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Measuring the impact of BIM on labor productivity in a small specialty contracting enterprise through action-research

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ABSTRACT

Productivity in the construction industry is a well-documented and expansive field of research. It benefits from over four decades of research that have developed models and methods for evaluation and identified multiple factors that influence it. In parallel, building information modeling (BIM) has emerged as a disruptive innovation, showing great potential to mitigate many of the factors negatively affecting construction productivity. Indeed, studies are increasingly looking into the impact of BIM on project performance. Improving construction productivity, labor productivity in particular, is one of the widely reported benefits. For organizations looking to transition to BIM, being able to grasp these benefits and quantify their impact is extremely important to ensure the viability of the BIM implementation process. This article presents the findings of an action-research project undertaken with a small mechanical contractor which investigates the impact of BIM on labor productivity on a large commercial project. The objective of the action-research was to assist the organization in reconfiguring its performance measurement practices in light of the transition to BIM and prefabrication. The article discusses the challenges of this reconfiguration and presents the findings from the performance measurement process which was put in place. The findings suggest a clear positive impact of BIM on labor productivity on the project studied: the areas that were modeled and prefabricated showed an increase in productivity ranging from 75% to 240% over the areas that were not modeled. More importantly, however, the article operationalizes a strategy allowing organizations to consistently assess their performance relating to labor productivity.

1. Introduction

Many instances of best practice and innovation involving building information modeling (BIM) implementation have been reported in the literature [17]. Experience tells us, however, that there remains a considerable gap between the leading edge (i.e. early adopters) and the majority in the construction industry [7]. Considering that implementing BIM represents considerable financial risk, especially for small or medium enterprises (SME), clear benefits need to emerge and be quantifiable in order for these SMEs to move forward with implementation. The promise of increased labor productivity is one such benefit that is stimulating the adoption and implementation of BIM in the construction industry. Indeed, this novel approach to project delivery is presented as a solution to overcome the apparent stagnation and even decline of labor productivity in the construction industry [54,55] While questions surrounding this macroeconomic view of labor productivity is debated [3,45],it remains that there is a general consensus around the need for significant improvement in the construction industry. Several strategies have been developed that touch on the potential of BIM to improve labor productivity, namely through project coordination [51] and prefabrication [37] among others. Many of these benefits have been reported [38] and attempts to quantify the impact of BIM on labor productivity have been recorded [29]. Additional work, however, is required to study, and more importantly to allow organizations to evaluate, the impact of BIM on labor productivity in the construction industry if it is to become grounds for justification of BIM adoption. In particular, the way in which they go about to measure this impact is often unreliable due to the sheer complexity of measuring labor productivity, which requires considerable effort in collecting and analyzing data in the field [56]. This represents a major barrier to developing this particular measure as a valid way to justify an organization's transition to BIM.

This article presents the findings of an action-research project undertaken with a specialty contracting small enterprise which adopted and has been implementing BIM since 2010. The organization with which we were performing the action-research project was founded in 2004 and operates in the Vancouver, British-Colombia area. It has 67 employees and is deployed along a project-based organizational structure across two divisions. It counts 24 office-based employees

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(project managers, coordinators, estimators as well as administrative staff) who form the project management team and 43 site based employees (superintendents, foremen, journeymen). The objective of this action-research project was to assist the organization in reconfiguring its performance assessment practices in order to allow it to effectively evaluate the impact of BIM on labor productivity. Working with the data that were made available through the organization's project management software and by reconfiguring part of their project performance measurement practices, the research team was able to operationalize a strategy for the organization that would allow them to benchmark and track their labor productivity on BIM projects. The key contribution of this article lies in the action-research approach taken to the reconfiguration of performance measurement practices within a small specialty contractor. The article focuses on labor productivity and BIM, a field of research which, while gaining popularity, is still relatively sparse, especially given the fact that labor productivity is seen as one of many measures benefitting the most from BIM. Lastly, the article develops a strategy aimed at measuring labor productivity in an effective manner which is not too onerous for small organizations.

2. Background

2.1. Measuring labor productivity

There exist different perspectives on what constitutes a measurement of labor productivity in the construction industry. These differences lie in the methods through which data are collected and analyzed, the quality of the data being analyzed and most importantly the scale at which the data are being collected. Two distinct perspectives on labor productivity in the construction industry are prevalent: the macro perspective and the micro perspective [15]. There is some controversy surrounding the macro perspective due to, among others, inconsistencies in measurement methods and lack of consensus on what should be measured [3,23]. The macro perspective does allow the identification of long-term trends at the industry level, for instance having identified stagnation or decrease in the US industry [54,55] or growth in the Canadian industry [35] and other countries such as the UK and Denmark [40]. Several studies have found that multifactor productivity, a combination of labor and capital costs producing an output, best suited for this perspective [59]. For organizations however, the usefulness of this perspective is questionable as it does not provide a basis for consistent comparison and the interpretation of the data can be misleading [23]. The micro perspective, which is focused on the task, is seen as a more suitable approach for organizations to benchmark their own labor productivity [15]. From this perspective, productivity is measured in terms of input and output at the individual work task level [24,39]. Durdyev and Mbachu [16] provide an operational definition of productivity as: "the amount or quantity of output of a process per unit of resource input […] where: Output could be in units or dollar value of product or service, revenue generated or value added; resource input could be in units or dollar value relating to manpower (i.e. man-hour), machinery (i.e. machine hour), materials (i.e. quantity), or money (i.e. dollar value)." (p.19) That being said, construction productivity is often taken to mean labor productivity. According to Halligan et al. [24] "this measure of productivity has several advantages: the meaning of the term labor productivity is relatively well understood; labor productivity is often the greatest source of variation in overall construction productivity; and the productivity of other inputs can often be measured with respect to labor productivity." (p.48) Park et al. [39] discuss the lack of a standardized definition for productivity in the construction industry. They choose to define labor productivity per the following equation:

$$\textit{labor productivity} = \frac{\textit{input (work hour)}}{\textit{output (quantity)}} \tag{1}$$

On the other hand, Halligan et al. [24] and many others after [e.g. 18, 21]), indicate that construction labor productivity should reflect units or work placed or produced per man-hour, per the following equation (also called the unit rate):

$$\textit{labor productivity (unit rate)} = \frac{\textit{output (quantity)}}{\textit{input (work hour)}} \tag{2}$$

The labor productivity performance factor is also seen as a way to measure productivity [57]:

$$\textit{performance factor} = \frac{\textit{estimated unit rate}}{\textit{actual unit rate}} \tag{3}$$

Lastly, the performance ratio has also been presented as a measure of productivity in, among others, Yi and Chan [60] where expected productivity, similarly to baseline productivity in Thomas and Završki [58] is calculated as the base rate of productivity when there are no disruptions to work:

$$\textit{performance ratio} = \frac{\textit{actual productivity}}{\textit{expected productivity}} \tag{4}$$

There exist many approaches to measuring and evaluating labor productivity in the field. The key is in its comparison across time or across systems. Indeed, productivity is a relative concept, which must be contextualized to be a valuable indicator of performance [6]. Methods such as field rating, work sampling, five-minute rating, field surveys and models such as the Method Productivity Delay Model [15], the Construction Productivity Management Model [34] or factor-based models [57] are aimed at identifying and mitigating factors that negatively impact productivity. Other models such as Baseline Productivity Analysis [58] and Measured Mile Analysis [50] are used as tools to quantify and evaluate variability of productivity, a useful measure of project success [32], which can act as an indicator of overall project performance and justify claims for lost productivity [26].

2.2. Factors affecting construction labor productivity

The field of research studying the various factors affecting construction labor productivity is a very well documented and expansive one. Considerable work over the past four decades has gone into identifying the factors that affect construction labor productivity [60]. While construction productivity and construction labor productivity have been taken as synonymous by some authors [24], there is an important distinction to be made between factors affecting both as they are not compiled at the same level: construction labor productivity is a subset of construction productivity [25]. Most studies categorize factors using a two tiered system. For example, Kazaz et al. [28] develop four categories of factors affecting construction labor productivity: organizational, economic, physical, and socio-psychological. The authors go on to identify 36 underlying factors within those categories. Rojas and Aramvareekul [46] also develop four categories which are: industry environment, manpower, management system and strategies, and external conditions, as well as identify 18 underlying factors within those categories. Dozzi and AbouRisk [15] identify 9 categories and 44 underlying factors. Enshassi et al. [19] identify 10 categories and 45 underlying factors. Dai et al. [44, citing CII, 2006], identify 12 categories and 83 underlying factors, and so forth. Several factors have been developed interchangeably as both a category and as an underlying factor. For instance, motivation as a factor influencing labor productivity has been presented as a category by Dozzi and AbouRisk [15], Enshassi, et al. [19] and Rivas et al. [44], among others, who then go on to develop underlying factors that affect worker motivation. On the other hand, motivation has been presented as an underlying factor among many others such as Dai et al. [14], Rojas and Aramvareekul [46], and Adrian [1]. It becomes apparent that while there is relative consensus surrounding the factors that affect construction labor productivity in the literature, the categorization of