DEVELOPMENT OF PRODUCTIVITY ASSESSMENT METHODOLOGY FOR CONCRETING PROCESS

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ABSTRACT

In spite of the development in construction industry; the productivity in this sector still considered as critical factor for most construction firms in developing and semi developing countries. In order to develop the productivity, several measures have been taken for some construction projects. This study highlights the topics of productivity monitoring and measurement in constructing sector. Performance measurements used to monitor the construction processes and activities. Building projects are taken as case study to show how these concepts can be used to analyze and develop the productivity of some options in this sector. Concreting process is taken as case study. The results pointed to the relative importance of this activity in terms of time and cost. 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.

Keywords: model, construction, concrete, productivity, monitoring, method, process.

INTRODUCTION

Many researchers have attempted to define precisely what are meant by productivity. One of the most generalized definitions of productivity is “effective and efficient utilization of all resources, labour, plant and materials” (Prokopenko, 1987). Oglesby make a clear distinction between performance and productivity. Performance as applied to associated works is a broad term, encompassing four main elements, namely productivity, safety, timeliness and quality. Productivity; which is measured primarily in term of cost, with satisfactory productivity usually implies work accomplished at reasonable price to the client and with a fair profit for the contractor (Oglesby *et al.*, 1989). Sumanth provides a basic definition of productivity, particularly as relevant to companies and enterprises namely partial productivity, total factor productivity and total productivity (Sumanth, 1984).

The low technology and low skilled employments make construction industry seemed as low productivity sector. In order to raise the level of construction productivity, it is recommended that construction projects should have the following features (Saad D. Ali., 2002):

- High degree of standardization;
- Building system should be easy and simple to construct and repetitive;
- Design is preferred to use pre-fabricated units or pre-assembled forming system;
- Well managed constructing methods with detailed planning and specifications; and
- High level of mechanized methods and skilled workers.

The first three points are design related, which make the construction of project more buildable. The last two points are constructing related and involve construction management and worker skilled. The construction features that contribute to low productivity in this sector can be outlined as follows (Saad D. Ali, 2002):

- Presence of large number of unskilled workers and shortage of suitable trained and skilled workers;
- Poorly developed subcontractors and subcontracting sector role;
- Lack of site management and construction management skills in projects teams; and
- Inadequate mechanization and automation in some sectors of this industry.

Performance measurements and benchmarking of various construction activities and operations are the best methods that may help to develop the productivity of this industry.

THE PRODUCTIVITY OF CONSTRUCTION SECTOR

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 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 (Jugdev K. *et al.*, 2001).

In special case, the productivity is related to a single input (workers-hours) and single output (item as area in m^2), and the simple productivity ratio index of these input and output can be calculated; this case has been assumed as closed system with all factors held constant except for the known input and output (Jugdev K. *et al.*, 2001).

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.

MANAGEMENT PRINCIPLES IN CONSTRUCTION

The factors such as planning, scheduling, work-study and quality control can improve the productivity for construction projects. Several other factors related to construction management must also take into account when maximum effort is made to increase productivity. Some of these factors are (Project management institute, 2004):

1. Provide training to improve worker's ability and skills, reaching to assign the right people to do the job.
2. Human resources management must developed by motivation to improve the competition in the performance, and enlarge the jobs to include challenge, variety and self-regulation.
3. Use computer aided technique in project scheduling and construction management methods such as critical path method (CPM) to optimize the time of related activities and make that resource and methods allow continuous task performance to reduce the idleness of labour force to minimum.
4. Make the number of project teams know that they are important to the organization and involve them in the making of the decisions affecting their jobs such as methods improvement.
5. Conduct productivity and performance study for the activity or operation level to produce benchmarks and to develop scientific methods as apart of the study to describe the detailed tasks performed for an activity or operation by individual or group in order to find out problem area and propose ways to improve.

Studying the above factors for each project activity will lead to increase the productivity, all of them have strong points as well as weaknesses but the greatest opportunity for the construction projects to increase productivity is by measure (points 4 & 5) factors. Performance measurements and benchmarking is a concentration on these two components helping to increase productivity through methods selection and productivity study.

CASE STUDY-CONCRETING WORK

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. Study started at the early day of 2003 up to the end of first quarter of 2006 to monitor the labour force performance and equipment resources in the concreting field of construction project in Iraq. The study was concern 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:

1. 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.
2. Compare the resources utilization of different concrete placing methods in term of cost and time, besides the producing of performance benchmarks for future.
3. Compare the cost of one cubic meter of concrete for the three methods.
4. Find out factors affecting concreting productivity and ways to improve it.

This case study was made in Diyala governorate projects during the period of study and under unsuitable Circumstances (political and economical), so the cost index is related to that period but the procedure is valid for other cases.

WEIGHTING OF CONCRETING WORK

The analysis of data related to projects under study refers that for (6) projects which is listed in Table-1, the weight of concreting work rate is (33.9 %) of total projects cost and if it is compare 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 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).

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Table-1. Rate of the concreting cost in $ US to total project work

Project	**Total project cost** $ US	**Civil and arch. work** $ US	**Concreting work cost** $ US	**Concreting cost to total project cost**	**Concreting cost to civil and arch. work cost**
Project 1	422630	389240	163910	38.8 %	42.1 %
Project 2	586000	498145	200695	34.2 %	40.3 %
Project 3	291700	247940	98345	33.7 %	39.7 %
Project 4	783000	665555	247280	31.6 %	37.2 %
Project 5	547200	465120	186270	34.0 %	40.1 %
Project 6	262630	223235	84150	32.0 %	37.8 %
Total	**2893160**	**2489235**	**980650**	**33.9 %**	**39.4 %**

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 (Table-2), it was found that the rate is (29.2%).

Table-2. Time rate of the concreting work.

Project	**Total project working days**	**Concreting working days**	**Rate of concreting to total project time**
Project 1	3024	886	29.3 %
Project 2	409	107	26.2 %
Project 3	435	152	35.0 %
Project 4	325	77	23.7 %
Project 5	690	186	27.0 %
Project 6	540	176	32.6%
Total	**5423**	**1584**	**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 time relative to the total project time will be as shown in Figure-1.

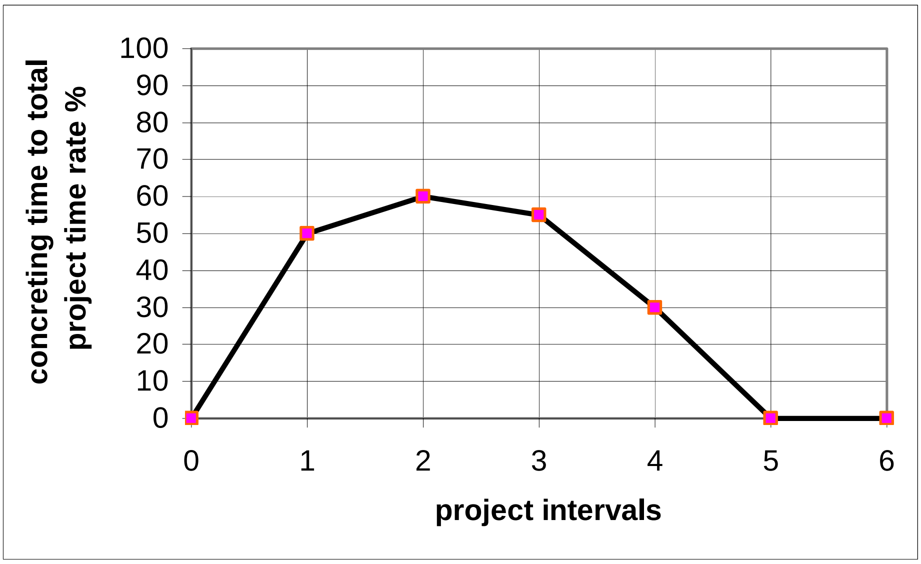

Figure-1. Concreting process duration relative to total project duration rate.

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Figure-2 explains the relative importance and weight of concreting cost across the project life cycle; also it determines the interval of maximum profit for improving concrete productivity in terms of cost.

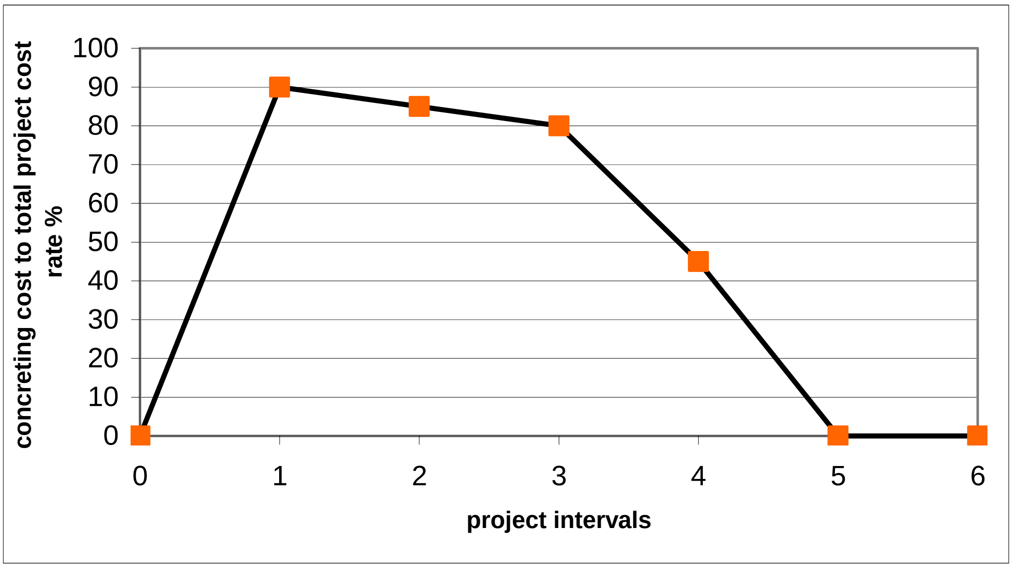

Figure-2. Rate of concreting expenditure to total project cost.

The area under curve in both Figures 1 and 2 represent 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.

METHODS OF CONSTRUCTION

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; handling method, half-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.

1. Handling 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 Iraqi Dinar from quantity surveying for the cost of concreting works for different sites, and the result was listed in Table-3.

Table-3. Detailed cost in $ US of concreting process using handling method.

No of workers in group		Technicians	Overheads	Total cost	Daily productivity	Cost of 1.0 m^3
No	15	2	17	295.0	10 m^3	29.5
Unit cost	10.0	30.0	5.0			
Total	150.0	60.0	85.0			

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 hrs).This means that the productivity is 1.25 m^3/hr of concrete or 0.8 hr for each 1.0 M^3 of concrete.

The characteristics of this method are:

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

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2. Half 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. The results are listed in Table-4.

Table- 4. Detailed cost in $ US of concreting process using half mechanized method.

No of workers in group		Technicians	Overheads	Mixing machine
No	10	2	12	1
Cost	10.0	30.0	5.0	300.0
Total	100.0	60.0	60.0	300.0
Total cost			520.0	
Daily productivity			50 m^3	
Cost of 1.0 m^3			10.40 ID	

This method is characterized by the following:

1. Linked between the hand working and mechanize.
2. Use simple machines for mixing concrete.
3. Moderate skills workers needed with technicians.
4. 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 hr 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^3 / hr.

3- Full mechanized method

This method can be distinguished by the using of machines in wide scale, 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-5:

Table-5. Detailed cost in $ US of concreting process using full mechanized method.

No of workers in group		Technicians	Overheads	Total cost in $ US	Daily prod. m^3	Cost in $ US /m^3
No	8	4	12			
Cost	10.0	30.0	5.0			
Total	80.0	120.0	60.0			
Track type	Shovels	Track Mixers	Concrete Pump	1560	260	6.0
No	2	3	1			
Rent rate	150.0	200.0	400.0			
Total cost	300.0	600.0	400.0			

The main features of full mechanized method can be outlined as below:

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

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

DISCUSSIONS

The summary of the results for the three methods in term of working day (8 hr) is shown in Table-6.

Table-6. Summary of production and cost for the three methods.

Methods	Productivity of one working day	Cost of one working day in $ US	Cost $ US / 1.0 m^3
Handling	10 m^3/day	295 ID /day	29.50 ID
Half Mechanized	50 m^3/day	520 ID /day	10.40 ID
Full Mechanized	260 m^3/day	1560 ID /day	6.00 ID

By graphing the data of Table-6 in terms of daily productivity, we get Figure-3. Consider the time as horizontal axis and productivity as vertical axis. The working days needed could be found for the concreting

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activity depending on the total quantity needed in cubic meter of concrete for each method from the projection on their curves (knowing that each fraction of time period should completed as one day; (e.g. 1.22 days should consider as 2.0 days).

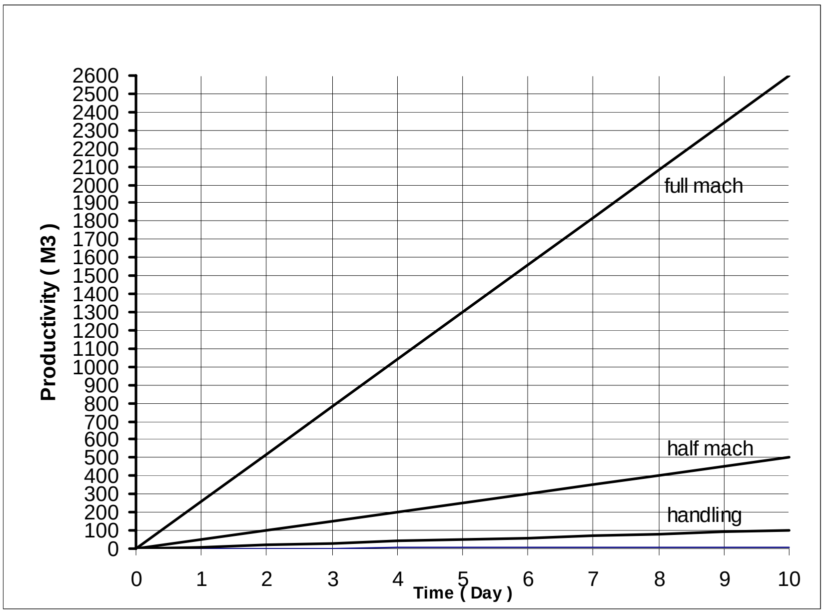

Figure-3. Time- productivity relation for the three methods.

Graphing the data in terms of daily cost, we get Figure-4, which considers the time as horizontal axis and the cost of working day as vertical axis. The total cost for each method can found from vertical projection of working days on each curve then from horizontal projection on cost axis, the total cost for each method could found. The decision of which method should used will not depend only on the least cost, but also study must doing for the availability of time, work space and project schedule with the cost of delay (ID/day). Then the decision could be taken to show the best method, which is most suitable solution for the concreting activity.

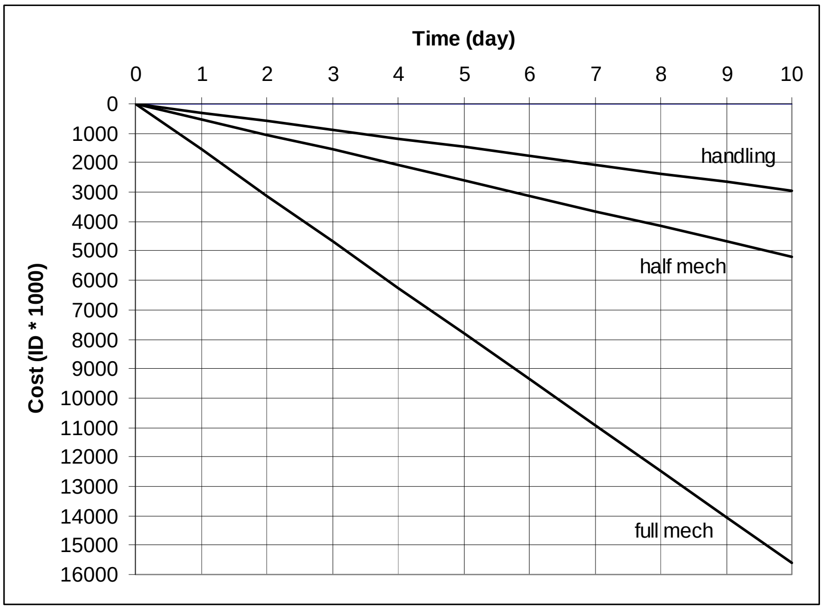

Figure-4. Time- cost relation for the three methods.

The backward reading of the two curves in figures 3&4 also can done depending on time available for the process to determine the maximum productivity of concreting process. This will give the best method or number of working group for each method in term of productivity. Then by comparing the cost using Figure-4, the total cost for each method could be done. The decision maker can give his order to choose the best method with its interval of time and total cost. In addition, the demand of tools, labour force and equipments will be very clear for the site engineer to manage this activity perfectly and accurately.

Another way, the results of working day needed and total concreting cost can be found by setting mathematical model for the curves in Figures 3 and 4. The formula derived for curve projection for Figure-3 will be:

$$\text{Total working day} = (X / a) \qquad \text{---------} (1)$$

Where

X = total concrete quantity for the process in m^3
a = method's productivity in m^3/day

and from Figure-4, the formula of curves projection will be:

$$\text{Total concreting cost} = (X / a) * b \qquad \text{----------} (2)$$

Where

b = 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 through construction management concepts especially performance measurements and benchmarking. The issues that discussed are those related with time interval available for the activity, total cost with the technique and labour skills needed for implementation in site.

Practical procedures are set for choosing the best method of construction, calculating the demand of time needed and the cost of construction method. The remote knowledge of construction methods with its main parameters; time, cost and productivity will give the project manager or the site engineer opportunity of taking the accurate decision in suitable time. This means; in brief words, successful project with successful construction management.

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