days needed for the process; in this case is 10 days and the second is vertical projection on the cost curve of Semi-Mechanized Method (C2) to determine the point of intersection with it. Step 3 is performing by horizontal

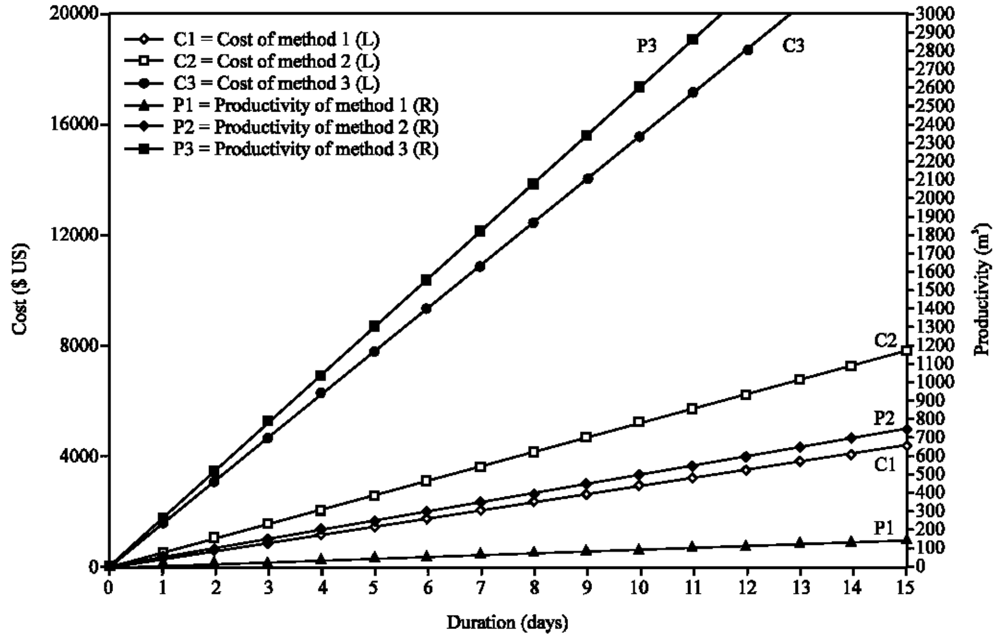

Fig. 2: Daily-productivity and daily-cost chart for the three methods

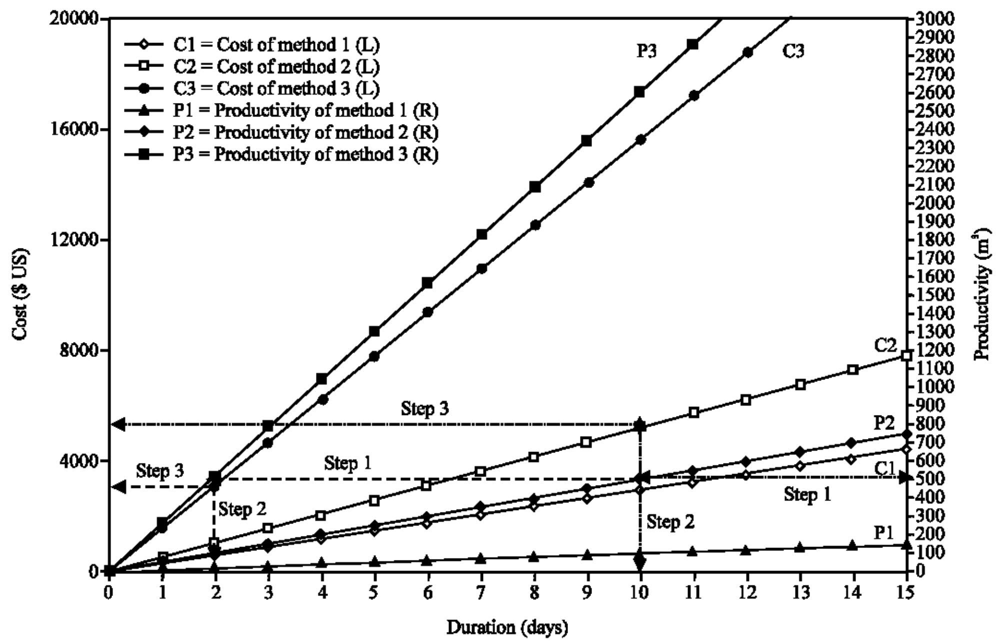

Fig. 3: Example to show the method of using the chart

projection from the point of intersection to the cost axis to determine the total cost for the process in this case is 5200 $. Repeating of these three steps for Full-Mechanized Methods show that the concreting duration is 2 days and cost of the process is and 3120 $.

It is clear from this chart that the manual method is related to small size work, unless we use several working groups, but the cost increment for the required work quantity should be taken into account. So the decision maker can give his order to choose the best method with its duration and total cost. In addition, the demand of tools, labour force and equipments will be very clear for the site engineers to manage this activity perfectly and accurately specially in case of using more than one team work.

Another way, the results of working day needed and total concreting cost can be found by setting mathematical model for the curves in Fig. 2. The formula derived for curve projection will be as below:

$$\text{Total working day} = (X/P) \tag{1}$$

Where:
X = Total concrete quantity for the process in m^3
P = Method's productivity in m^3 day^{-1} And Total

$$\text{Concreting Cost} = (X/P)*C \tag{2}$$

Where:
C = Cost of one working day

Equation 2 can be used for the three methods to obtain the total concreting cost (applying a and b for each method) and choose the best method as mentioned.

CONCLUSIONS

This study highlights the basic concepts of construction productivity and its characteristics through work study, then summarize how and where it can be improved utilizing construction management concepts especially performance measurements and value engineering. The finding explains that the gap between productivity and cost curve for the same duration is directly proportional to the production cost of one cubic meter of concrete. This means the smallest gap the lowest concreting cost and vise versa. The relation between productivity and cost was liner increment with the duration for the three methods.

Choosing the best method of construction have been developed using comparative procedures for calculating the demand of time needed and the cost of construction method. For small size works, the manual method was the best for concreting work less than 50 m^3 for work more than 50 m^3 and less than 260 m^3, the Semi Mechanized Method was the best and finally for work size more than 260 m^3, the full mechanized method was the most suitable. This procedure valid for Iraq price and productivity index and can be used after multiplying each value by correction factor.

For planning purposes, this chart also can be used to provide max working group according to the site limitations.

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REFERENCES

Amiruddin, I., A.M. Abd and Z.B. Chik, 2007. Modeling of risk assessment for integrated project management system in construction. ARPN J. Eng. Applied Sci., 2: 37-43.

Jongeling, R., J. Kim, M. Fischer, C. Mourgues and T. Olofsson, 2008. Quantitative analysis of workflow, temporary structure usage and productivity using 4D models. Automat. Construct., 17: 780-791.

Lam, E.W.M., A.P.C. Chan and D.W.M. Chan, 2008. Determinants of successful design-build projects. J. Construct. Eng. Manage., 134: 333-341.

Lin, G. and Q. Shen, 2007. Measuring the performance of value management studies in construction: Critical review. J. Manage. Eng., 23: 2-9.

Male, S., J. Kelly, M. Gronqvist and D. Graham, 2007. Managing value as a management style for projects. Int. J. Project Manage., 25: 107-114.

Shen, Q. and G. Liu, 2003. Critical success factors for value management studies in construction. J. Construct. Eng. Manage., 129: 485-491.