A Review on Factors Affecting Productivity of Multi-Storey Building Construction

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Abstract

Productivity is the one of the most important factor that affects overall performance of any small or medium or large construction industry. It could be defined as the ratio of output of required quality to the inputs for a specific production situation. Productivity measurement at construction site level enables companies to monitor their own performance against their site performance. Multi-factor productivity is an indication of the productivity with which selected factors of production are used in the creation of the output of a firm, industry, etc. This paper is a literature review on Multi-factor productivity of multi storey buildings. 17 papers are studied for this review. In all literatures, analysis of factors affecting labor productivity or material productivity is done and models are generated for labor productivity. There is minimal reference to the wholesome approach of productivity.

Keywords — *productivity,construction industry, multi-factor productivity*

I. INTRODUCTION

Productivity is one of the key components of every company’s success and competency in the market. Construction companies may gain advantage over their competitors by improving upon productivity to build projects at lower costs yet most contractors do not systematically and properly address this strategic issue or evaluate its impact on the project’s profit. Productivity measurement at construction site level enables companies to monitor their own performance against their site performance. The fundamental concept underlying all productivity measures is a comparison of the output of a production process, an industry, or an economy with the corresponding factors of production required to generate that output. The output and inputs of production thus constitute the basic components of every productivity measure. Productivity measures are formulated as a ratio of output to one or more of the inputs. Productivity can be defined in terms of a single factor input, such as labor productivity, or in in terms of many or all factor inputs, which is multi-factor productivity.

II. LITERATURE REVIEW

Abdulaziz M. Jarkas and Camille G. Bitar (2012) [1] identified and ranked the relative importance of factors that affected labor productivity on construction sites in Kuwait.A representative sample of contractors have participated in the questionnaire survey, comprising 45 productivity factors, classified under the following four primary groups: (1) management; (2) technological; (3) human/labor; and (4) external. The paper started with a literature review of studies relevant to this investigation. The relevant data to this investigation were collected by a closed-ended questionnaire survey. The respondents considered were ranging from general directors to project managers, with a minimum of 15 years of practical experience in the construction industry. The data collected were analyzed using the relative importance index technique. The surveyed contractors ranked lack of labor supervision as the most important factor affecting labor productivity in management group, clarity of technical specifications ranked first technological group,labor motivation is ranked first in human/labor group,effect of temperature ranked first in external group. The clarity of technical specifications factor ranks first among the 45 factors explored, and thus considered the most significant factor affecting construction labor productivity in Kuwait with a relative importance index of 81.67%

Abraham Assefa Tsehayae and Aminah Robinson Fayek (2016) [2] provided a methodology that addresses CLP modelling challenges using an explicit representation of context and formulates a hybrid FIS modeling approach that incorporates FISs developed using a data-driven fuzzy clustering technique combined with a GA-based optimization process. The research was conducted in five major stages: (1) defining the CLP-influencing parameters; (2) defining context for CLP modeling; (3) data collection and development of contexts; (4) FIS design for development of the base context-specific models; and (5) optimization and validation of FIS-based context-specific models. The development of the context-specific CLP models beginswith identifying, classifying, quantifying, and documenting the parameters influencing CLP. The data for concrete pouring activity used for investigating the role of context in CLP modeling in this paper was gathered from six building projects in the greater Edmonton area of Alberta, Canada. Data collection took place between June 2012 and October2014 in collaboration with two partnering companies. The first three projects were built by Company 1, a multinational construction company with over 100 years of experience, and the last three were built by Company 2, a local construction company with over 40 years of experience. The projects included a mixed-use office staff demand facility building, an industrial warehouse building, a commercial warehouse building, a mixed residential and community center building, a mixed commercial-residential building, and an institutional building. Concrete pouring was studied in three data collection cycles, where each cycle extended over a month long period and encompassed different weather seasons. For each data collection case, WS observations were made for the crew under study, and parameters (factors and practices), total man-hours and installed quantities were documented. This study applied correlation based feature selection (CFS). The CFS algorithm is a simple and powerful filter feature selection method that evaluates the relevance of features in explaining the variance of an output variable (CLP) using the Pearson correlation coefficient. The context-specific models are developed using FISs. The fuzzy sets representing the linguistic terms in the condition and conclusion parts of the if-then rules are characterized by their MBFs, which numerically represent the degree to which an element belongs to a set and fits the concept expressed by the linguistic term. Based on the selected features and associated data sets of each context, the four context-specific fuzzy inference CLP models were developed in a base-case form. Additionally, a fifth generic CLP model based on the combined data set was developed in a base-case form. The accuracy of the models was evaluated using RMSEB, where B represents the base or pre optimization CLP model. The models developed through this study can be used to predict the CLP of concreting activities for new projects.

Bon-Gang Hwang et al. (2017) [4]identified the critical factors affecting the productivity of green building construction projects by assessing the likelihood, impact, and criticality of the factors with comparisons against traditional projects.26 factors were identified from a comprehensive literature review and interviews with industry experts. A questionnaire survey was then performed with 32 professionals experienced in green building projects, and three post survey interviews were also conducted. Post survey interviews were conducted with three industry experts who possess the relevant experience in both traditional and green construction.They all confirmed that the findings of this study were reasonable and consistent with their expectations, which helped validating the findings from the survey. The respondents of questionnaire consisted of project managers, quantity surveyors, contractors, consultants, and developer firms.The results indicated that workers' experience, technology, design changes, workers' skill level, and planning and sequencing of work were the top five most critical factors affecting the productivity of green building construction projects.

Gholamreza Heravi and Ehsan Eslamdoost (2015) [5] developed a labor productivity model based on multilayer feed forward neural networks trained with a back propagation algorithm by which complex mapping of factors to labor productivity is performed. To prevent networks from over fitting and improve their generalization, early stopping and Bayesian regularization are implemented and compared. The results proved a better prediction performance for Bayesian regularization than early stopping. To demonstrate the prediction performance of the presented models, the developed models are implemented at two real power plant construction projects. Moreover, in order to extract the influence rate of each factor on the predictive behavior of the neural network models and to identify the most influential factors a sensitivity analysis is conducted. This paper focused on the work involved in installing the concrete foundations of gas, steam, and combined cycle power plant construction projects in the developing country of Iran. The results proved a better prediction performance for Bayesian regularization than early stopping. To demonstrate the prediction performance of the presented models, the developed models are implemented at two real power plant construction projects.

Jiukun Dai et al. (2013) [7] analyzed the underlying structure of the factors affecting construction productivity and identified which factors the craft workers consider to be more relatively important as well. This research identified 83 factors affecting construction labor productivity through 18 focus groups with craft workers and their immediate supervisors on ninejobsites throughout the U.S. The writers also compared their results to similar previous efforts, and identified significant differences that may impact future productivity improvement strategies. After the focus groups identified 83 factors affecting construction labor productivity, the research team administered a survey to 1,996 craft workers on 28 industry projects throughout the U.S. to quantify their relative importance.The research performed factor analysis on the frequency and agreement factors separately, due to different rating scales as described earlier. For the frequency factors, factor analysis was performed based on the product of the frequency and severity rating for each factor. As measured by the average latent factor score, craft workers considered that Construction Equipment potentially has the most negative impact on construction labor productivity among the frequency latent factors, followed by Material, Tool and Consumable, Engineering Drawing Management, and Direction and Coordination. Among the agreement latent factors, Training, Craft Worker Qualification, Superintendent Competency, and

Foremen Competency have a small positive impact on construction labor productivity from the craft workers' perspective.

Joanicjusz Nazarko and Ewa Chodakowska (2015) [8] used DEA and Tobit regression for analysing productivity of the construction industry in Europe. Productivity of the construction sector in 25 European countries is analysed in the article. In this study a BCC DEA model was built on the assumption of variable return to scale was employed. Tobit regression was applied to explore the impact of the economic performance of a country on the labour productivity in its construction industry. The data used in the efficiency evaluation study covers the period from 2006 to 2012 and comes from the Eurostat databases. In order to measure productivity of construction industry in Europe DEA BCC-O model was used. Number of persons employed was chosenas the input. Turnover and gross operating surplus are outputs. The DEA results revealed huge differences in productivity of construction industry and their trends. Malmquist index identified possible technological change during analysed periods.It was proven,on the basis of regression analysis, that the interpretation of efficiency scores without taking account general economic conditions of the country can lead to inappropriate conclusions.

Khaled, Mahmoud El-Gohary and Remon, Fayek Aziz (2013) [9] identified and ranked factors perceived to affect construction labor productivity in the Egyptian construction context with respect to their relative importance. The study was based on a survey designed to gather all necessary information in an effective way. The studied targeted population includes clients, consultants and contractors. The survey presents 30 productivity factors generated on the basis of related research works on construction productivity which were classified under three primary categories: (a) human/labor; (b) industrial; (c)management. For analyzing data, the Relative Importance Index (RII) technique was used. The most important factors identified are Labor experience and skills, Incentive programs, Availability of the material and ease of handling, Leadership and competency of construction management and Competency of labor supervision.

Rodrigo A. Rivas et al. (2011) [11] identified the productivity factors affecting projects in a Chilean construction company on the basis of questionnaires administered to both direct workers and midlevel employees. This paper reported on a case study conducted to explore the main factors affecting labor productivity.Analysis of the questionnaire results helped to determine organizational and managerial weaknesses and facilitated comparison of the findings with previous productivity studies. The main findings indicated that the critical areas affecting construction productivity were related to materials, tools, rework, equipment, truck availability, and the workers'motivational dynamics.The data for this study were the results of 28 questionnaires administered to direct workers and midlevel employees working on the projects. Questionnaires administered to craftsmen were used to capture perceptions of project personnel regarding productivity issues because a good understanding of the factors influencing productivity can be obtained from the workforce's viewpoint.The main productivity factors identified were materials, tools, equipment, trucks, and rework.

Wen Yi1 and Albert P.C. Chan (2013) [13] presented a review on labor productivity in the construction industry. The study aimed to investigate the state of the art and trends in CLP research, and to identify key research areas.It carried out a three-stage literature review to conduct a content analysis of CLP papers from 1983 to 2011. A total of 135 CLP-related papers were identified from the selected journals.Six major areas on CLP research interests have been identified through a detailed review and analysis on the selected 113 papers, including factors affecting CLP; CLP modeling and evaluation; method and technology for CLP improvement; CLP trends and comparisons; effect of change/variation on CLP; and baseline/ benchmarking CLP. Paul M. Goodrum et al. (2009) [10] examined how changes in material technology have influenced labor and partial factor productivity in the United States construction industry between 1977 and 2004. The researchers presented this examination in three parts.The paper examined labor and partial factor productivity changes in the United States between 1977 and 2004 for 100 different construction activities ,examined changes in material technology over the same time period using five material technology characteristics,examined relationship between material technology changes and productivity changes in construction are examined. This research examined changes in construction productivity at the activity level. The researchers collected output and input data for 100 activities from the 1977 and 2004 manuals of the Means Building Construction Cost Data.Using the material technology factors, the ANOVA analyses compared changes in labor and partial factor productivity from 1977 to 2004 between two groups of activities i.e activities that experienced an improvement per each of the study's material technology factor and activities that did not experience an improvement. Regression models were built by introducing a series of dichotomousbinary variables for the five material technology factors, which included strength, weight, curability, installation and modularity.The findings confirmed a positive relationship between technology and productivity improvement, the findings also show that the relationship was stronger between material technology and partial factor productivity than between material technology and labor productivity.

Tao Wang et al. (2016) [12] investigated the long- and short-run impacts between material productivity and selected socioeconomic factors, such as energy intensity, economic structure, international trade and resource endowment in the case of China by using the auto-regressive distributed lag model over the period of 1980-2010. This paper applied the auto-regressive distributed lag model to investigate the dynamic impacts of energy intensity for secondary industry, tertiary industry value added per GDP, trade openness and domestic extraction per capita on MP in the case of China .This study focued on variables that can represent the current situation of the socioeconomic and technological system in China; in addition, these factors should affect national material consumption. this study applies augmented Dickey-Fuller, Phillips-Perron, Dickey-Fuller generalized least squares and the KPSS unit root tests to test the order of integration. This study applies a diagnostic and stability test to check the model. This study used a Wald joint significance test to examine the co-integration relationship. After identifying a co-integration relationship among variables, this study proceeded to estimate the marginal impacts of SEI, TVA,TO and DEC on MP in the long and short run. This study applies the Toda-Yamamoto approach based on the vector auto regression (VAR) model at various levels to investigate the direction of the causal relationship between these variables. The validity and robustness of model results were assessed through diagnostic tests, stability tests and the Gregory-Hansen co-integration test under the assumption of structural breaks. The T-Y approach based on vector auto regression (VAR) model at various levels was used to examine the direction of causal relationship between these variables. The model confirmed the existence of co-integration among the variables both in the long and short run. The results indicated that energy intensity, trade openness, domestic extraction per capita are the significant factors for material productivity. Argaw Tarekegn Gurmu and Ajibade Ayodeji Aibinu (2017) [3] identified construction equipment management practices that have the potential to improve productivity in multi-storey building projects. This study used an exploratory sequential mixed-methods research design involving a combination of qualitative and quantitative data in two phases. The qualitative phase may be used to build an instrument that best fits the sample under study, identify appropriate instruments to use in the follow up quantitative phase, or specify variables that need to go into a follow-up quantitative study. In exploratory sequential mixed methods, the researcher first begins by exploring with qualitative data, and then During Phase I, in-depth interviews were conducted with 19 experts who have been involved in the delivery of multistorey building projects. The qualitative data were analyzed, and construction equipment management practices that have the potential to improve productivity were identified. In Phase II, data were collected from 39 principal contractors on 39 projects using questionnaires The quantitative data were analyzed to prioritize the practices identified in Phase I, and on that basis, a scoring tool for measuring the practices was developed; a logistic regression model was also developed for predicting the probability of exceeding baseline productivity factor using a sigmoid graph when the score of the practices is known. Construction equipment maintenance, construction equipment procurement plans, and construction equipment productivity analysis are identified as the three construction equipment management practices that could improve productivity in multistory building projects. Govindan Kannan (2014) [6] evaluated the performance of the tools and to record observations. The paper focused on repair costs, residual value and total cost and productivity, typically referred to as total cost of ownership. The paper dont cover any aspects of the future designs of machines nor explore the trends of the construction equipment market. All of the concepts and tools developed around this research were found to be well accepted in the construction industry. Resale Value Model was developed. The model on resale value considers manufacturer, auction year, year of manufacture, and auction price. The probability (likelihood) of failure approach uses an instance of life on the basis of predefined parameters. This approach requires the simulation of multiple instances with different component lives on the basis of a predefined distribution.

III. CONCLUSIONS

Productivity measurement provides the necessary data to analyze factors for project owners, constructors, and management professionals to control construction progress, estimate the cost of future construction projects, and determine its competitiveness in the global market. Multi-factor productivity is an indication of the productivity with which selected factors of production are used in the creation of the output of a firm, industry, etc. Workers' skill level, lack of labor supervision, construction method, type of the project, rework, working overtime, tools and equipment shortage, incentive programs, payment delays, working condition are found to be the most influential factors affecting labor productivity. Lack of material, poor site layout, timely payments, improper materials delivery to site, Storage of materials on site, Material Procurement ,Wastage, Weather conditions, material requirement planning, inspection and testing, quality of materials are found to be the most influential factors affecting material productivity. Equipment breakdown, poor site layout, fund shortage to procure, improper maintenance, fast and efficient repair of equipment, type of the project, specification and standard, lack of tools and equipment are found to be the most influential factors affecting equipment productivity. In all literatures, analysis of factors affecting labor productivity or material productivity is done and models are generated for labor productivity. There is minimal reference to the wholesome approach of productivity.

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