Role of Management Strategies in Improving Labor Productivity in General Construction Projects in New Zealand: Managerial Perspective

Nariman Ghodrati[1]; Tak Wing Yiu, M.ASCE[2]; Suzanne Wilkinson[3]; and Mehdi Shahbazpour, Ph.D.[4]

Abstract: This study aimed to quantify the effectiveness of a set of implemented management strategies including incentive programs, labor management, training, communication, supervision, planning, resource scheduling, use of advanced construction methods, and management of construction in improving labor productivity. These management strategies are widely implemented because they are believed to improve labor productivity in general construction projects. However, their effectiveness and relationship with labor productivity have not been systematically studied. Data were collected from 111 general construction projects. The statistical tests confirmed that labor productivity is significantly higher in construction projects with a high-level implementation of the management strategies compared with low-level implementation. The results showed that management strategies such as communication and incentive programs have a strong positive relationship with labor productivity. This paper's major contribution to the overall body of knowledge is that it proves and quantifies the effectiveness of and the relationship of these management strategies with labor productivity through more comprehensive statistical methods than previous studies. It also introduces a tool to assist construction managers in benchmarking the implementation level of the management strategies against similar projects to reveal the areas that require further improvement to achieve higher labor productivity. **DOI: 10.1061/(ASCE)ME.1943-5479.0000641.**

Author keywords: Labor productivity; Management strategies; Construction management; Productivity.

Introduction

The construction industry is a significant driver of the national economy (Alaghbari et al. 2017; Naoum 2016). In New Zealand, the industry contributed 5.2% of the gross domestic product (GDP) in 2013 (Statistics New Zealand 2015), and in Australia, it accounted for 7.7% of the GDP in 2015 (Department of Industry, Innovation and Science 2015). These figures indicate that the performance of the industry plays a significant role in the growth of the economy nationally (Naoum 2016). Thus, the construction industry must improve its productivity by efficient use of laborers and other resources (Hughes and Thorpe 2014). The industry has achieved substantial improvements by implementing advanced technologies, materials, and heavy equipment (Caldas et al. 2015; Goodrum et al. 2009; Grau et al. 2009). Despite improvements, labor productivity is still problematic; for years, the construction industry has been struggling to improve labor productivity (Heravi and Eslamdoost 2015). The cost of labor is the main motivation for this improvement since it accounts for 30–50% of total construction costs (Heravi and Eslamdoost 2015; Nasir et al. 2015; Shan et al. 2015). In addition, construction laborers spend 50–75% of their productive time on non-value-added activities that do not affect the overall performance of the project (Diekmann et al. 2004). Labor productivity has a substantial impact on the final cost of projects (Liu et al. 2011). Improving labor productivity is a key factor in executing successful construction projects that lead to significant profits for the industry and its clients. It will also assist the industry to enhance overall performance and, in so doing, improve the contribution to the growth of the national economy.

Improving labor productivity is a management case (Nasir et al. 2015). Construction managers apply a wide range of management strategies at the project level to improve labor productivity and achieve project objectives (Dai and Goodrum 2012; Dai et al. 2009; Shan et al. 2011, 2015). These strategies are based on the experience and knowledge of the managers. Quite often, construction managers fail to apply effective strategies that enhance labor productivity in construction projects because their actual impact on labor productivity is not evident (Caldas et al. 2015). In order to improve labor productivity, it is necessary for construction managers to know the extent to which the implemented management strategies affect labor productivity. Because of the shortage of skilled laborers in the construction industry (Brandenburg et al. 2006; Dai and Goodrum 2012), identifying the strategies and practices that can improve the effectiveness of the workforce becomes a major priority (Tsehayae and Robinson Fayek 2014). However, the main challenge for construction management teams is to identify the overall impact of their strategies on labor productivity. Shan et al. (2015) urged researchers to investigate the relationship between management strategies and labor productivity to determine the most

[1]Ph.D. Candidate, Faculty of Engineering, Dept. of Civil and Environmental Engineering, Univ. of Auckland, Private Bag 92019, Auckland 1142, New Zealand (corresponding author). Email: ngho228@aucklanduni.ac.nz

[2]Senior Lecturer, Faculty of Engineering, Dept. of Civil and Environmental Engineering, Univ. of Auckland, Private Bag 92019, Auckland 1142, New Zealand. Email: k.yiu@auckland.ac.nz

[3]Professor, Faculty of Engineering, Dept. of Civil and Environmental Engineering, Univ. of Auckland, Private Bag 92019, Auckland 1142, New Zealand. Email: s.wilkinson@auckland.ac.nz

[4]Innovation Strategy Analyst, Fletcher Building, Private Bag 92114, Auckland 1142, New Zealand. Email: mehdi.shahbazpour@fbu.com

Note. This manuscript was submitted on September 8, 2017; approved on March 13, 2018; published online on July 27, 2018. Discussion period open until December 27, 2018; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Management in Engineering***, © ASCE, ISSN 0742-597X.

effective management strategies that can be applied by construction managers to improve labor productivity. Understanding the relationship between these two variables is critical for construction management teams, especially if resources are limited and they have to prioritize the allocation of the resources (Nasirzadeh and Nojedehi 2013).

Although there is a significant amount of literature on factors that affect labor productivity in different locations and project types, few studies have attempted to provide a method to investigate and quantify the impacts of management strategies on labor productivity. The impacts of the management strategies on labor productivity need to be quantified through a systematic and comprehensive approach. This is crucial in decision making for planning and scheduling current and future projects (Heravi and Eslamdoost 2015; Song and AbouRizk 2008). This study fills this gap by identifying the impacts of management strategies on labor productivity through statistical methods. The outcomes of the study can assist practitioners to develop a wider perspective regarding the management strategies that improve labor productivity and to achieve an efficient utilization of the workforce. To complete general construction projects more productively, practitioners can allocate resources and focus on the management strategies with high impacts on labor productivity.

In this study, management practices refer to individual practices that are performed by a construction management team in order to improve labor productivity. Management strategies comprise several management practices with similar concepts that affect certain areas.

Literature Review

Construction Productivity Definitions

The concept of productivity sounds simple and clear. Productivity can be defined as the ratio of output divided by input. However, it is hard to define and measure, particularly in the construction industry (Nasir 2013). According to Park et al. (2005), there are no standard definitions and tools that can be used to collect productivity data in the US construction industry. The lack of sufficient and reliable data is the main barrier in measuring productivity in construction projects. Nevertheless, there are terms that are generally used in the industry to measure productivity, although they vary across different projects or construction firms. These terms are briefly presented here; for more information, see Thomas et al. (1990).

Total factor productivity (TFP) takes into account multiple factors for producing an output. It is a ratio of total output divided by all inputs. It is given by the equation

$$\text{TFP} = \frac{\text{Total output}(\$)}{\text{Labor}(\$) + \text{Material}(\$) + \text{Equipment}(\$) + \text{Energy}(\$) + \text{Capital}(\$)}$$

This term is a useful macro-level productivity measure that is mostly applied in economic studies and strategic decision making. TFP is not applicable in construction projects or sites because there are significant problems tracking all the required inputs (Park et al. 2005; Thomas et al. 1990).

Factor productivity (FP) or the project-specific model (Shehata and El-Gohary 2011) was introduced by Thomas et al. (1990) as a suitable term for project-specific purposes. It is a more accurate definition than TFP and is useful for specific program planning and estimating on individual projects (El-Gohary and Aziz 2014; Nasir 2013). FP is a ratio of an output (units) to dollars of input (Thomas et al. 1990)

$$\text{FP} = \frac{\text{Physical output (unit)}}{\text{Dollars}}$$

Construction companies prefer to measure productivity through a more specific term in which the units of outputs are specific and can be measured accurately (Shehata and El-Gohary 2011). Single factor productivity (SFP) is a narrowly defined version of FP. Because labor productivity has a substantial impact on the cost of projects, contractors are mostly interested in labor productivity. Labor productivity is categorized under SFP because a single factor (labor cost or work hours) is considered the only input to calculate productivity (Thomas et al. 1990). Labor productivity can be calculated in one of the following ways:

$$\text{Labor productivity} = \frac{\text{Output}}{\text{Labor cost (\$)}}$$

$$\text{Labor productivity} = \frac{\text{Output}}{\text{Work hour}}$$

Construction companies use different terms to calculate labor productivity since there is no standard definition of productivity in the industry (Nasir 2013; Park et al. 2005). In the absence of a standard definition and data collection tool, benchmarking labor productivity among different construction projects is a problematic case in the construction management domain (Park et al. 2005; Shehata and El-Gohary 2011).

Factors Affecting Labor Productivity

Rojas and Aramvareekul (2003) found that the fact that labor productivity can be managed and controlled indicates a massive opportunity for labor productivity improvements in the construction industry. Consequently, identifying factors that affect labor productivity in the construction industry has received significant attention from both academia and practitioners. Numerous studies have attempted to ascertain the most dominant factors in labor productivity (Table 1). Because of space limitations, only the top 10 factors of each study have been entered into the table. These factors can be categorized in three main areas (management, human, and external). A quick review of Table 1 shows that the proportion of management-related factors in top 10 factors is higher than human and external factors. Although other factors are categorized under human and external areas, some of them can be influenced by different management strategies and practices such as human resource management. This highlights the crucial role of construction managers and their strategies in labor productivity improvement (El-Gohary and Aziz 2014). In addition, it also supports the notion that labor productivity is manageable and can be improved by applying effective management practices (Liberda et al. 2003).

Although many studies in the construction industry have aimed at establishing a generalized list of factors with substantial impacts on labor productivity, there is no agreement among researchers on such a list (Panas and Pantouvakis 2010). Furthermore, there is no general method to assess the accuracy of the impact of the identified factors on labor productivity (Caldas et al. 2015; Yi and Chan 2014). Such a method would be very beneficial for construction practitioners to improve labor productivity by identifying and applying the most effective factors. It would also help them to

Table 1. Factors affecting labor productivity in the construction industry

Area	Factors	References
Management	Adequacy of planning and risk process; amount of remuneration; availability of material; clarity of instruction and information exchange; competency of labor supervision; construction method; contractual strategy and contractor selection; constructability; construction equipment; ethical behavior of manager; effective communication; engineering management; giving responsibility; health and safety; incentive payments; job security; leadership and competency of construction management; material supply chain; poor decision making; proper planning; project organizational culture; project management style; promotion opportunities; relationship management; rework; site layout; stringent/delayed inspection; subcontracting; timeliness of remuneration; tools and consumables; work overtime; training; clear drawing and specifications; site facility; construction process; construction method; lack of integration of the management information system for the project	Durdyev and Mbachu (2011); Ghoddousi et al. (2015); Kazaz and Ulubeyli (2007); Kazaz et al. (2008); El-Gohary and Aziz (2014); Dai et al. (2009); Liberda et al. (2003); Abdul Kadir et al. (2005); Enshassi et al. (2007); Mojahed and Aghazadeh (2008); Soekiman et al. (2011); Jarkas and Bitar (2012); Jarkas et al. (2015); Klanac and Nelson (2004); Heravi and Eslamdoost (2015); Ghoddousi and Hosseini (2012); Jarkas and Radosavljevic (2013); Naoum (2016); Alaghbari et al. (2017)
Human	Motivation; worker skill and experience; worker attitude; worker satisfaction; worker fatigue and boredom; worker competence, qualification	Heravi and Eslamdoost (2015); Liberda et al. (2003); Ghoddousi et al. (2015); Kazaz and Ulubeyli (2007); Mojahed and Aghazadeh (2008); Enshassi et al. (2007); El-Gohary and Aziz (2014); Dai et al. (2009); Durdyev and Mbachu (2011); Naoum (2016); Alaghbari et al. (2017)
External	Availability of workforce; design change; design complexity; extent of variation/change orders during execution; financial difficulties of owners; labor strikes; government influences; project characteristics; social insurance; weather; availability of material in the market; political and security situation	Abdul Kadir et al. (2005); Klanac and Nelson (2004); Durdyev and Mbachu (2011); Soekiman et al. (2011); Enshassi et al. (2007); Jarkas et al. (2015); Jergeas (2009); Ghoddousi and Hosseini (2012); Jarkas and Radosavljevic (2013); Naoum (2016); Alaghbari et al. (2017)

allocate resources to management strategies that target the dominant factors in improving labor productivity rather than putting effort into management strategies with minor or no impact. Identifying the dominant factors is the fundamental step in improving labor productivity (Ghoddousi et al. 2015). The findings lead construction managers to implement a wide range of management strategies and practices in order to reinforce the factors in the areas that positively affect labor productivity and eliminate the factors that have a negative impact. Nevertheless, a lack of empirical evidence exists to show the effectiveness of the implemented management strategies and practices in improving labor productivity.

Management Practices that Affect Labor Productivity

While new technologies, materials, and innovations provide opportunities to the construction industry to improve labor productivity, their influence is not substantial without the necessary management practices to support and control labor productivity (Cox et al. 2003; Shan et al. 2015). The importance of the management practices and strategies in the improvement of labor productivity was emphasized by Adrian (2004), Nasir et al. (2015), and Thomas and Horman (2006). Thomas et al. (2003) showed that more than half of nonproductive work hours were caused by ineffective management practices. So, to achieve optimum outcomes in their projects, it is crucial for construction management teams to identify the most effective management strategies to improve labor productivity. Over the years, researchers have attempted to establish a list of the best management practices that have maximum impact on labor productivity. Cox et al. (2003) indicated the substantial impacts of quality control, on-time completion, cost, safety, dollars per unit, and units per staff hour on labor productivity and construction performance. Different studies have recommended several management practices that can improve labor productivity in construction projects (Adrian 2004; Doloi 2008; Huang et al. 2009; Park 2006). Although these studies have recommended some management practices, few of them have attempted to quantify the impact of the management practices on labor productivity in construction projects. As a result, most of them have not provided empirical evidence to prove the effectiveness of their recommendations.

Two studies by Caldas et al. (2015) and Shan et al. (2015) revealed that construction projects with a high implementation of certain management programs have experienced higher labor productivity compared with construction projects with a lower level of implementation. These studies investigated industrial construction projects located in North America. These projects had different characteristics compared with other sections of the industry. They were mostly more complex and well planned, and the implementation level of applied technologies in these projects was much higher than in other construction domains (Shan et al. 2015). Consequently, the findings cannot be fully generalized to other project types and domains in the industry (Caldas et al. 2015). The applied statistical methods in these studies have several limitations that have been highlighted by their authors, so further investigations are still warranted in this area (Shan et al. 2015). Furthermore, location plays an important role in the labor productivity topic (El-Gohary and Aziz 2014; Ghoddousi et al. 2015; Jarkas et al. 2015; Kaming et al. 1997; Kazaz et al. 2008). Labor productivity is related to factors such as government influences and legislations, weather conditions, working culture, and availability of materials. These factors are unique to each location (Abdul Kadir et al. 2005; Jarkas and Bitar 2012; Kazaz and Ulubeyli 2007). This situation reduces the generalizability of findings about labor productivity. Therefore, the findings of the previous studies that have mostly been conducted in North America cannot be fully implemented and generalized to other locations. To tackle this issue, further investigations are

required in different locations to help construction practitioners understand the impacts of implemented management strategies on labor productivity (Caldas et al. 2015; Nasir et al. 2015).

The literature review provided at this stage indicates that several factors and management strategies can affect labor productivity at the project level. However, the findings of these studies are accompanied by several limitations that have been discussed. An extensive background review of the literature was performed to identify the factors and management strategies that can potentially improve labor productivity.

Research Method

The methodology applied in this study consists of an extensive background review of the literature in order to identify the factors and management strategies that potentially can improve labor productivity, using expert interviews to develop a management strategy assessment index (MSAI), and hypothesis development and testing to identify the impacts of the management strategies on labor productivity.

Developing MSAI

As a result of the extensive background review of the literature, a list of management strategies was established to be used for developing MSAI. The aim at this stage of the study was to develop MSAI in order to assess the implementation level of management strategies in construction projects. Interviews with experts were carried out at this stage. The interview can be utilized if a deep understanding of a problem is required (Muijs 2010). It provides more insight regarding the complex concept of the various impacts of management strategies on labor productivity. The interviewees were selected from a pool of senior construction managers with over 15 years of experience in the New Zealand construction industry. More than 25 senior construction managers from leading New Zealand construction companies were invited to participate in the interviews, and a total of 19 interviews were conducted. The list obtained from the previous stage was presented to senior construction managers in the interview sessions. The interviewees were requested to review the list and comment on the availability and applicability of each management practice and strategy in the context of general construction projects in New Zealand. They could also add other management strategies that affect labor productivity from their perspective. This stage is important in order to verify the essential management practices to improve labor productivity and develop MSAI. The research team reviewed, adjusted, and redefined the initial list based on the information obtained from interviewees. Some management strategies identified in previous studies such as automation and integration were eliminated after conducting interviews. Automation is defined as the use of computerized devices to manipulate data or produce a product, and integration can be defined as sharing information among parties or the melding of information sourced from separate systems (O'Connor and Yang 2004; Shan et al. 2015). According to the interviews, the implementation of these strategies is at a premature stage in the general construction projects in New Zealand. Small companies are the major players in the general construction domain. These companies do not have sufficient resources to implement automation and integration in their work processes. Information is shared by using email and transferring files rather than a well-established and secure system that can be integrated into other parties' work systems. According to a senior project manager in a leading construction company,the industry is still traditional and low tech. Small construction companies simply do not have sufficient resources to integrate automation into their working process. In addition, there is a lack of futuristic vision in the construction training system. Trainees still are learning traditional and low-tech building methods. In this situation, using automation and integration can cause further difficulties as many companies in this domain [general construction] are not well-equipped and prepare for this change. The real impacts [advantages] of automation and integration on labor productivity will be evident in future.

Therefore, currently it is not possible to measure the real impacts of automation and integration on labor productivity in general construction projects. These management strategies have been proven to be effective in industrial and infrastructure construction projects that are not part of the scope of this study (Caldas et al. 2015; Shan et al. 2015). However, Shan et al. (2015) found that automation and integration do not have a significant impact on labor productivity compared with other management programs in major construction trades. As a result, the final version of MSAI was developed, consisting of 48 management practices grouped into nine management strategies (Table 2).

In order to identify and measure the impacts of management strategies on labor productivity, a questionnaire survey based on MSAI was utilized in this study. This survey was conducted to collect data from general construction projects (except single residential and industrial projects) across New Zealand. Each project received a score based on the implementation of nine management strategies (MSAI score). A list of construction contractors was obtained from the Civil Contractors New Zealand (CCNZ) website. A total of 706 general construction projects were identified from their websites. The survey forms were sent to 514 general construction projects by email or mail because the contact details of the rest of the projects could not be obtained. The survey was completed by either the project manager or the site manager of each project, since they have sufficient knowledge and information regarding the topic and the project. A Likert scale from 1 to 7 (1 = never, 7 = very frequent) was applied to assess the level of implementation of each management practice. To measure labor productivity, the participants were asked to rate it in their projects. This approach was adopted from Dai et al. (2009). Labor productivity was rated from 1 (significantly low) to 7 (extremely high). In this approach, productivity is measured based on the perception of the participants (in this study referred to as the productivity score). The main limitation of the subjective measurements is that they suffer from systematic biases (Donchev and Ujhelyi 2014). Despite the limitation of the subjective measurement, it was implemented in this study because there is no standard way to measure labor productivity in construction projects in New Zealand. Because different companies use different methods, benchmarking labor productivity is more difficult. The authors considered different ways for measuring labor productivity such as staff hours per square meter of the project. Subcontracting is widely applied in general construction projects in New Zealand; in many cases, details such as the number of laborers or staff hours are not properly reported and recorded by subcontractors and main contractors, respectively. The results of interviews with the experts indicated this issue as well. Consequently, staff hours per square meter and similar methods do not truly reflect labor productivity in such projects. In addition, Wall et al. (2004) found that subjective and objective measures of company performance were positively correlated and that they could validate the findings of the subjective measurement. Also, a study on the advantages and disadvantages of subjective measurements by Jahedi and Méndez (2014, p. 105), found that "subjective measures of specific and well defined concepts are correlated well with the facts they intended to

Table 2. Management strategies and practices in MSAI

Reference	Management strategy	Management practice
Park (2006); Doloi (2008); Jergeas (2009); Bernold and AbouRizk (2010)	Incentive programs	1. Performance-based incentives 2. Health and safety incentives 3. Incentives for no rework 4. Recognition programs for laborers with outstanding performance
Jergeas (2009); Caldas et al. (2015)	Labor management	1. Create a sense of ownership or control for individual tasks 2. Engaging crew in task briefing and debriefing 3. Using part-time laborers 4. Using repeating construction crews 5. Using skilled laborers 6. Increasing the number of laborers
Jergeas (2009); Bernold and AbouRizk (2010); Caldas et al. (2015)	Training	1. Providing organizational and project management training for the site supervisors 2. Providing job training to construction crews 3. Investing in training programs 4. Improving first-line leadership (site supervisors), which may include training/coaching/mentoring
Huang et al. (2009); Jergeas (2009); Bernold and AbouRizk (2010)	Communication	1. Regular and effective communication on construction status with the project stakeholders 2. Clear roles, responsibility, and authority 3. Effective site communication 4. Giving laborers clear and direct instructions
Jergeas and Van der Put (2001); Bernold and AbouRizk (2010)	Supervision and leadership	1. Allocating experienced supervisors 2. Assigning sufficient authority to the supervisors 3. Sufficient number of supervisors to manage the workforce 4. Enhancing leadership and decision making for the supervisors
Park (2006); Doloi (2008); Huang et al. (2009); Jergeas (2009); Shan et al. (2015)	Planning	1. Completing sufficient front-end planning 2. Implementing detailed construction planning (e.g., WorkFace Planning) 3. Managing construction activities with adequate sequencing and trade(s) utilization 4. Providing workers the tools, equipment, and materials in a timely manner 5. Anticipating problems and planning for them in advance 6. Having sufficiently advanced engineering and procurement before starting tasks 7. 100% issued for construction drawing must be ready before commencement of construction
Jergeas (2009)	Resource scheduling	1. Applying a realistic and practical work schedule 2. Providing overtime opportunities 3. Applying additional working shifts
Park (2006); Caldas et al. (2015)	Use of construction methods	1. Lean construction 2. Industrialization 3. Prefabrication 4. Modularization 5. Work packaging 6. Constructability
Park (2006); Jergeas (2009); Bernold and AbouRizk (2010); Shan et al. (2015)	Management of construction	1. Material management 2. Equipment management 3. Site facility management 4. Safety management 5. Quality management 6. Material and supply chain management 7. Change and rework management 8. Risk management 9. Stakeholder management 10. Innovation management

quantify." The study showed that subjective measurements can be used in other research areas such as labor productivity. Considering the previously mentioned factors and the results of interviews with the experts, management perception of labor productivity provides a reasonable sense of the labor productivity on their projects.

Hypothesis Development

As discussed previously, labor productivity can be improved by implementing management strategies at a project level (Birdi et al. 2008; Caldas et al. 2015; Dai et al. 2009; Shan et al. 2011, 2015). Based on this evidence, we expect that

Hypothesis 1: Construction projects with a high level of implementation in terms of the management strategies will achieve higher labor productivity than those projects with a low implementation level.

To test Hypothesis 1, an independent sample t-test was applied to test the difference between the two groups. Projects with an implementation level above 5% of the mean were classified in the high-implementation group. Projects that were scored 5% below the mean were grouped in the low-implementation group (Nasir et al. 2015). Projects within the 5% were not entered into the test. Although the assumption of the normality of the population mean must be met for the t-test technique, according to the central limit theorem the sample mean will be almost normal if the sample size is more than 20 (Box et al. 1978).

In addition, a multiple regression analysis (MRA) was conducted to measure the relationship between the management strategies and labor productivity. MRA is a technique that can be used to measure the relationship between several independent variables (management strategies) and a dependent variable (labor productivity score; Hair et al. 1998). A regression equation is shown as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 \cdots + b_9X_9 + e$$

where Y = productivity score; X_i = management strategies; a and b_i = unknown constants; and e = random error for any set of values for X_i when $i = 1, 2, 3, \ldots, 9$.

The investigated management strategies in this study have been identified through an extensive literature review and interview with experts. Thus, it is expected that

Hypothesis 2: There is a significant difference in the means of labor productivity between the group of construction projects with a high level of implementation of each management strategy and the projects with a low level of implementation.

To test Hypothesis 2, a series of t-tests were done. A similar approach to Hypothesis 1 was adopted to group construction projects based on the implementation level of each management strategy. The results of t-tests can be complementary to the findings of MRA and provide further justification for applying each management strategy for improving labor productivity in general construction projects. All the statistical methods in this study were performed on the data collected through the questionnaire survey.

Results and Discussion

Data were collected from 111 general construction projects (21.6% response rate) with a value of between $5 and $50 million in New Zealand. Eight of the returned questionnaires were eliminated from the analysis due to missing data. Among the respondents, 64% were project managers and 36% were site managers. Moreover, 77% of the respondents had more than 10 (58% more than 15) years of work experience in the New Zealand construction industry. Because the majority of respondents have a high level of experience in the New Zealand construction industry, their perceptions of labor productivity are a valid benchmark in construction projects. This provides further justification for using the labor productivity score method in this study.

Tables 3 and 4 provide the results of descriptive analysis on the implementation levels of management practices and strategies, respectively. Effective site communication received the highest score (mean = 5.70), followed by providing workers the tools, equipment, and materials in a timely manner (mean = 5.64) and giving laborers clear and direct instructions (mean = 5.60). As shown in Table 4, communication strategy received the highest score among all management strategies, with a mean score of 5.62. Planning and management of the construction strategies ranked as the second and third management strategies with means of 5.22 and 5.04, respectively. In terms of the implementation level of incentive programs, it received the lowest score (mean = 3.60), which indicates that construction management teams rarely use incentives to improve labor productivity in their projects.

An independent sample t-test was conducted to test Hypothesis 1, and the results are presented in Table 5. Levene's test, a statistical test to assess whether the variance of groups is statistically different, was performed to examine the equality of the variance in the sample data. Before applying comparing techniques such as the t-test, one should check that the underlying populations have a common variance (Gastwirth et al. 2009). The mean labor productivity scores in high-level and low-level implementation groups were 5.63 and 3.97, respectively. The difference between the labor productivity scores of the two groups was statistically significant with the assumption of equal variance ($p < 0.001$; Table 5). The results of the t-test support Hypothesis 1. So, it can be concluded that construction projects with a high level of implementation of the investigated management strategies have significantly higher labor productivity than projects with a low-level implementation. Nevertheless, significance does not show the practical importance of the differences between the two groups. For this purpose, the effect size (Cohen's d) was calculated. According to Cohen (1988), an effect size over 0.8 indicates

Table 3. Top 10 management practices implemented by practitioners

Management practice	Mean
Effective site communication	5.70
Providing workers the tools, equipment, and materials in a timely manner	5.64
Giving laborers clear and direct instructions	5.60
Regular and effective communication on construction status with the project stakeholders	5.57
Clear roles, responsibility, and authority	5.50
Engaging crew in task briefing and debriefing	5.44
Using repeating construction crews	5.40
Quality management	5.32
Completing sufficient front-end planning	5.19
Anticipating problems and planning for them in advance	5.09

Table 4. Management strategies implemented level and rank

Management strategy	Mean	Rank
Incentive	3.60	9
Labor management	4.86	5
Training	4.62	7
Communication	5.62	1
Supervision	5.03	4
Planning	5.22	2
Resource scheduling	4.78	6
Use of advanced construction methods	4.16	8
Management of construction	5.04	3

Table 5. Comparison of labor productivity score between low-level and high-level implementers of the management strategies

	Implementation level		Test for equality variances		Equal variance assumed		Equal variance not assumed		
Parameter	Low	High	F	Sig	t	Sig	t	Sig	Effect size
Productivity score	3.97	5.63	0.49	0.48	–4.60	**0.000*****	–4.66	0.000	1.12

Note: $F = F$-test; Sig = significance; and $t = t$-test. Bolded p-values correspond to the results of whether the test of equality variances passed or not.
***($P < 0.001$).

Table 6. MRA of the management strategies on labor productivity score

Management strategies (independent variables)	Standardized coefficient (β)
Incentives	0.30
Labor management	0.15
Training	—
Communication	0.31
Supervision	—
Planning	0.10
Resource	0.09
Use of advanced construction methods	—
Management of construction	0.09
R^2	0.36
P-value	0.000

Note: The dependent variable was the labor productivity score.

a large effect. The result also confirmed the practical importance of the implementation of the investigated management strategies for improving labor productivity in general construction projects (Table 5).

To determine the relationship between labor productivity and management strategies, MRA was further conducted (Table 6). The variance inflation factor (VIF) was applied to test the multicollinearity between the independent variables. Multicollinearity refers to the correlation among more than two independent variables in MRA. It reduces the prediction power of each independent variable (Hair et al. 1998). All independent variables had a VIF near 1.5, so multicollinearity was not a concern. Independent error term is an important assumption in all types of linear regression. It is commonly violated when each error is related to its immediate predecessor (autocorrelation). The Durbin–Watson test tests the null hypothesis that the error terms are not autocorrelated against the alternative (Mendenhall et al. 1996). The result of the Durbin–Watson test was satisfactory, so no autocorrelation was detected.

As shown in Table 6, except for training, supervision, and the use of advanced construction methods, all other management strategies had a significant impact on labor productivity. The rest of the management strategies explained 36% of the total variance on labor productivity from a management perspective ($R^2 = 0.36$). While the results of the MRA showed that the overall model was very significant, the p value was 0.000, which is less than widely regarded statistically significant levels of 0.05 or even 0.01 (Table 6; Nasir et al. 2015). According to Table 6, communication strategies had the greatest influence on labor productivity ($\beta = 0.31$), followed by incentive ($\beta = 0.30$) and labor management strategies ($\beta = 0.15$). The regression model did not show a significant relationship between the use of advanced construction methods, supervision, and training and the labor productivity score. However, that does not necessarily mean that a relationship does not exist. In the MRA, all independent variables were entered into the model at once to reduce the model overfitting (enter approach; Babyak 2004; Hoggarth et al. 2015). Therefore, it is possible that, in the presence of dominant variables such as communication and incentive programs, the minor impacts of other variables become insignificant in the regression model. It is also possible that some unforeseen factors prevent these management strategies from affecting labor productivity significantly. What is evident is that the relative impact on labor productivity of the use of advanced construction methods, supervision, and training is less when compared with impacts of other investigated management strategies. Similar issues have been reported in previous studies by Nasir et al. (2015) and Shan et al. (2011, 2015). For instance, material management has been recognized as a factor that affects labor productivity in previous studies (El-Gohary and Aziz 2014: Kazaz et al. 2008), but a study conducted by Shan et al. (2015) in industrial construction projects could not detect a significant relationship between labor productivity in concrete trade and material management.

A series of t-tests were performed to test Hypothesis 2. To illustrate the significance of each management strategy, the labor productivity score difference between the projects with a low implementation level and a high implementation level were reported. The results are shown in Table 7. There was homogeneity of variances for productivity scores for high- and low-implementation groups in all management strategies except use of advanced construction methods. According to Table 7, it is evident that construction projects with a high-level implementation of the management strategies, except for use of advanced construction methods, have a significantly higher labor productivity score. The comparison of labor productivity scores shows that an 18.4% ($p < 0.05$; supervision) to a 41.0% ($p < 0.01$; communication) labor productivity difference was observed among construction projects with a high- and low-implementation level.

Management practices in the use of advanced construction methods, such as lean construction, prefabrication, modularization, and industrialization, have been recognized as drivers of labor productivity in previous studies (Court et al. 2009; Dai et al. 2009; Jergeas and Van der Put 2001). However, the result of the t-tests did not show a significant difference ($p > 0.05$) between productivity scores in high-level and low-level implementers. This can be explained through the shortage of a skilled workforce in the New Zealand construction industry (Construction Sector Leaders Group 2013; Page and Norman 2014). Using new construction methods requires a highly skilled and trained workforce (Badir et al. 2002; Tam et al. 2005). The shortage of a skilled workforce hinders construction management teams from utilizing all of the potential capabilities of new construction methods in their projects. Consequently, implementing new construction methods without having a skilled workforce on site cannot improve labor productivity as expected.

The result of the t-tests supported Hypothesis 2 (except the use of advanced construction methods). Therefore, construction projects with a high implementation level of management strategies experience significantly higher labor productivity compared with their peers with a low-level implementation. Considering only the significance can be misleading, so the results of t-tests regarding training

Table 7. Comparison of labor productivity score between low-level and high-level implementers of each management strategy

Management strategy	Implementation level			Test for equality variances		Equal variance		Effect size
	Low	High	Diff%	F	Sig	Assumed	Not assumed	
Incentive programs[a]	3.7	5.6	33.9	0.33	0.569	**0.004**	0.003	0.87
Labor management[a]	4.1	5.5	25.4	0.54	0.462	**0.001**	0.002	0.78
Training[a]	4.1	5.1	19.6	0.45	0.504	**0.003**	0.003	0.48
Communication[a]	3.3	5.6	41.0	0.19	0.663	**0.001**	0.001	0.94
Supervision[b]	4.0	4.9	18.4	2.5	0.118	**0.020**	0.018	0.46
Planning[b]	4.0	5.2	23.1	0.74	0.391	**0.038**	0.039	0.62
Resource scheduling[a]	4.0	5.4	25.9	2.59	0.112	**0.002**	0.002	0.62
Use of advanced construction methods	4.0	4.6	13.0	9.52	0.003	0.178	**0.185**	0.34
Management of construction[b]	3.9	4.9	20.4	0.0	0.989	**0.046**	0.046	0.59

Note: Bolded p-values correspond to the results of whether the test of equality variances passed or not.
[a]Statistically significant at the 99% confidence interval ($\alpha = 0.01$).
[b]Statistically significant at the 95% confidence interval ($\alpha = 0.05$).

and supervision can be interpreted in contradiction to the findings of MRA. According to Table 7, despite a significant difference in labor productivity scores, these two management strategies have a small effect size (Cohen's $d < 0.5$) on labor productivity (Cohen 1988). Since the effect sizes are small, their relationships with labor productivity can become insignificant in the presence of the management strategies with larger impacts in the MRA.

The top three influential management strategies obtained from the MRA were similar to the findings from the t-tests (Tables 6 and 7). The findings of the t-tests and MRA indicate that, in order to improve labor productivity, allocating resources to the dominant strategies, such as communication and incentives programs, is more effective than other strategies. Applying the findings can help construction management teams achieve significant savings on project costs by improving labor productivity and avoiding resource allocation to less-effective management strategies and practices. Even so, further investigation is required to explore the details, especially through different productivity measurement methods.

The findings of this research show that labor productivity can be improved through implementation of management strategies. The main contribution to the body of knowledge is that this research quantifies the effectiveness of a series of management strategies in improving labor productivity in general construction projects through a more comprehensive statistical approach that addresses the limitations of previous studies in this research area. This research effort reveals the importance of the investigated management strategies to construction practitioners and encourages them to pursue improvements. For construction management teams that are going to improve labor productivity, it is not necessary to enhance the implementation level of all the management strategies at the same time. This is especially important when there are limited resources available, which is common in general construction projects. In this situation, it is advised that the construction management team allocate available resources to the management strategies such as communication, incentive programs, and labor management that have been proven to have maximum impacts on labor productivity. Contractors can boost labor productivity by having an effective communication strategy in place on construction sites. Practices such as regular and effective communication on construction status with other project stakeholders and effective site communication among subcontractors and main contractors can significantly reduce delay and non-value-added activities on construction sites. Incentive programs have significant impacts on labor productivity (El-Gohary and Aziz 2014; Heravi and Eslamdoost 2015; Kazaz and Ulubeyli 2007). A combination of incentives including performance, safety, and quality incentives is more effective than performance-based incentives because they put the safety of laborers in jeopardy (Choudhry and Fang 2008). Applying recognition programs is another practice that can be applied by contractors to inspire enthusiasm among laborers. Nesan and Holt (1999) showed that construction laborers achieve outstanding performance in working environments in which recognition has been implemented by the management. They also found that recognition is more effective in motivating laborers when it is applied at a group level rather than an individual one.

A comparison between the findings in Table 4 and the results of the t-test and MRA (Tables 6 and 7) shows that currently construction managers fail to apply some of the effective management strategies and practices in their projects. While incentive programs and labor management are identified as the second and third most effective management strategies in improving labor productivity, construction managers have not implemented them frequently in their projects (Table 4). This could be the result of a lack of available evidence related to the effectiveness of these management strategies. Consequently, managers allocate resources and put effort into other less-effective management strategies rather than incentive programs and labor management strategies. The findings of this study provide sufficient empirical evidence for construction managers regarding the effectiveness of each management strategy, which will help them select and implement management strategies that will have the maximum impact on labor productivity.

The information available in Table 4 potentially can be used as a benchmark by construction management teams to compare their implementation of the management strategies with other construction projects that are participating in this research. For instance, after a project manager completes MSAI, if the implementation score of one or several of the management strategies is lower than the mean scores shown in Table 4, it indicates areas that require further improvement in order to achieve a higher labor productivity. To achieve a substantial improvement in labor productivity by a thorough high-level implementation of these management strategies, construction managers must aim to achieve at least 5% above the mean scores in Table 4.

Conclusion

To improve labor productivity in construction projects, the impacts of the management strategies for improving labor productivity must be identified and recognized. This research investigated the impacts of nine management strategies on labor productivity and identified

the effectiveness of these strategies in general construction projects. The results showed that construction projects with high implementation levels of the investigated management strategies have a better labor productivity than their peers with low-level implementation. Communication, incentives programs, and labor management were observed as having the strongest relationship with labor productivity in general construction projects. The results confirmed the capacity of MSAI in improving labor productivity and demonstrating the areas that require further improvements in general construction projects. The findings of this study can help practitioners to recognize and implement the most effective management strategies in order to improve labor productivity and maximize the utilization of the workforce.

There are limitations to this study as well. First, labor productivity was measured based on the perception of management. Although this method provided valuable findings, it is also associated with the limitations of subjective measurements. For future studies, different measurement methods should be applied to validate the findings of the current study. Furthermore, the scope of this study was limited to general construction projects in New Zealand. Further studies are necessary to investigate the same observed relationships in projects in different construction domains and locations. The current study applied only statistical methods to quantify the effectiveness of the management strategies in improving labor productivity. Since labor productivity was measured by a subjective method, different types of analysis such as analytical hierarchy or multiattribute utility theory can be used to provide further insight and validate the findings of this study. These structured methods can determine the priority level of the management strategies that were obtained from the statistical analysis.

Finally, construction projects with different types of operations (e.g., on-site or off-site operations) have different characteristics. Therefore, influencing factors can affect the level of labor productivity differently in different projects. At the same time, construction methods also affect labor productivity of different projects in different manners. Project managers therefore have the chance to improve labor productivity in their projects by using the right construction method that is in synergy with the available technology, material, and equipment. In this study, different types of operation (use of advanced construction methods) were investigated as a management strategy that can affect labor productivity. The impact of management practices such as lean construction, prefabrication, industrialization, and modularization were investigated in improving labor productivity in general construction projects. In future studies, labor productivities can be categorized and monitored in relation to the type of operation (construction method) such as industrialized building system (IBS) projects or modular projects. The objective will be to measure the impacts of each management strategy on labor productivity.

Acknowledgments

The authors acknowledge the National Science Challenge—Building Better, Homes, Towns and Cities (BBHTC) for supporting this research.

References

Abdul Kadir, M. R., W. P. Lee, M. S. Jaafar, S. M. Sapuan, and A. A. A. Ali. 2005. "Factors affecting construction labour productivity for Malaysian residential projects." *Struct. Surv.* 23 (1): 42–54. https://doi.org/10.1108/02630800510586907.

Adrian, J. J. 2004. *Construction productivity: Measurement and improvement.* Champaign, IL: Stipes Publishing.

Alaghbari, W., A. A. Al-Sakkaf, and B. Sultan. 2017. "Factors affecting construction labour productivity in Yemen." *Int. J. Constr. Manage.* https://doi.org/10.1080/15623599.2017.1382091.

Babyak, M. A. 2004. "What you see may not be what you get: A brief, nontechnical introduction to overfitting in regression-type models." *Psychosom. Med.* 66 (3): 411–421.

Badir, Y. F., M. R. Abdul Kadir, and A. H. Hashim. 2002. "Industrialized building systems construction in Malaysia." *J. Archit. Eng.* 8 (1): 19–23. https://doi.org/10.1061/(ASCE)1076-0431(2002)8:1(19).

Bernold, L. E., and S. M. AbouRizk. 2010. *Managing performance in construction.* Hoboken, NJ: John Wiley & Sons.

Birdi, K., C. Clegg, M. Patterson, A. Robinson, C. B. Stride, T. D. Wall, and S. J. Wood. 2008. "The impact of human resource and operational management practices on company productivity: A longitudinal study." *Pers. Psychol.* 61 (3): 467–501. https://doi.org/10.1111/j.1744-6570.2008.00136.x.

Box, G. E., W. G. Hunter, and J. S. Hunter. 1978. *Statistics for experimenters.* Hoboken, NJ: John Wiley & Sons.

Brandenburg, S. G., C. T. Haas, and K. Byrom. 2006. "Strategic management of human resources in construction." *J. Manage. Eng.* 22 (2): 89–96. https://doi.org/10.1061/(ASCE)0742-597X(2006)22:2(89).

Caldas, C. H., J.-Y. Kim, C. T. Haas, P. M. Goodrum, and D. Zhang. 2015. "Method to assess the level of implementation of productivity practices on industrial projects." *J. Constr. Eng. Manage.* 141 (1): 04014061. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000919.

Choudhry, R. M., and D. Fang. 2008. "Why operatives engage in unsafe work behavior: Investigating factors on construction sites." *Saf. Sci.* 46 (4): 566–584. https://doi.org/10.1016/j.ssci.2007.06.027.

Cohen, J. 1988. *Statistical power analysis for the behavioral sciences.* 2nd ed. Hillsdale, NJ: Lawrence Erlbaum.

Construction Sector Leaders Group. 2013. *Construction sector workforce plan for greater Christchurch.* Christchurch, New Zealand: Construction Strategy Group.

Court, P. F., C. L. Pasquire, G. F. Gibb, and D. Bower. 2009. "Modular assembly with postponement to improve health, safety, and productivity in construction." *Pract. Period. Struct. Des. Constr.* 14 (2): 81–89. https://doi.org/10.1061/(ASCE)1084-0680(2009)14:2(81).

Cox, R. F., R. R. A. Issa, and D. Ahrens. 2003. "Management's perception of key performance indicators for construction." *J. Constr. Eng. Manage.* 129 (2): 142–151. https://doi.org/10.1061/(ASCE)0733-9364(2003)129:2(142).

Dai, J., and P. M. Goodrum. 2012. "Generational differences on craft workers' perceptions of the factors affecting labour productivity." *Can. J. Civil Eng.* 39 (9): 1018–1026. https://doi.org/10.1139/l2012-053.

Dai, J., P. M. Goodrum, W. F. Maloney, and C. Srinivasan. 2009. "Latent structures of the factors affecting construction labor productivity." *J. Constr. Eng. Manage.* 135 (5): 397–406. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:5(397).

Department of Industry, Innovation and Science. 2015. *Australian Industry Report.* Canberra, ACT, Australia: Office of Chief Economist.

Diekmann, J. E., M. Krewedl, J. Balonick, T. Stewart, and S. Won. 2004. *Application of lean manufacturing principles to construction.* Research Rep. 191-11. Austin, TX: Construction Industry Institute, Univ. of Colorado at Boulder.

Doloi, H. 2008. "Application of AHP in improving construction productivity from a management perspective." *Constr. Manage. Econ.* 26 (8): 841–854. https://doi.org/10.1080/01446190802244789.

Donchev, D., and G. Ujhelyi. 2014. "What do corruption indices measure?" *Econ. Polit.* 26 (2): 309–331. https://doi.org/10.1111/ecpo.12037.

Durdyev, S., and J. Mbachu. 2011. "On-site labour productivity of New Zealand construction industry: Key constraints and improvement measures." *Constr. Econ. Build.* 11 (3): 18–33. https://doi.org/10.5130/ajceb.v11i3.2120.

El-Gohary, K. M., and R. F. Aziz. 2014. "Factors influencing construction labor productivity in Egypt." *J. Manage. Eng.* 30 (1): 1–9. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000168.

Enshassi, A., S. Mohamed, Z. A. Mustafa, and P. E. Mayer. 2007. "Factors affecting labour productivity in building projects in the Gaza Strip." *J. Civil Eng. Manage.* 13 (4): 245–254.

Gastwirth, J. L., Y. R. Gel, and W. Miao. 2009. "The impact of Levene's test of equality of variances on statistical theory and practice." *Stat. Sci.* 24 (3): 343–360. https://doi.org/10.1214/09-STS301.
Ghoddousi, P., and M. R. Hosseini. 2012. "A survey of the factors affecting the productivity of construction projects in Iran." *Technol. Econ. Dev. Econ.* 18 (1): 99–116. https://doi.org/10.3846/20294913.2012.661203.
Ghoddousi, P., O. Poorafshar, N. Chileshe, and M. R. Hosseini. 2015. "Labour productivity in Iranian construction projects: Perceptions of chief executive officers." *Int. J. Prod. Perform. Manage.* 64 (6): 811–830. https://doi.org/10.1108/IJPPM-10-2013-0169.
Goodrum, P. M., D. Zhai, and M. F. Yasin. 2009. "Relationship between changes in material technology and construction productivity." *J. Constr. Eng. Manage.* 135 (4): 278–287. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:4(278).
Grau, D., C. H. Caldas, C. T. Haas, P. M. Goodrum, and J. Gong. 2009. "Assessing the impact of materials tracking technologies on construction craft productivity." *Autom. Constr.* 18 (7): 903–911. https://doi.org/10.1016/j.autcon.2009.04.001.
Hair, J. F., R. E. Anderson, R. L. Tatham, and W. Black. 1998. *Multivariate data analysis.* 5th ed. Upper Saddle River, NJ: Prentice Hall.
Heravi, G., and E. Eslamdoost. 2015. "Applying artificial neural networks for measuring and predicting construction-labor productivity." *J. Constr. Eng. Manage.* 141 (10): 04015032. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001006.
Hoggarth, P. A., C. R. H. Innes, J. C. Dalrymple-Alford, and R. D. Jones. 2015. "Prediction of driving ability: Are we building valid models?" *Accid. Anal. Prev.* 77: 29–34. https://doi.org/10.1016/j.aap.2015.01.013.
Huang, A. L., R. E. Chapman, and D. T. Butry. 2009. *Metrics and tools for measuring construction productivity: Technical and empirical considerations*. Gaithersburg, MD: US Department of Commerce, National Institute of Standards and Technology, Office of Applied Economics.
Hughes, R., and D. Thorpe. 2014. "A review of enabling factors in construction industry productivity in an Australian environment." *Constr. Innov.* 14 (2): 210–228. https://doi.org/10.1108/CI-03-2013-0016.
Jahedi, S., and F. Méndez. 2014. "On the advantages and disadvantages of subjective measures." *J. Econ. Behav. Organ.* 98: 97–114. https://doi.org/10.1016/j.jebo.2013.12.016.
Jarkas, A. M., R. A. Al Balushi, and P. K. Raveendranath. 2015. "Determinants of construction labour productivity in Oman." *Int. J. Constr. Manage.* 15 (4): 332–344. https://doi.org/10.1080/15623599.2015.1094849.
Jarkas, A. M., and C. G. Bitar. 2012. "Factors affecting construction labor productivity in Kuwait." *J. Constr. Eng. Manage.* 138 (7): 811–820. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000501.
Jarkas, A. M., and M. Radosavljevic. 2013. "Motivational factors impacting the productivity of construction master craftsmen in Kuwait." *J. Manage. Eng.* 29 (4): 446–454. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000160.
Jergeas, G. 2009. *Improving construction productivity on Alberta oil and gas capital projects.* A Report Submitted to: Alberta Finance and Enterprise. Edmonton, AB, Canada: Univ. of Calgary. Accessed March 10, 2015. http://www.albertacanada.com/files/albertacanada/improving_construction_productivity.pdf.
Jergeas, G., and J. Van der Put. 2001. "Benefits of constructability on construction projects." *J. Constr. Eng. Manage.* 127 (4): 281–290. https://doi.org/10.1061/(ASCE)0733-9364(2001)127:4(281).
Kaming, P. F., P. O. Olomolaiye, G. D. Holt, and F. C. Harris. 1997. "Factors influencing construction time and cost overruns on high-rise projects in Indonesia." *Constr. Manage. Econ.* 15 (1): 83–94. https://doi.org/10.1080/014461997373132.
Kazaz, A., E. Manisali, and S. Ulubeyli. 2008. "Effect of basic motivational factors on construction workforce productivity in Turkey." *J. Civil Eng. Manage.* 14 (2): 95–106. https://doi.org/10.3846/1392-3730.2008.14.4.
Kazaz, A., and S. Ulubeyli. 2007. "Drivers of productivity among construction workers: A study in a developing country." *Build. Environ.* 42 (5): 2132–2140. https://doi.org/10.1016/j.buildenv.2006.04.020.
Klanac, G. P., and E. L. Nelson. 2004. "Trends in construction lost productivity claims." *J. Prof. Issues Eng. Educ. Pract.* 130 (3): 226–236. https://doi.org/10.1061/(ASCE)1052-3928(2004)130:3(226).
Liberda, M., J. Ruwanpura, and G. Jergeas. 2003. "Construction productivity improvement: A study of human, management and external issues." In *Proc., Construction Research Congress: Wind of Change: Integration and Innovation*, edited by K. R. Molenaar and P. S. Chinowsky, 1–8. Honolulu, HI: Construction Research Council of the Construction Institute of ASCE; Engineering and Management Program, Univ. of Colorado at Boulder.
Liu, M., G. Ballard, and W. Ibbs. 2011. "Work flow variation and labor productivity: Case study." *J. Manage. Eng.* 27 (4): 236–242. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000056.
Mendenhall, W., T. Sincich, and N. S. Boudreau. 1996. *A second course in statistics: Regression analysis*. Vol. 5. Upper Saddle River, NJ: Prentice Hall.
Mojahed, S., and F. Aghazadeh. 2008. "Major factors influencing productivity of water and wastewater treatment plant construction: Evidence from the deep south USA." *Int. J. Proj. Manage.* 26 (2): 195–202. https://doi.org/10.1016/j.ijproman.2007.06.003.
Muijs, D. 2010. *Doing quantitative research in education with SPSS.* 2nd ed. London: Sage.
Naoum, S. G. 2016. "Factors influencing labor productivity on construction sites: A state-of-the-art literature review *and a survey." Int. J. Prod. Perform. Manage.* 65 (3): 401–421. https://doi.org/10.1108/IJPPM-03-2015-0045.
Nasir, H. 2013. "Best Productivity Practices Implementation Index (BPPII) for Infrastructure Projects." Ph.D. thesis, Dept. of Civil and Environmental Engineering, Univ. of Waterloo, Canada. Accessed, March 1, 2015. http://hdl.handle.net/10012/7731.
Nasir, H., C. T. Haas, C. H. Caldas, and P. M. Goodrum. 2015. "An integrated productivity-practices implementation index for planning the execution of infrastructure projects." *J. Infrastruct. Syst.* 22 (2): 04015022. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000275.
Nasirzadeh, F., and P. Nojedehi. 2013. "Dynamic modeling of labor productivity in construction projects." *Int. J. Proj. Manage.* 31 (6): 903–911. https://doi.org/10.1016/j.ijproman.2012.11.003.
Nesan, L. J., and G. D. Holt. 1999. *Empowerment in construction: The way forward for performance improvement.* Baldock, England: Research Studies Press.
O'Connor, J. T., and L.-R. Yang. 2004. "Project performance versus use of technologies at project and phase levels." *J. Constr. Eng. Manage.* 130 (3): 322–329. https://doi.org/10.1061/(ASCE)0733-9364(2004)130:3(322).
Page, I., and D. Norman. 2014. *Prefabrication and standardisation potential in buildings*. Study Rep. 312. Porirua, New Zealand: BRANZ.
Panas, A., and J. Pantouvakis. 2010. "Evaluating research methodology in construction productivity studies." *Built Hum. Environ. Rev.* 3 (1): 63–85.
Park, H.-S. 2006. "Conceptual framework of construction productivity estimation." *KSCE J. Civil Eng.* 10 (5): 311–317. https://doi.org/10.1007/BF02830084.
Park, H.-S., S. R. Thomas, and R. L. Tucker. 2005. "Benchmarking of construction productivity." *J. Constr. Eng. Manage.* 131 (7): 772–778. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:7(772).
Rojas, E. M., and P. Aramvareekul. 2003. "Labor productivity drivers and opportunities in the construction industry." *J. Manage. Eng.* 19 (2): 78–82. https://doi.org/10.1061/(ASCE)0742-597X(2003)19:2(78).
Shan, Y., P. M. Goodrum, D. Zhai, C. Haas, and C. H. Caldas. 2011. "The impact of management practices on mechanical construction productivity." *Constr. Manage. Econ.* 29 (3): 305–316. https://doi.org/10.1080/01446193.2010.538070.
Shan, Y., D. Zhai, P. M. Goodrum, C. T. Haas, and C. H. Caldas. 2015. "Statistical analysis of the effectiveness of management programs in improving construction labor productivity on large industrial projects." *J. Manage. Eng.* 32 (1): 04015018. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000375.
Shehata, M. E., and K. M. El-Gohary. 2011. "Towards improving construction labor productivity and projects' performance." *Alex. Eng. J.* 50 (4): 321–330. https://doi.org/10.1016/j.aej.2012.02.001.

Soekiman, A., K. S. Pribadi, B. W. Soemardi, and R. D. Wirahadikusumah. 2011. "Factors relating to labor productivity affecting the project schedule performance in Indonesia." *Procedia Eng.* 14: 865–873. https://doi.org/10.1016/j.proeng.2011.07.110.

Song, L., and S. M. AbouRizk. 2008. "Measuring and modeling labor productivity using historical data." *J. Constr. Eng. Manage.* 134 (10): 786–794. https://doi.org/10.1061/(ASCE)0733-9364(2008)134:10(786).

Statistics New Zealand. 2015. "Gross Domestic Product: March 2015 quarter." Accessed February 10, 2015. https://www.stats.govt.nz/browse_for_stats/economic_indicators/gdp/grossdomesticproduct_HOTPMar15qtr.aspx.

Tam, C. M., V. W. Y. Tam, J. K. W. Chan, and W. C. Y. Ng. 2005. "Use of prefabrication to minimize construction waste—a case study approach." *Int. J. Constr. Manage.* 5 (1): 91–101. https://doi.org/10.1080/15623599.2005.10773069.

Thomas, H. R., and M. J. Horman. 2006. "Fundamental principles of workforce management." *J. Constr. Eng. Manage.* 132 (1): 97–104. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:1(97).

Thomas, H. R., M. J. Horman, R. E. Minchin, Jr., and D. Chen. 2003. "Improving labor flow reliability for better productivity as lean construction principle." *J. Constr. Eng. Manage.* 129 (3): 251–261. https://doi.org/10.1061/(ASCE)0733-9364(2003)129:3(251).

Thomas, H. R., W. F. Maloney, R. M. W. Horner, G. R. Smith, V. K. Handa, and S. R. Sanders. 1990. "Modeling construction labor productivity." *J. Constr. Eng. Manage.* 116 (4): 705–726. https://doi.org/10.1061/(ASCE)0733-9364(1990)116:4(705).

Tsehayae, A. A., and A. Robinson Fayek. 2014. "Identification and comparative analysis of key parameters influencing construction labour productivity in building and industrial projects." *Can. J. Civil Eng.* 41 (10): 878–891. https://doi.org/10.1139/cjce-2014-0031.

Wall, T. D., J. Michie, M. Patterson, S. J. Wood, M. Sheehan, C. W. Clegg, and M. West. 2004. "On the validity of subjective measures of company performance." *Pers. Psychol.* 57 (1): 95–118. https://doi.org/10.1111/j.1744-6570.2004.tb02485.x.

Yi, W., and A. P. C. Chan. 2014. "Critical review of labor productivity research in construction journals." *J. Manage. Eng.* 30 (2): 214–225. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000194.