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MEASUREMENT OF CONSTRUCTION LABOR PRODUCTIVITY FOR FORMWORK OF THE HIGH-RISE BUILDING PROJECT

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Abstract

Labor productivity is among the most critical factors that heavily impact the achievement of a construction projects. In construction sites, construction techniques, construction organization, human resource management, working conditions and worker personal characteristics have significant effects on the labor productivity. Formwork, among others, is a common task in every construction project. This paper presents the measurement of labor productivity by work sampling method for floor and beam formwork of high-rise buildings in Ho Chi Minh City, Vietnam. The research identifies the proportion of time consumption for effective tasks, supportive tasks, and ineffective tasks of formwork as follows: 32%, 35%, and 33% respectively. In other words, the change in the proportion of ineffective work over periods of time through a working day enables a conclusion that the labor productivity of floor and beam formwork workers begins low, then increases gradually, and finally decreases toward the end of each working session.

Keywords : Formwork; construction projects; labor productivity; work sampling

I. Introduction

Labor productivity is one of the critical factors that affect the completion and success of construction project [III], [IV], [XIV]. It has a tremendous impact on the volume of work completed in a project and hence impacts the cost, time and quality of the construction project[VIII], [X], [XII], [XIX]. This study applies the Work Sampling method to measure labor productivity for the floor and beam formwork of a high-rise building project in Ho Chi Minh City, Vietnam. The results highlight that ineffective work accounts for up to 33% of formwork workers' total working time every day.

II. Research Background

Labor productivity has driven much scholarly interest[XVII]. Kaming, et al. [IX]studied labor productivity in seven construction projects in an attempt to determine the ratio of actual working time and idle time. The author uses Work Sampling for constructionconcrete, formwork and steel reinforcement. Results point to a very high proportion of idle time in the Table1. The significant obstacles of labor productivity are: redoing work, inappropriate equipment and lack of materials.

Table 1: The ratio between working time and non-working time

Time	Constructionconcrete	Formwork	Steel reinforcement
Working time	51%	44%	56%
Non-working time	49%	56%	44%

Studies concerning the working time of workers in construction projects reveal that ineffective activities account for 53% of the total working time of a project. The causes of productivity waste all come from a lack of specific planning, including resource unavailability, lack of supervision, irrational site layout, redundancy of manpower, lack of construction procedures, and inappropriate work assignments[I].

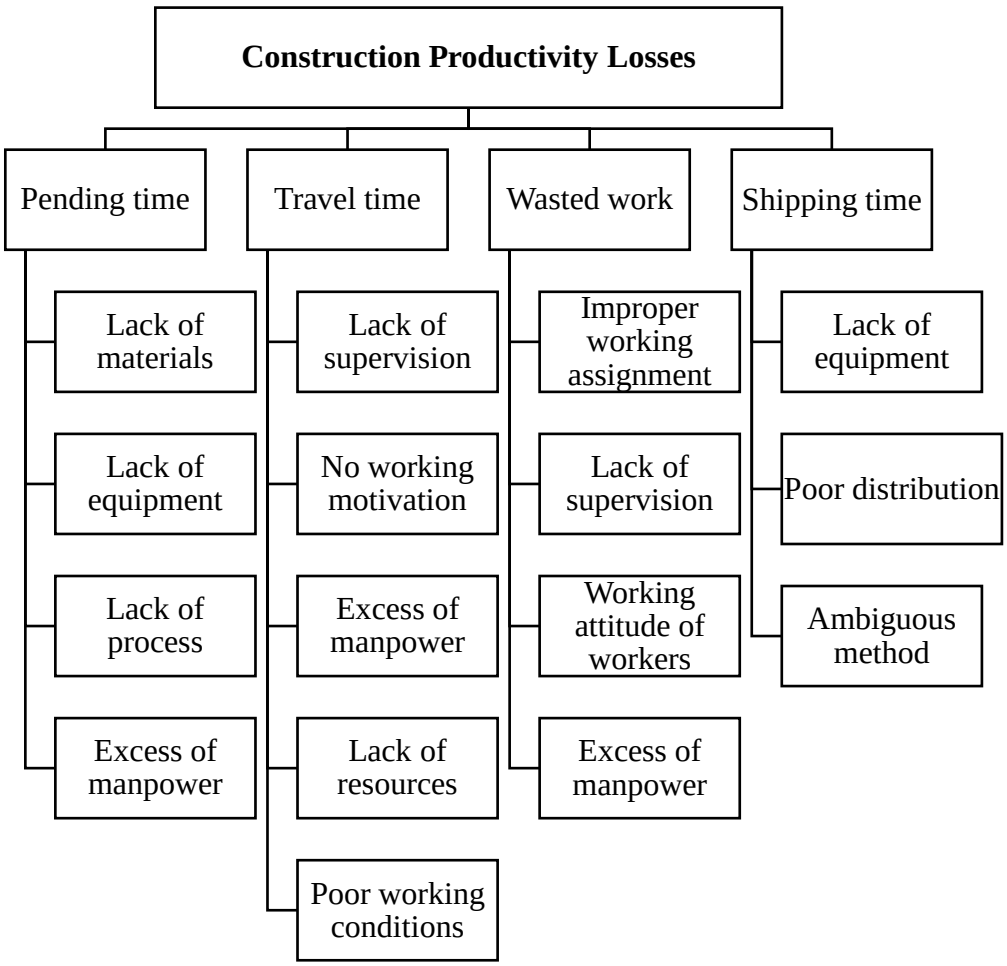

Fig. 1: The main causes of construction productivity losses

Wasted productivity can affect the performance of workers. This influence is conveyed by the labor productivity curve, which is affected by the fluctuation of factors including design, management, construction and environment[IV]. The labor productivity curve can show irregular patterns that are hard to interprete. The study of [IV]was conducted from the contractor's perspective, with the labor productivity curve appearing in its ideal pattern. The influence of factors on the productivity curve would be quantified based on the change in the curve pattern.

Work sampling is used not only to measure the productivity curve but also for indirect quantification of labor productivity, since it does not measure the output of a task but only measures the time ratio (effective against ineffective) in the course of a specific task [XIV], [XVI]. The two following assumptions have been associated with the work sampling results, which are used for measuring labor productivity: (i) First

assumption: shortened pending time and reduced delay will enable productivity rise; and (ii) Second assumption: the effective working time is related to output and labor productivity.

The work sampling method can be used for quantifying the waste and fluctuation of tasks done on site. It may reveal information on specific factors that harm labor productivity because samples are taken by direct observation[VI]. The labor productivity results of a task or the whole project obtained from work sampling can help the Project Management Unit to make appropriate management plans or to focus on finding the cause of delay and inefficiency so as to improve the labor productivity of the project team[V].

The influencers of labor productivity are the source to ineffective activities in construction[XIII]. Controlling and understanding the causes will help the Project Management Unit identify what is troubling the project, enabling them to better solve problems and control the project. It is necessary to plan and focus on managing the potential incurrence of ineffective times and to mitigate risks and consequences.

III. Research Methodology

Work sampling is a method used to measure labor productivity over time for the evaluation of work progress[II], [VII]. It facilitates the Project Management Unit to assess and identify problems in the construction work process so as to improve performance and thus working efficiency[XIII], [XVIII]. This study only took samples of the floor and beam formwork onthe fourth floor of a high-rise building in Vietnam.The data collection process is shown in Table 2. This data table is adapted to the project features. The number of samples is estimated to be 32 (i.e., 16 samples in a working session). The time interval between two consecutive samples is 15 minutes.

Table 2: Assignments of formwork tasks

No.	Effective tasks	Supportive tasks	Ineffective tasks
1	Erection of scaffolding and bracing	Launching formwork and equipment (R <4m)	Suspension of work for checking
2	Putting formwork in place	Reading drawings	Resting and smoking
3	Fixing wedges and linking formwork	Fabrication of wooden beams and wooden formwork	Manual hauling
4	Boring and welding bracing bars	Checking the formwork sizes	Searching for tools
5		Measurement of elevation and calibration	Correction
			Other tasks

Data are collected at the construction site using the designed sheet. Supervision shall be done in the course of sampling. The evaluation and classification of construction workers into 3 groups (effective, supportive, and ineffective) shall be carried out in turn. The groups of workers can inter-change quickly; therefore, a camera is the best tool to use so as not to disturb their performance. The research data collection proceeded for 15 days in a total of 480 observations.

IV. Results and Discussion

The results point out the percentages of time spent on groups of task (effective, inefficient, and supportive task) in each work. The timewise variation of such time proportions of tasks in a day are also revealed.

Table 3: Work sampling data sheet for beam and floor formwork

Time	Effective tasks		Supportive tasks		Ineffective tasks		Total	
	N	%	N	%	N	%	N	%
Morning period (7:00-11:00)								
7:00-8:00	78.00	19.60 %	160.00	40.20 %	160.00	40.20 %	398.00	100 %
8:00-9:00	128.00	37.43 %	114.00	33.33 %	100.00	29.24 %	342.00	100 %
9:00-10:00	130.00	38.01 %	118.00	34.50 %	94.00	27.49 %	342.00	100 %
10:00-11:00	106.00	32.52 %	98.00	30.06 %	122.00	37.42 %	326.00	100 %
Afternoon period (13:00-7:00)								
13:00-14:00	92.00	23.71 %	150.00	38.66 %	146.00	37.63 %	388.00	100 %
14:00-15:00	130.00	38.69 %	116.00	34.52 %	90.00	26.79 %	336.00	100 %
15:00-16:00	120.00	35.71 %	112.00	33.33 %	104.00	30.95 %	336.00	100 %
16:00-17:00	96.00	29.81 %	108.00	33.54 %	118.00	36.65 %	322.00	100 %
Total	**880.00**	**31.54 %**	**976.00**	**34.98 %**	**934.00**	**33.48 %**	**2790.00**	**100 %**

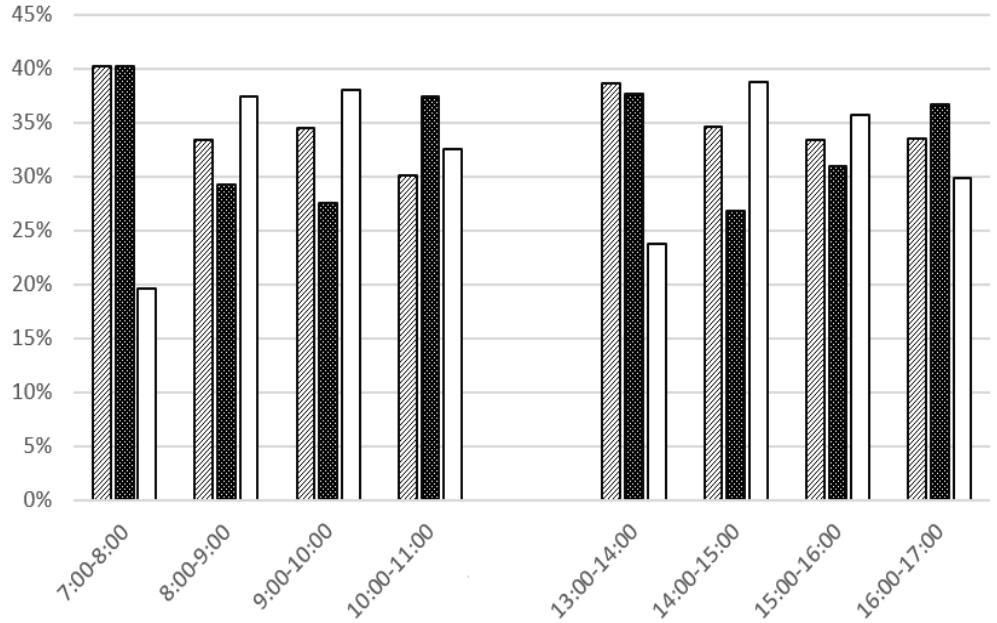

Fig.2: Percentages of task groups by work efficiency over time

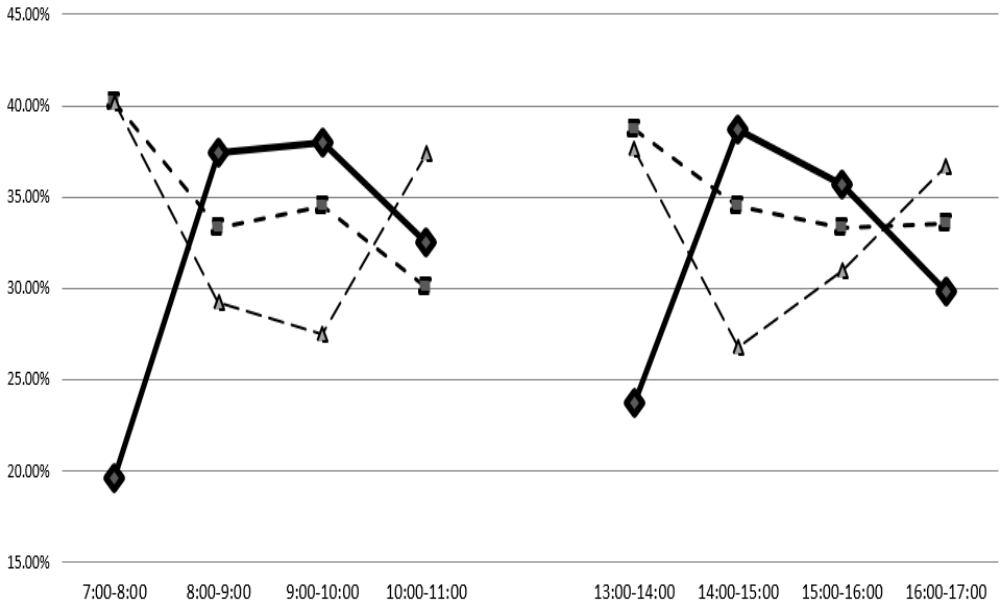

Fig. 3: The average time consumption of a worker

Floor and beam formwork has average proportions of effective, supportive and ineffective tasks in one day of 32%, 35%, and 33%, respectively (see Figure 2 and Figure 3). In general, the formwork has a high rate of ineffective tasks. However, this is a desirable rate given the working environment at the construction sites and a construction team consisting of highly skilled and well-coordinated workers.The rates of work efficiency are defined by groups of time, and each day is divided into two working sessions (morning and afternoon). In general, the shape pattern of three bars representing three proportions of work efficiency. At the beginning of working sessions (7h-8h and 13h-14h), those bars in the middle of trios are the highest, i.e. inefficient task occupies the largest part. Meanwhile, during the mid-session time (8h-10h and 14h-16h), the pattern of bar trio changes as the effective and supportive tasks increase and the ineffective tasks decrease.

These trends balance out the three bars, and they are approximately of the same height. The later time of working sessions (10h-11h and 16h-17h) sees the trio returning to the initial pattern seen at the beginning of the session and the transcendence of ineffective tasks. It is also notable that the average time proportions of a worker in a working day show more evidently the timewise change of productivity. An effective task is presented by a curve with the maximum values (9h-10h and 14h-15h), while an ineffective task is presented by a curve with minimum values (9h-10h and 14h-15h). A supportive task appears as a polyline in the morning; the higher values are mostly seen at the session beginning, while the line comes down toward the session end.The fall of effective time at the earlier and later parts of each working session warns of a loss of productivity. The Project Management Office(PMO) and contractor should pay close attention to these periods of time to address the causes of lost productivity and thus improve productivity. Such fall may be attributed to the loose management of workers at the beginning and the end of each working session. Another cause may come from the psychology or fatigue of tired workers.

V. Conclusion

The work sampling method is a powerful method for measuring labor productivity in construction. Our research is carried out on the floor and beam formwork of a high-rise building project in Ho Chi Minh City. The research reveals that ineffective tasks account for 33% of the total working time in a day. The rate of ineffective tasks is high at the earlier and later times of each working session due to the workers' psychological or physical condition. Work sampling helps the project manager to monitor the use of time in the perfomance of work. An abnormal rate of ineffective tasks portends a drop of labor productivity and prompts the Project Management Office(PMO) to find the causes of decreased productivity and address them to enhance labor productivity. Aside fromwork sampling, follow-up studies can

pursue the learning curve theory approach to further dissect the research findings. The learning curve method helps to quantify the labor productivity and probe the loss of labor productivity that results from detrimental factors.

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