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LABOR PRODUCTIVITY IN OFF-SITE CONSTRUCTION: A LITERATURE REVIEW AND IMPLICATIONS FOR FUTURE RESEARCH

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Labor productivity, critically important to profitability in the construction, is one of the most frequently discussed topics in the industry, and yet at the same time, is one of the most poorly understood. A literature review was conducted with the aim to identify how labor productivity is studied in the construction industry and what methodological issues exist. The literature review also investigated leading studies in productivity factors in construction generally, and considerations of productivity in relation to the off-site construction (pre-fabrication) sector specifically. The paper outlines general approaches to studying labor productivity in the construction sector. The review found that productivity is usually discussed in the literature under at least three separate topics, namely, the delimitation of construction (what is the precise aspect of construction under investigation), the measurement of productivity (what inputs and outputs are considered), and the identification of the factors that explain productivity. The review found that three issues undermining investigations into productivity in the construction sector were lack of a uniform approach to studying productivity, neglect of relevant variables, and limited generalizability. From this finding, it is recommended that a multi-factor approach is used to analyze productivity in construction. Concerning productivity considerations in relation to the adoption of off-site production approaches to construction, the literature review found that opting to use prefabrication increased overall productivity, led to reduced crew sizes, reduced onsite congestion, reduced cycle time, reduced debris, reduced total structural cost, and improved constructability.

Keywords: Engineering project management, Construction productivity, Off-site construction, Operational management, Relative importance index, Literature review.

1 INTRODUCTION

Productivity as it relates to construction is usually discussed under three separate topics. The first is the delimitation of construction, which is the definition of the particular aspect of construction under investigation. Analysts may be interested in conventional onsite construction projects or off-site activities such as prefabrication. The second issue is the precise measurement of productivity (Sezer and Brochner 2014). This topic concerns how productivity will be measured whether total employee hours, or another input will be used, and whether output will be measured in valued of products, volume of products, produced volume, and installed volume and so on. The third is the identification of the factors that explain productivity growth or decline. These may be human resource related or linked with external factors such as material quality and state regulation (Sezer and Brochner 2014). The following sub-

section will deal with the second topic of productivity in construction, namely, the precise measurement of productivity.

2 STUDING PRODUCTIVITY IN CONSTRCTION

Labor productivity, based on output per worker most typically measured as quantity produced per employee or value added per employee, is often cited as "the simplest measure of productivity" (Loosemore 2014). In this sense, hourly inputs are commonly used to measure labor productivity. Typically, the labor hour will be used as the input while the quantity of completed work will be used as the output.

2.1 Lack of a Unified Approach

There is a lack of consensus concerning how productivity should be evaluated in the construction sector (Kadir *et al*. 2005, Jarkas 2010, Loosemore 2014). Construction labor productivity (CLP) is an example of a labor productivity approach and can be determined dividing the installed quantity by the actual work hours. Thus, the lower the value obtained from the calculation, the higher the productivity (Yi and Chan 2014).

The authors believe that this is a superior method to cost-based output measures which are affected substantially by external factors. Nonetheless, one of the challenges is determining what installed quantity will be measured. For example, concrete placement and steel placement are largely different tasks, with the former being possible to measure in terms of cubic meters and the latter more suitably measured in linear meters (Yi and Chan 2014). Another example of this general approach, as used by Kadir *et al.* (2006), was referred to as actual labor productivity. The team calculated actual labor productivity by multiplying the crew size by the working time (hours) and then dividing the product of that by the building floor area (m^2).

However, these approaches have been criticized by Loosemore (2014) who states, inter alia, that researchers can have great difficulty in identifying, gathering data, and reporting the most valid factors. For example, the scholar notes "increased output per worker is not necessarily an accurate measure of productivity since it does not take into account how new technologies can affect productivity" (Loosemore 2014). Eastman and Sacks (2008) found that labor productivity can even 'increase' due to labor shortages, and concerning technology noted that the construction sector often lags behind other sectors such manufacture. The authors also argue that the construction workforce and its training is most often in a state of flux, which confounds measures of productivity. Testimony to this, in a different context, would be Zakeri *et al.* (1996) study in Iran in which it was found that only 2% of construction employees had remained with their current employer for five years or more.

2.2 Neglect of Relevant Variables

Neglect of relevant variables is a second issue. There are concerns raised regarding the focus on labor productivity at the expense of other arguably important considerations such as capital, material, and transportation productivity (Poh and Chen 1998, Kadir *et al.* 2006, Loosemore, 2014). For example, Loosemore (2014) describes capital productivity, as "the technology-related elements of productivity...the output return on capital investment", and argues that while it is a critical variable concerning productivity in construction generally it is very difficult to determine independently of labor productivity and vice versa.

An example of an attempt to address these issues was referred to as average labor productivity. Vogl and Abdel-Wahab (2014) considered the effect of labor (L), capital (K), and materials (M), using the production function (f) to make conclusions on how the construction output (Y) could be viewed in terms of labor productivity. The authors report that one of the difficulties with this approach is that there are international differences in the way that labor is used in construction and that certain components cannot be isolated.

Arguably again not all factors were considered. For example, in the broader construction research, environmental conditions, such as the impact of harsh weather conditions, tends to feature less and more in the different methodologies, as do regulation matters such as employee relations and even intellectual property issues (Loosemore 2014). Yet another recommended approach has been total factor productivity, involving consideration of as wide a selection of variables as possible including management practices, extent of change on a site, and work environment in order to determine productivity (Talhouni 1990). Loosemore (2014) applied this approach to a study of 72 sub-contractors and found that "poor site management, poor coordination and planning, trust and respect between managers and workers and supervisory training and skills" each had a significant moderating effect on labor productivity. However, studies using total factor productivity are often seen as unreliable due to their scarcity and the difficulty in, as mentioned, in identifying, gathering data, and reporting the most valid factors (Carson and Abbott 2012, Loosemore 2014).

2.3 Limited Generalizability

Limited generalizability has been another issue plaguing productivity research, and probably the most significant threat to reliability and validity of research in the area. It has been very difficult to compare and contrast findings from studies of productivity due to not only the differences in research methodologies but also in differences in the nature of the construction projects being studied (Loosemore 2014). Even some of the leading professional association definitions recognize this difficulty. For example, the American Association of Cost Engineers (AACE) (2013) defines productivity as a "relative measure of labor efficiency, either good or bad, when compared to an established base or norm". The focus on the relativism undermines the body of research through greatly reducing its generalizability. One approach to studying productivity that has emerged in more recent years reflecting the relative definition just mentioned, has been to compare expected productivity with actual productivity (Allmon *et al.* 2000).

3 FACTOR OF LABOR PRODUCTIVITY IN CONSTRUCTION

The following sub-section will deal with the third topic of productivity in construction, namely, identifying and analyzing factors that impact on productivity.
In the field of productivity factor analysis, one of the leading researchers has been Paul Olomolaiye (Olomolaiye *et al.* 1987, Olomolaiyi 1990, Olomolaiyi *et al.* 1998). In the 1980s, Olomolaiye *et al.* (1987) visited seven construction sites in Nigeria and after interviews with 83 tradespersons including 32 joiners, 26 bricklayers, and 25 steel fixers found that a lack of materials/tools, duplicated efforts or repeated work, instruction delays, inspection delays, absenteeism, incompetency of supervisor, and changing crew members were the most influential groups of problems undermining labor productivity. Again in the 1990s, Olomolaiye worked with factors of productivity identifying similarities and differences between constructions projects

in developing and developed settings (Zakeri *et al.* 1996). It was noted that lack of materials and rework were often considered the most significant factors adversely affecting productivity in developing settings. In Iran concerning construction labor productivity, with 141 construction operative respondents it was found that a lack of materials was cited as the dominant reason for poor productivity, followed by equipment breakdown, poor supervision, absenteeism, and crew turnover. Similar findings were reported in Lim and Alum's (1995) study in Singapore.

Drawing from the work of Olomolaiye and Lim and Alum, Enshassi *et al.*'s (2007) study focused on 45 factors relevant to productivity, which were placed into manpower, leadership, motivation, time, materials/tools, supervision, project safety, quality, and external factor groups. The validity of these groups was affirmed through interviews with personnel from 83 contracting companies in the Gaza Strip. The researchers were able to make a number of conclusions on the importance of personnel management and motivational measures (Enshassi *et al.* 2007). They suggested tying compensation to performance, and ensuring that the pay, fringe benefits, workplace safety, and other employment conditions were at least competitive in the relevant context. As part of the recommendations, the researchers also argued that contracting companies should maintain historical records of productivity. These groups of factors relevant to productivity, or very similar ones, have since been used in a number of studies (Rivas *et al.* 2011, Yi and Chan 2014)

4 FACTOR OF LABOR PRODUCTIVITY IN OFFSITE CONSTRUCTION

Productivity has also been investigated in relation to off-site construction methods, such as prefabrication and modularisation (Alazzaz and Whyte 2015). The use of prefabrication was found to increase overall productivity, lead to reduced crew sizes, reduced onsite congestion, reduced cycle time, reduced total structural cost, and improved constructability when applied to construction projects (Kadir *et al.* 2006).

With respect to off-site construction methods, as mentioned, the high cost of investment generally means that information concerning which factors may increase or decrease productivity is especially valuable (Rivas *et al.* 2011). Hanafi, Khalid, Razak, and Abdullah (2010), conducted a study into factors of labor productivity concerning the installation of prefabricated components. They noted that it appeared that the previous studies to that point in time did not focus specifically on identifying and listing the dominant factors that influence labor productivity in relation to the installation works of prefabricated components. There also appear to be very few studies that have investigated factors of productivity gather information concerning labor productivity during the off-site prefabrication process.

5 BUILDING UPON SECONDARY RESEARCH

As a result of a comprehensive review of the literature, a multi-factor approach will be used to analyze productivity in construction. More specifically, ten factor groups, containing a total of 43 factors will be used to analyze productivity in three off-site construction companies. The factor groups and factors were drawn from the research of Olomolaiye (Olomolaiye *et al.* 1987, Olomolaiyi 1990, Olomolaiyi *et al.* 1998), and in particular Enshassi *et al.* (2007). The factors are Materials/Tools group (3 factors): material shortages, tool and equipment shortages, and unsuitability of materials storage location, Supervision group (4 factors): drawings and specifications alteration during execution, inspection delay, rework, and supervisors' absenteeism, Leadership group (3 factors): lack of labor surveillance, misunderstanding between labor and superintendents, and lack of periodic meeting with labor, Quality group (3

factors): inefficiency of equipment, low quality of raw materials, and high quality of required work, Time group (5 factors): working 7 days per week without taking a holiday, misuse of time schedule, method of employment (using direct work system), increasing number of labors, and working overtime, Manpower group (8 factors): lack of labor experience, labor disloyalty, labor dissatisfaction, misunderstanding among labor, lack of competition, increase of laborer age, labor absenteeism, and labor personal problems, Project group (4 factors): working within a confined space, Interference, construction method, and type of activities in the project, External group (1 factor): augmentation of government regulations, Motivation group (6 factors): payment delay, lack of financial motivation system, lack of labor recognition programs, non-provision of transport means, lack of place for eating and relaxation, and lack of training sessions, Safety group (6 factors): accidents, violation of safety precautions, bad ventilation, working at high places, unemployment of safety officer on the construction site, and noise. A 5-point Likert scale importance scoring system and a relative importance index (RII) will be used to rank the 43 factors.

It should be noted that such an approach is derived from general construction studies, as opposed to studies in the manufacturing sector. While off-site construction would appear to have similarities to manufacturing, Hook and Stehn (2008) on a review of 14 studies between 1995 and 2005, found that off-site construction was "clearly influenced by a production culture that has similarities to a traditional construction culture." Eriksson *et al.* (2014) reported similar findings while some people may think off-site construction, and construction in general, has much to learn from the manufacturing sector, practically there are a number of barriers limiting to applicability of manufacturing management practices to construction whether it be on or off-site.

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