AN INVESTIGATION INTO CONSTRUCTION MANAGEMENT PRACTICES INFLUENCING LABOUR PRODUCTIVITY IN MULTI-STOREY BUILDING PROJECTS

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ABSTRACT

Productivity improvement in construction projects is essential for the economic growth of a country, for increasing the profit margin of contractors and for reducing the project delays and the related consequences such as liquidated damages. Previous studies indicate that management related problems are negatively influencing labour productivity in construction projects. However, understanding the management practices which are suitable for improving productivity in specific project type in a certain location, planning the appropriate practices, monitoring the implementation of the planned practices, and assessing whether the implemented practices are associated with high or low productivity can help to increase productivity. Previous studies identified the best practices for increasing productivity in infrastructure and industrial construction projects in North America. However, it is possible that none of these practices is suitable to enhance productivity in multi-storey building construction projects in Australia as the management practices and their effectiveness would depend on the context such as differences in the resources supply chain within the local market, local regulatory requirements and project types. Furthermore, there is little or no research conducted on what these practices might be and which of them are the most important in the context of multi-storey building projects in Victoria, state Australia. Also, no research has been conducted on how the management practices that could enhance productivity in multi-storey building projects are measured, planned, monitored and evaluated. Additionally, no tool has been developed to predict a productivity value or a probability of exceeding a certain productivity value when the levels of planning of the management practices are known.

The purpose of this research is to identify the management practices that have the potential to improve productivity in multi-storey building construction projects, refine and validate scoring tools for measuring, planning, controlling and evaluating the practices in the context of building projects, and develop a tool for predicting the probability of exceeding a baseline productivity factor when the levels of planning of the management practices are determined. The research adopted a two-phase exploratory sequential mixed methods design. During Phase-I, in-depth interviews were conducted with 19 experts who have been involved in the delivery of multi-storey building projects. The qualitative data was analysed, construction management practices that have the potential to improve productivity were identified, and the unweighted scoring tools for the practices were prepared. In Phase-II, quantitative data was collected from 39 principal contractors on 39 projects using questionnaires. During stage I of the quantitative data analysis, the data collected from the 39 principal contractors' experts regarding the relative importance of the practices in enhancing the productivity of multi-storey building projects were analysed to prioritise the practices identified in Phase I, and on that basis, the weighted scoring tools were prepared. During stage II of the quantitative data analysis, the data collected from the 39 multi-storey building projects were analysed to validate the scoring tools and to develop as well as validate the logistic regression model for predicting the probability of exceeding baseline productivity factor using a sigmoid graph when the scores of the practices are known.

Overall, 47 construction management practices that have the potential to improve productivity in multi-storey building projects in the context of Victoria state, Australia have been identified and prioritised. The practices 'well-defined scope of works,' 'safety and health policy,' and 'safety and health plan' are found to be the three most important practices. The findings of the correlation analyses revealed that all the 47 construction management practices are positively associated with productivity. The output of linear regression analysis also indicated that there is a positive and statistically significant relationship between productivity and the management practices. The findings of Friedman test showed that the practices 'well-defined scope of work,' 'safety and health policy,' 'safety and health plan,' 'hazard analysis,' 'long-lead materials identification,' 'safe work method statement' and 'toolbox safety meetings' are equally important to improve productivity in multi-storey building projects. The study revealed that high levels of implementation of the construction management practices are associated with low levels of project delays. The use of practices also varied according to the project costs.

Long-lead materials identification, procurement plans for materials, and materials delivery schedule are found to be the three most important construction materials management practices. Construction equipment maintenance, construction equipment procurement plan, and construction equipment productivity analysis are identified as the three construction equipment management practices. Traffic control plan, project start-up plan, machinery positioning strategy, project completion plan, and dynamic site layout plan are found to be the top five practices which are related to construction methods. Well-defined scope of work, short interval plan, buildability review, construction work packages, and regulatory requirement are found to be the five most important pre-construction phase management practices. Clear delegation of responsibility, stability of organizational structure, and crew composition are found to be the three most important human resource management practices. Finally, safety and health policy, safety and health plan, and hazard analysis are the three most important safety and health practices.

The scoring tools which can be used to measure, plan, monitor and evaluate the management practices have been refined and validated. Thus, the scoring tools for construction materials management practices, construction equipment management practices, pre-construction phase management practices, management practices related to construction methods, human resource management practices, and safety and health practices are prepared and validated. The baseline scores against which the users of the scoring tools assess the adequacy of their practices have been determined and validated. The baseline scores can be used as benchmarks to evaluate if the planned or implemented management practices on a certain multi-storey building project would be associated with high or low productivity. Hence, the baseline scores for the overall management practices, construction materials management practices, construction equipment management practices, pre-construction phase management practices, management practices related to construction methods, human resource management practices, and safety and health practices are set.

Logistic regression models that can be used for predicting the probability of exceeding baseline productivity factors are built and validated. The associated sigmoid graphs have been developed to determine the corresponding probabilities when the scores of the construction management practices are known. Thus, the logistic regression models for predicting the probability of exceeding baseline productivity factors based on the aggregated scores of the construction management practices as well as based on the scores of construction materials management practices, construction equipment management practices, preconstruction phase management practices, management practices related to construction methods, human resource management practices, and safety and health practices are built and validated. Additionally, linear regression models which are used to predict the productivity factors of multi-storey building projects based on the scores of the construction management practices are developed and validated.

The study has practical implications. Contractors involved in the construction of multi-storey buildings in Victoria state, Australia can implement the identified practices to enhance productivity in their projects. They can also measure their management practices and evaluate whether their practices are adequate or not. Furthermore, the contractors can use the probability-based predictive model to assess the risk of low productivity for specific levels of implementations of the construction management practices. During the project planning phase, the management practices scoring tools can be used to plan appropriate practices which can be implemented to potentially increase productivity. Moreover, the productivity predicting tools can be used to estimate the productivity of a certain multi-storey building project based on the levels of planning of the management practices. By using the estimated productivity, the likelihood of occurrence of project delays can be predicted, and corrective actions can be taken prior to commencing the construction of the project. During the construction phase, the scoring tools can be used to control the implementation of the planned practices. Finally, during the project closure phase, the scoring tools can be used to evaluate whether the implemented practices are associated with the predicted productivity. If not, lessons can be learnt, and suitable practices can be planned for future projects.

This research contributes to the body of knowledge in construction management by identifying and prioritising the management practices which are suitable to enhance labour productivity in multi-storey building construction projects. The findings of the study can facilitate international comparisons as well as sectoral comparison and provide useful information for future researchers and companies seeking construction works in Australia. This study also contributes to the growth accounting framework (neoclassical economic growth theory) by investigating the under-researched areas of the drivers of labour productivity. The technological advancement and capital deepening are the two main factors which were explained by the theory. However, the theory did not provide an in-depth explanation of the management practices. This research increases the understanding of the importance of the management practices for increasing labour productivity in the context of multi-storey building projects.

DECLARATION

This is to certify that:

- the thesis comprises only my original work towards the PhD except where indicated in the Preface,
- due acknowledgement has been made in the text to all other material used,
- the thesis is fewer than 100 000 words in length, exclusive of tables, maps, bibliographies and appendices.

Argaw Tarekegn Gurmu
December 2017

LIST OF PUBLICATIONS

The following papers have been drawn from this PhD thesis and published in peer-reviewed journals and conferences. Parts of these papers appear in different chapters of this thesis.

Journal Articles

Gurmu, A. T., and Aibinu, A. A. (2017), "Investigation of Construction Equipment Management Practices for Improving Labour Productivity in Multi-Storey Building Construction Projects", *Journal of Construction Engineering and Management,* Vol. 143 No. 10, pp. 0401708.

Gurmu, A. T., and Aibinu, A. A. (20xx), "Survey of Management Practices Enhancing Labour Productivity in Multi-Storey Building Construction Projects", *International Journal of Productivity and Performance Management*. (Accepted, please refer Appendix-9B for acceptance letter).

Gurmu, A. T., Aibinu, A. A. and Chan, T. K. (2016), "A study of best management practices for enhancing productivity in building projects: construction methods perspectives", *Construction Economics and Building,* Vol. 16 No. 3, pp. 1-19. (Please refer Appendix-9C).

Conference Papers

Gurmu, A. T., Aibinu, A. A. and Chan, T. K. (2016), "An investigation into construction methods influencing productivity of building projects", *in Systems engineering test and evaluation conference (SETE), 2016*, Engineers Australia, pp. 17.

Gurmu, A. T., Aibinu, A. A. and Chan, T. K. (2016), "Construction Management Practices Influencing Productivity in Building Projects", *in Proceedings of the 5th World Construction Symposium, 2016*, University of Moratuwa, Sri Lanka, pp. 122-132.

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CHAPTER ONE

1 INTRODUCTION

1.1 Introduction

This chapter presents an introduction to the thesis and consists of ten sections. The background of the research is described in Section 1.2. The research problems are stated in Section 1.3, and the research questions are presented in Section 1.4. The objectives of the research are described in section 1.5. The knowledge gap is explained in Section 1.6. In Section 1.7, the research design and methodology is highlighted. The significance of the study is summarised in section 1.8. The structure of the thesis is indicated in section 1.9. Finally, the summary of the chapter is presented in Section 1.10.

1.2 Research Background

The construction industry makes a significant contribution to the economy of a country. In Australia, the industry comprised 8.29% of the annual gross value added (GVA) in the year 2015 making it a significant contributor to the economy (Australian Bureau of Statistics, 2016a). The proportions of the contributions of different industries to Australia’s annual GVA from 2010 to 2015 is indicated in Figure 1-1. Accordingly, in the years 2011, 2012 and 2013 the construction industry was the second major contributor, and in the years 2010, 2014 and 2015 the industry was the third largest contributor.

Despite its significance, the productivity growth of the industry is low. According to the Australian Productivity Commission (2015) report, in the year 2013-14, the labour productivity growth for the total economy was 1.4% whereas the labour productivity growth in the construction industry was -1.0%. The report also indicated that multifactor productivity in construction industry declined but only marginally. Thus, the labour productivity growth rate was low when compared to multi-factor productivity. Multifactor productivity is measured as output per unit of combined inputs of labour and capital, while labour productivity is measured as output per unit of labour input in ‘hours worked’ (Productivity Commission, 2013). In most construction productivity studies conducted at the project level, the term productivity and labour productivity are used interchangeably. El-Gohary and Aziz (2014) explained that in construction, productivity usually refers to labour productivity. In this research, the term productivity refers to the labour productivity at the construction project level.

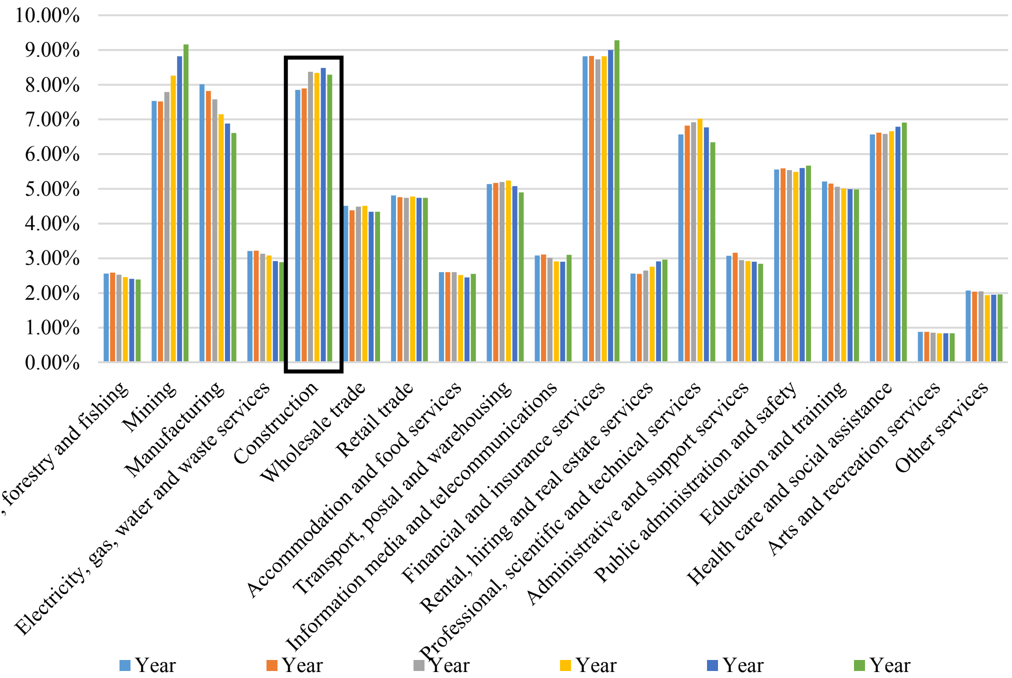


Figure 1-1 Shares of GVA of Various Industries in Australia (Plotted using data obtained from Australian Bureau of Statistics (2016a))

Enhancing the productivity of construction projects is essential for increasing the profit margins of contractors, for reducing the possibility of the construction project delays, and for economic growth of a country. The occurrence of the project delays could lead to liquidated damage or the financial penalty due to the late delivery of the construction projects by the contractors. According to the Australian Standards' general conditions of contract AS 2124-1992 Clause 35.6, if a contractor fails to complete a project by the practical completion date, then the contractor shall be indebted to the project owner for the liquidated damages at the rate specified in the appendix part of a specific contract (Standards Australia, 2000). The rate could be some percentage of the project cost, for instance, 0.1% of project cost per day, or a lump sum amount such as $AUD1000 per day. The improvement in project level productivity can also increase the industry level productivity which in turn leads to the economic growth of Australia. The study conducted by PWC (2013) indicated that increasing Australian construction industry productivity by 1% could result in the national benefit of 1.252 billion Australian Dollars (AUD).

1.3 Statement of the Problem

To date, there is no systematic and established tool for planning, monitoring and evaluating the management practices that have the potential to improve productivity in multi-storey building construction projects. During project planning phase, contractors involved in the construction of multi-storey building projects can use the tool for planning appropriate practices that should be implemented to potentially enhance productivity in their projects. During the construction phase, they can use the tool for monitoring whether the planned practices are adequately implemented or not. If not, corrective actions will be taken to reduce the loss of productivity related to the management of the projects. Moreover, during the project completion phase, the contractors can use the tool to evaluate whether the implemented practices are associated with higher or lower productivity. If the productivity is low, then lessons can be learned from the past project, and suitable practices will be planned for a new project.

In multi-storey building construction projects in Victoria State, Australia, understanding what the management practices are, planning the appropriate practices, monitoring the implementation of the planned practices, and assessing whether the implemented practices are associated with high or low productivity can help to increase productivity. Previous researchers in Australian context reported the loss of productivity due to management-related problems. Hughes and Thorpe (2014) identified rework, lack of materials and overcrowding as some of the major productivity deterrents. However, knowing the management practices that could enhance productivity, and being able to plan and control them could reduce the negative effects of the loss of productivity such as project delay, liquidated damage, and reduction in profit margins of contractors. For example, the practice ‘preparation of dynamic site layout’ can reduce overcrowding and contractors can prepare site layout plans that are suitable for different phases of construction such as excavation, structure, and site works. Similarly, rework due to changes in design can be reduced by adopting and controlling the implementation of the essential practices such as ‘buildability review.’ In Australian construction projects, Love (2001) estimated that the mean direct and indirect costs associated with rework are 6.4% and 5.6% of contract value respectively. The loss of productivity associated with lack of materials can also be minimised by implementing practices such as ‘long-lead materials identification.' If the long-lead materials are not identified during preconstruction phase, the productivity of a project can be reduced due to shortage of materials. In the context of Australia, as most construction materials are imported from overseas, missing the implementation of the practice 'long-lead materials identification' can lead to project delay and additional costs associated with the delay. The procurement and delivery of the critical materials could take longer time and projects can be delayed. Thus, identifying and prioritising the management practices, and preparing a method to measure, plan, monitor and evaluate the practices in the context of multi-storey building projects is essential for enhancing the productivity of the projects.

Additionally, during project planning phase, means of assessing the probability of exceeding baseline productivity based on a measured value of the construction management practices is not developed. The implementation of adequate or higher levels of the practices can help to increase the probability of achieving higher levels of productivity whereas the implementation of inadequate or lower level of the practices decreases the probability of attaining higher levels of productivity. Thus, developing a tool which can be used to estimate this probability is essential. Knowing the probability of achieving higher productivity levels can help construction project managers to plan for the implementation of appropriate practices on a proposed multi-storey building project. For instance, if the chance of having a productivity that exceeds the baseline productivity is low, then the project managers can make the decision to increase the proposed level of implementation of the practices to increase the chances of having an associated higher level of productivity.

1.4 Research Questions

To address the problems described in the previous section, this research is designed to answer the following questions.

RQ1: What are the management practices that have the potential to improve productivity in multi-storey building construction projects in the context of Victoria State, Australia?

RQ2: Which management practices are the most important to enhance productivity in multi-storey building construction projects?

RQ3: How can the management practices that have the potential to improve productivity in multi-storey building construction projects be measured, planned, and controlled?

RQ4: What tool can be used for predicting the probability of exceeding baseline productivity factor based on a score of the management practices?

1.5 Research Objectives

The main objectives of this research are:

1) To identify and prioritise the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia.
2) To refine and validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects.
3) To build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices.

1.6 Rationale for the Research

1.6.1 Lack of Techniques of Integrating Productivity and the Level of Implementation of the Management Practices

Although previous studies have developed tools for measuring construction management practices for industrial and infrastructure projects (CII, 2013a, CII, 2013b), the existing tools do not integrate probability function when assessing productivity levels based on the known level of planning or implementation of the practices. Thus, users of the existing scoring tool have no means of assessing or forecasting the probability of exceeding a baseline productivity factor based on the implementation of the construction management practices. For instance, the baseline score for the management practices that have the potential to enhance productivity in industrial projects in North America is found to be 65% or 1300 points out of maximum 2000 points (Caldas et al., 2014). However, the users of this tool can only assess whether their scores are lower or higher than the baseline score. They cannot assess whether their scores would lead to high or low productivity as compared to baseline productivity. The method which can be used to compute the probability of exceeding baseline productivity factor is not developed by previous researchers.

1.6.2 Lack of Method of Measuring, Planning, Monitoring and Evaluating the Management Practices in Building Construction Projects

Previous researchers have developed two different techniques to measure management practices in the context of industrial and infrastructure construction projects (CII, 2013a, CII, 2013b, Nasir, 2013). However, no tool has been developed to measure, plan, monitor and evaluate the management practices for building projects. The existing measurement tools cannot be applied to building projects in Australia because the practices for enhancing productivity in multi-storey building projects could be different and the relative weight assigned to each practice would be different as well. The findings of the previous studies confirmed that the management practices scoring tools vary based on the type of projects, and they cannot be used interchangeably (Nasir et al., 2015, Caldas et al., 2014, CII, 2013a, CII, 2013b).

1.6.3 Dearth of Research Identifying Management Practices Having Potential to Enhance Productivity in Building Projects

Previous studies identified the best practices that could improve productivity in infrastructure and industrial construction projects in North America (Caldas et al., 2014, Nasir et al., 2015). However, it is possible that none of these practices is appropriate for improving productivity in multi-storey building construction projects. Also, management practices and their effectiveness would depend on the context such as differences in the resources supply chain, local regulatory requirements and project type (Bloom and Van Reenen, 2010). Thus, management practices for improving productivity would vary across project types and from country to country. It may also vary across different Australian construction markets. For instance, the use of control system for tool delay is found to be one of the management practices that could enhance productivity in industrial projects, but the practice is not applicable to infrastructure projects (Caldas et al., 2014). Similarly, construction equipment utility requirement has been identified as the practice that could improve productivity in infrastructure projects but not for industrial projects (Nasir et al., 2015). Furthermore, while traffic control plan, project completion plan, and communications, coordination and agreements are identified as the best practices for enhancing productivity in infrastructure construction projects, they are not included in the list of best practices for industrial construction projects in North America (Caldas et al., 2014, Nasir et al., 2015). Moreover, the priority given to the management practices that are suitable for both project types is different.

Thus, projects are not homogeneous when considering management practices that have the potential to enhance their productivity. This study departs and extends existing research in the area by focusing on multi-storey building projects in Victoria State, which is the second largest construction market in Australia (Australian Bureau of Statistics, 2016b). There is little, or no research has been conducted on what these practices might be and which of them are the most important in the context of multi-storey building projects in Australia. Therefore, an investigation of management practices which are suitable for improving productivity in multi-storey building construction projects is essential.

1.7 Research Design and Methodology

This study adopted exploratory sequential mixed-methods research design involving a combination of qualitative and quantitative data in two phases. The mixed-methods research design can be classified into three categories: convergent parallel, explanatory sequential and exploratory sequential (Creswell, 2013). In convergent parallel mixed methods, the researcher collects both qualitative and quantitative data, analyses them separately, and then compares the results to see if the findings confirm or disconfirm each other. Explanatory sequential mixed-methods involves a two-phase project in which the researcher collects quantitative data in the first phase, analyses the results, and then uses the results to plan or build on to the second qualitative phase. In exploratory sequential mixed-methods, the researcher first begins by exploring with qualitative data and then uses the findings in a second quantitative phase. The qualitative phase may be used to build an instrument that best fits the sample under study, to identify appropriate instruments to use in the follow-up quantitative phase or to specify variables that need to go into a follow-up quantitative study (Creswell, 2013). In this research, the exploratory sequential mixed-methods is used because construction management practices identified by previous studies might not be applicable to the Victorian construction industry and there could be other practices that are specific to the local industry. Thus, exploratory study is conducted first by collecting and analysing qualitative data obtained from interviews during the first phase. On the basis of the qualitative data, appropriate management practices are identified, and their levels of implementations are refined to suit the multi-storey building construction projects. To investigate the relationship between productivity and the practices, assign the weights to the management practices, validate the management practices scoring tools in the context of the multi-storey building projects, and develop as well as validate the productivity predicting tools, the quantitative data is collected and analysed during Phase II of the research.

To address part of objective 1 which is “to identify the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia,” data relating to the management practices were collected in Phase 1 using interviews. Nineteen professionals who have experience in delivering multi-storey building projects in Victoria were interviewed. They have a five to forty years work experience and have been working as general manager, construction manager, project manager, project coordinator, project engineer, site engineer, contract administrator, supervisor and cost manager. Finally, the qualitative data analysis reached a saturation point, and management practices that have the potential to improve productivity in multi-storey construction building projects were identified. During Phase I, part of objective 2 or “to refine the scoring tools” was also achieved. The implementation levels of the identified practices were refined, and unweighted scoring tools were prepared. The outputs of the first phase were used as an input to the second phase.

The quantitative data were collected and analysed to address part of objective 1 or “ to prioritize the practices,” part of objective 2 or “ to validate the scoring tools” and objective 3 of the study which is “to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices.” The quantitative data were collected using interview questionnaire survey whereby the survey was self-administered. Respondents were asked the questions face-to-face and requested to write their answers (Fowler Jr and Cosenza, 2009). The approach can increase the response rate, and in this study, it allowed the researcher to clarify issues during the interview survey. The data were collected from principal contractors’ experts and multi-storey building projects which were completed between 2011 and 2016 in the state of Victoria, Australia. The first part of the survey data was analysed using relative importance index technique, the construction management practices were prioritised, the weight proportions for the levels of implementation of the practices were computed, and weighted scoring tools were prepared. The second part of the survey data was analysed, and the scoring tools were validated. Correlation analysis was conducted, and the relationship between productivity and the practices was investigated. Linear and logistic regression analyses were carried out, and the tools which can be used for predicting productivity factors and the probability of exceeding baseline productivity factors based on the score of the management practices were developed and validated.

1.8 Significance of the Research

This study contributes to the neoclassical economic growth theory by investigating the under-researched aspect of the theory. As shown in Figure 1-2, technological advancement, capital deepening and management practices are the drivers of labour productivity. The first two factors are explained in-depth by the theory. The growth accounting framework, which is based on the neoclassical economic theory, proposes that management practices could improve labour productivity. However, the theory does not explain the management practices in detail. For instance, which practices, in which context, could enhance labour productivity is not studied. Thus, this research helps to increase the understanding of the types of practices that can be implemented to increase labour productivity in the context of multi-storey building construction projects.

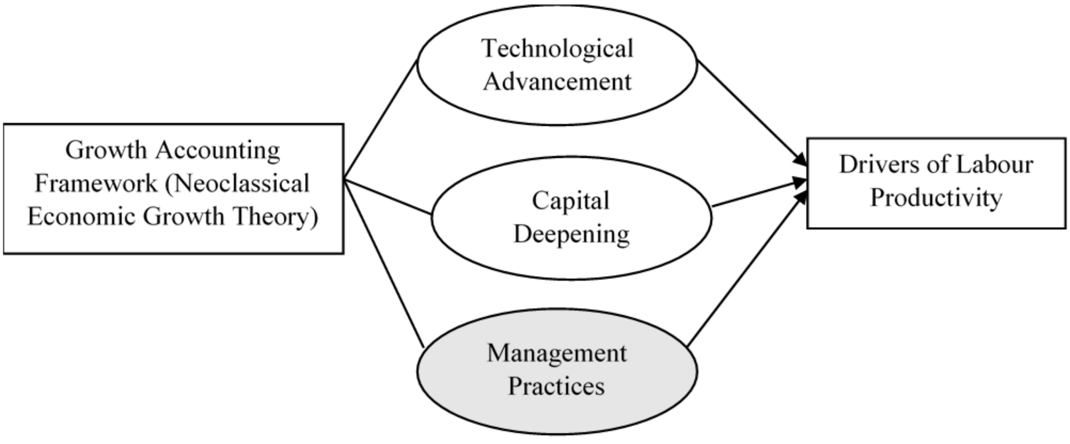


Figure 1-2 The Contribution of the Research to a Theory

This study also contributes to the body of knowledge in construction management by identifying and prioritising the management practices that are suitable to enhance productivity in multi-storey building projects. The findings of the research can be used as international and sectoral comparisons and provide useful information for future researchers and companies seeking construction works in Australia. Contractors involved in the construction of multi-storey buildings in Victoria State, Australia can implement the identified practices to enhance productivity in their projects. As a result of the improvement in the projects' productivity, the productivity of Australian construction industry will increase which in turn can lead to the growth in the economy of the country. During the project planning phase, the management practices scoring tools can be used to plan appropriate practices which can be implemented to potentially increase productivity. Moreover, the productivity predicting tools can be used to estimate the productivity of a certain multi-storey building project based on the levels of planning of the management practices. By using the estimated productivity, the likelihood of occurrence of project delays can be predicted, and corrective actions can be taken prior to commencing the construction of the project.

The finding of the study is applicable to multi-storey building construction projects in Victoria State, Australia. It can also be adopted by contractors involved in building construction projects in other countries. However, validation is required as management practices might vary from country to country.

1.9 Thesis Structure

This thesis comprises of ten chapters. In Chapter 1, the background of the research, statement of the problem, research questions, objectives of the research, rationale for the research, research design and methodology, significance of the study and thesis structure are presented. In the second chapter, a systematic review of literature is conducted to identify the knowledge gap, the main features of the Victorian construction industry (the context of the study) and factors influencing the productivity of construction projects in Australia as well as in the international contexts are reviewed. Chapter 3 provides the conceptual frameworks of the study. In this chapter, the neoclassical economic growth theory (growth accounting framework) is reviewed, and the preliminary conceptual frameworks of productivity and the construction management practices are developed. The fourth chapter presents the research design, the research approach, and methods of data collection and analysis during both phases of the study. In Chapter 5, the analysis of the qualitative data collected during the first phase of the research answers RQ1. The context-specific management practices that have the potential to improve productivity in multi-storey building construction projects are identified, the implementation levels of the identified practices are refined to suit Victorian construction industry, and on that basis, unweighted scoring tools are prepared.

In the sixth chapter, the preliminary quantitative data has been analysed. The background of respondents is described, productivity factors of the projects are calculated, and the descriptive data analysis of the management practices is carried out. In Chapter 7, the analysis of the data collected during Phase II of the study answers RQ2 and RQ3.The quantitative data is analysed, the weights of the management practices are computed, the weighted scoring tools are prepared and validated, and the relationship between productivity and the management practices is investigated. Chapter 8 provides an answer to RQ4. The linear and logistic regression analyses are conducted, and the tools which can be used for predicting productivity based on a score of the management practices are built and validated. Chapter 9 presents the discussions of the findings of the study. Chapter 10 concludes the thesis by summarising the key findings of the study. The theoretical and practical implications of the research are also presented in Chapter 10. Following the list of references, supplementary information such as questionnaire and raw data used in the quantitative and qualitative data analysis are presented in the Appendix part of the thesis.

1.10 Summary

The purpose of this study is to identify and prioritise the management practices that have the potential to increase productivity in multi-storey building projects in Victoria State, Australia. Furthermore, the study is designed to refine tools which can be used for measuring the practices and predicting the productivity of a multi-storey building project based on a score of the practices. Identification and measurement of the practices are essential for the improvement of productivity. Contractors involved in multi-storey building construction projects can use the scoring tools to assess the adequacy of their practices and take corrective actions to potentially enhance productivity. The scoring tools can be used during planning, construction and completion phases of a project to plan, monitor, and evaluate the management practices respectively. The productivity and probability prediction tools can also be used during the project planning phase to help contractors' project managers to plan appropriate practices. This chapter presented the research background, statement of the problem, research questions, research objective, rationale for the study, a summary of research design and methodology, the significance of the research, and the thesis structure. The review of the relevant literature is presented in the next chapter.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

This chapter presents the comprehensive review of the literature to support the argument described in Chapter 1. It specifically describes the fields of knowledge that are related to the rationale part of this research. The chapter starts by describing the context of the study. The features of the construction industry of the Victoria State, Australia are explained and a multi-storey building project is defined in Section 2.2. A systematic review of the literature has been conducted in Section 2.3, and the knowledge gap is identified. Following this section, the existing literature is categorised into three sections (Section 2.4, 2.5 and 2.6) and reviewed accordingly. Section 2.4 explains an overview of Australian construction industry productivity studies; Section 2.5 describes the factors negatively influencing construction projects' productivity and Section 2.6 addresses management practices that have the potential to enhance productivity in industrial and infrastructure projects. Lastly, the summary of the chapter is presented in Section 2.7.

2.2 Characteristics of the Victorian Construction Industry

Construction projects' productivity is influenced by factors such as government regulations, the project delivery models adopted in the local construction industry, resource supply chain, the availability and strength of unions, and other issues which are peculiar to a certain location. Consequently, the management practices of the construction projects vary from country to country. This section describes the context of the study.

Definition of a Multi-Storey Building Project and Classification of Construction Projects

In Australia, construction projects can be broadly classified into two: engineering and building. This research focuses on productivity improvement in building construction projects because a significant level of activity occurs in this sector. In June 2016, the values of works done in the Australian building and engineering sectors were 54% and 46% respectively (Australian Bureau of Statistics, 2016b). Building construction projects can be classified based on the number of storeys. According to Australian

Building Regulations (2006), a multi-storey building has a rise in storeys of more than three. This research investigates productivity improvement in multi-storey building construction projects as their construction processes are more complex due to the involvement of complex engineering services. The South Australian Department for Communities and Social Inclusion (2016) apartment design guideline states that multi-storey buildings have more complex design and construction systems. For the sake of brevity, the term 'building projects' is used to refer to multi-storey building construction projects.

The Market Structure

The construction sector in Victoria State, Australia is dominated by a few large contractors that engage numerous small companies. As indicated in Table 2-1, at the end of 2014/15 financial year, the proportion of companies involved in building construction were 0.06%, 0.78% and 99.15% for firms employing over 200 workers, 20-199 workers, and 0-19 workers respectively (Australian Bureau of Statistics, 2016c).

Table 2-1 Number of Construction Firms Operating in Victoria in 2014/2015 (adapted from Australian Bureau of Statistics (2016c))

		Number of Companies Operating at end of 2014/15 financial year			
State	*Sector*	Non-employing	1-19 Employees	20-199 Employees	200+ Employees
Victoria	House Construction	7455	4806	63	6
	Other Residential Building Construction	4393	1072	21	3
	Non-Residential Building Construction	2508	1164	85	5
	Total	14356	7042	169	14
	Percentage	**66.52%**	**32.63%**	**0.78%**	**0.06%**

The Regulatory Bodies

The Australian Fair Work Commission stipulates the minimum wages, ordinary working hours, overtime rates, and other issues related to employment conditions in building construction projects (Fair Work Commission, 2016). The 2015/16 minimum wage is 18.17 Australian Dollars (AUD), and additional allowances are provided based on the experience of the tradesperson. The 2015/16 ordinary working hours is 38 hours per week, and it is between 7:00 am and 6:00 pm Monday to Friday. According to the Commission, all the time worked beyond the ordinary working hours must be paid at the rate of one and half time for the first two hours and double time thereafter and a minimum of three hours is considered for the payment purpose. Similarly, the Commission specifies that all the time worked on Sundays should be paid at double rate. Moreover, the Commission sets the minimum wages based on the skill level of the employees and prepares the "Building and Construction General On-site Award 2010" in which the minimum wages which correspond to the skill levels of the general construction workers (CW) and engineering construction workers (ECW) are specified (Table 2-2). As indicated in the Table, the minimum 2015/16 hourly wage for CW level 1a is AUD 18.61 and the minimum hourly wage for CW level 8 is AUD 23.69.

Table 2-2 The Minimum Wages of Construction Workers in 2015/16 (adapted from Fair Work Commission (2016))

Skill Level	*Minimum weekly wage*	*Minimum hourly wage*
Level 8 (CW/ECW 8)	900.40	23.69
Level 7 (CW/ECW 7)	879.20	23.14
Level 6 (CW/ECW 6)	854.70	22.49
Level 5 (CW/ECW 5)	832.50	21.91
Level 4 (CW/ECW 4)	807.80	21.26
Level 3 (CW/ECW 3)	783.30	20.61
CW/ECW 1 (level d)	745.50	19.62
CW/ECW 1 (level c)	731.80	19.26
CW/ECW 1 (level b)	721.60	18.99
CW/ECW1 (level a)	707.00	18.61

The skill required for each level is also specified in the Building and Construction General On-site Award 2010. Accordingly, the skill level CW1 (level a) is assigned to workers commencing activities in the construction industry. Their levels become CW1 (level b) and CW1 (level c) after working 3 and 12 months in the industry respectively. However, for CW1 (Level d), the workers are required to have certificates, or they should have construction skills assessment results which are equivalent to the required competency standards in accordance with the Recognition of Prior Learning (RPL) principles or other requirements stipulated in the building and construction award (Fair Work Commission, 2016). According to the Fair Work Commission, Recognition of Prior Learning (RPL) is 'the formal recognition of skills attained through on-the-job experience and/or training and may include formal qualifications such as overseas qualifications, which have up until now been unrecognised.'

The Environment Protection Authority of Victoria (EPA) has prepared guidelines that help contractors to comply with Section 48A (unreasonable noise from residential premises) of the Environment Protection Act 1970. The authority stipulates that the normal working hours for commercial building construction sites and large-scale developments (at least four storeys) in non-residential zone is from 7:00 am to 6:00 pm on weekdays and from 7:00 am to 1:00 pm on Saturday; and for large residential developments in residential areas the normal working hours is from 7:00 am to 6:00 pm during weekdays and from 9:00 am to 1:00 pm on Saturday (EPA, 2016). According to the Authority, failure to control the noise during construction period is an offense against the Environment Protection Act 1970 and a person who contravenes Section 48A of the Act is liable to a penalty of not more than 120 penalty units, and in the case of continuing offence to a daily penalty of not more than 30 penalty units for each day during which the offence continues after conviction (Environment Protection Act, 2010).

In Victoria State, depending on the type of construction activities, the Construction Management Plan (CMP) should be prepared by the contractors and approved by the pertinent city councils prior to the commencement of a project. For instance, according to the guidelines provided by the city of Melbourne, the Construction Management Plan (CMP) is prepared to ensure that the construction sites do not adversely affect the safety, health, amenity, traffic and the surrounding environment (City of Melbourne, 2005). The city council requires the contractors to address the six elements of the CMP: (1) Public Safety, Amenity and Site Security; (2) Operating Hours, Noise and Vibration Controls; (3) Air and Dust Management; (4) Stormwater and Sediment Control; (5) Waste and Materials Reuse; and (6) Traffic Management. According to the city council, the approved CMP is a contract between the contractor and the city, and if there is noncompliance, the city can withdraw Security Deposit which is provided in relation to a CMP and rectify the remedy (City of Melbourne, 2005). The city also stipulates that the following permits should be sought for specific activities: permit to erect a gantry, overhead protective awning over the road or footpath; permit for a vehicle crossing (permanent or temporary); permit to occupy space on road or footpath; permit to erect a hoarding; permit for a road opening; permit for a road closure; permit for a construction zone; permit to use a mobile crane; permit for rubbish skips and builder’s bins; permit for works and temporary structures in City of Melbourne parks and gardens; permit to work outside prescribed hours; permit for excavation and/or protection works; and approval for a legal point of discharge or a temporary point of discharge (City of Melbourne, 2005).

In Victoria, occupancy permits are required prior to occupation of a new building. According to Victorian Building Authority (VBA), an occupancy permit is a document that signifies that a building surveyor is satisfied that the completed building construction work is appropriate for occupation. Building construction works for new units or apartments always require an occupancy permit, and it is an offence to use a new home that does not have occupancy permit (VBA, 2016).

The Union

The Victorian construction industry is characterised by the presence of Construction, Forestry, Mining, and Energy Union (CFMEU). The union prepares a calendar for construction sites that typically comprises of 36 working hours per week, rostered days off (RDO) and other events in a financial year (CFMEU, 2016a). Moreover, in most construction projects, the union signs a contractual agreement known as Enterprise Bargaining Agreement (EBA) in which the minimum payments and other working conditions are agreed between a contractor and the union. Under certain circumstances, the union has also the authority to suspend the construction works. The health and safety representatives can issue the Provisional Improvement Notice (PIN) to the contractor if there are unsafe working conditions, or they can suspend the construction work if there is an immediate threat to the workers (CFMEU, 2016b). According to Worksafe Victoria (2008), the Provisional Improvement Notice is a written direction requiring a person (contractor) to remedy the breach (or likely breach) of Workplace Health and Safety (WHS) Act or Regulation. The health and safety representatives (HSRs) can issue a PIN if they believe, on reasonable grounds, that a provision of the Occupational Health and Safety Act 2004 (OHS Act) or the Occupational Health and Safety Regulations 2007 is being contravened; or has been contravened, and it is likely that the contravention will continue or be repeated (Worksafe Victoria, 2008a).

The Project Delivery Models

In Australia, the project delivery models which are predominantly used to deliver non-residential building and civil (road and bridge) projects can be broadly grouped into: (1) Traditional (Construct Only), (2) Design and Construct including common variants such as Design, Construct and Maintain (DCM); Design, Construct and Operate (DCO); and Design, Construct, Maintain and Operate (DCMO), (3) Managed (Managing Contractor, Construction Management), (4) Direct Managed, (5) Relationships (Alliance), and (6)

Public Private Partnership (Austroads, 2014). According to Austroads (2014), the Construction Management delivery model is used for the construction of buildings, and in this model, the project owner engages the designer and trade contractors directly. A construction manager that usually receives a time-based fee or percentage of the cost of the works is employed to act as client's agent and manages the delivery of the construction works. The Managing Contractor delivery model is used for the construction of large complex buildings, and it involves a principal contractor being engaged as a managing contractor that manages the development of the design, coordinates production of construction documentation, enters into contracts and manages the delivery of the works on behalf of the project owner (Austroads, 2014). The managing contractor delivery model typically includes a two-stage contractual arrangement. In Stage 1, based on a preliminary project brief which is prepared by the project owner, the design is developed collaboratively, and the contractor prepares a guaranteed construction sum (GCS) or other variants such as lump sum. If the contractor's offer in Stage 1 is accepted, then Stage 2 involves documentation, construction, and commissioning of the project. The work packages to be subcontracted are competitively tendered by the managing contractor in an open book type of arrangement, and only the actual cost of construction is paid up to the agreed GCS cap (Austroads, 2014).

The Construction Materials Supply

Most building materials in Australia are imported from overseas. Wheeldon (2012) reported that the import of building materials is increasing due to the rising investment costs in the manufacturing sector in Australia. The Housing Industry Association (HIA) recommended the establishment of Australian building product accreditation scheme as the usage of the building materials which are manufactured offshore is increasing in Australia and some of these materials did not comply with Australian standards (HIA, 2012). The Prefabricated construction system is increasing at about 5% per year (PrefabAUS, 2014). Hampson and Brandon (2004) indicated the increment of off-site manufacturing practices in Australian construction industry.

The High-risk Construction Tasks

The Victorian Occupational Health and Safety Regulation 2007 classified the construction industry under the hazardous industries and provided the list of high-risk construction works. Accordingly, some of these works include any construction activity where there is a risk of a person falling more than 2 metres; demolition works; trench excavation if the excavated depth is more than 1.5 metres; and an activity which involves any movement of the powered mobile plant. The regulation stipulates that any person must not perform high-risk construction work unless a Safe Work Method Statement (SWMS) is prepared for the particular work. The work should also be carried out in accordance with the statement. A Safe Work Method Statement is a document that specifies the high-risk construction activities, the hazards arising from these activities, and the measures to be taken to control the risks (Safe Work Australia, 2014b).

Safe Work Australia stipulates the hierarchy of risk controlling techniques from highest to the lowest level (Safe Work Australia, 2011). Accordingly, Level 1 or eliminating the hazard, for instance, includes avoiding the risk of fall from a height by working on the ground. It is the most effective control measure. Level 2 control measures are used when it is not suitable to use Level 1 techniques. They comprise of: (i) substituting the hazard with something safer, for example, replacing solvent-based paints with water-based solvents (ii) isolating the hazard from people, for instance, install guard rails around exposed edges and holes in floors, and (iii) using engineering controls which involves some mechanical devices, for example, the use of trolleys or hoists to move heavy loads. Level 3 control measures, which are the least effective in minimising risks, rely on human behaviour and supervision. These actions include (i) the use of administrative controls such as developing the procedures on how to operate machinery safely and using signs to warn people, and (ii) the use personal protective equipment (PPE) such as hard hats and gloves (Safe Work Australia, 2011). The next section presents the systematic review of the literature.

2.3 Systematic Review of Literature

This research used Scopus as a search engine to identify the journals which frequently publish construction productivity related articles. Yi and Chan (2014) conducted the critical review of labour productivity research in construction journals from 1983 to 2011 and found that Journal of Construction Engineering and Management (JCEM), Construction Management and Economics (CME), Engineering, Construction and Architectural Management (ECAM), Journal of Management in Engineering (JME), International Journal of Project Management (IJPM), Automation in Construction (AIC), Building Research and Information (BRI), Building and Environment (BAE), Canadian Journal of Civil Engineering (CJCE), and Journal of Computing in Civil Engineering (JCCE) frequently publish articles which are related to construction labour productivity. The authors used the search engine, Scopus, to identify the journals and articles.

Naoum (2016) conducted the literature review of construction labour productivity studies from 1970 to 2014 and identified journals which publish articles related to construction labour productivity. Accordingly, Journal of Engineering and Management (JCEM), Journal of Management in Engineering (JME), Construction Management and Economics (CME), Engineering, Construction and Architectural Management (ECAM), International Journal of Project Management (IJPM), International Journal of Productivity and Performance Management (IJPPM), Journal of Computing in Civil Engineering (JCCE), Construction Innovation (CI) and Journal of Built Environment (BE) are found to be the journals which frequently publish construction labour productivity related articles. The findings of Naoum (2016) and Yi and Chan (2014) regarding the identification of the journals that published the most construction productivity-related articles are similar.

This research used the following 12 journals as starting point to search the articles related to construction labour productivity which were published between 1983 and 2016. The journals include (1) Journal of Construction Engineering and Management (JCEM), (2) Construction Management and Economics (CME), (3) Engineering, Construction and Architectural Management (ECAM), (4) Journal of Management in Engineering (JME), (5) International Journal of Project Management (IJPM), (6) Automation in Construction (AIC), (7) Building Research and Information (BRI), (8) Building and Environment (BAE), (9) Canadian Journal of Civil Engineering (CJCE), (10) Journal of Computing in Civil Engineering (JCCE), (11) Journal of Productivity and Performance Management (IJPPM) and (12) Journal of Construction Innovation (JCI). Accordingly, 511 articles that have the keywords “productivity” and “construction” in their titles, abstracts and keywords were identified during Stage I of the review. The summary of the results of the literature review during Stage I is presented in Table 2-3, and the list of articles including the names of the authors as well as the years of publications are included in Appendix-8.

Table 2-3 Summary of the Number of Journal Articles

No.	*Journals*	*No of articles*
1	Journal of Construction Engineering and Management (JCEM)	192
2	Construction Management and Economics (CME)	83
3	Engineering, Construction and Architectural Management (ECAM)	31
4	Journal of Management in Engineering (JME)	28
5	International Journal of Project Management (IJPM)	24
6	Automation in Construction (AIC)	58
7	Building Research and Information (BRI)	16
8	Building and Environment (BAE)	14
9	Canadian Journal of Civil Engineering (CJCE)	37
10	Journal of Computing in Civil Engineering (JCCE)	20
11	Journal of Productivity and Performance Management (IJPPM)	5
12	Construction Innovation (CI)	3
	Total	***511***

After reviewing the references sections of the 511 articles, more journals and journal articles, which are relevant to this study, were identified (Figure 2-1). Accordingly, Australasian Journal of Construction Economics and Building (AJCEB), Journal of Infrastructure Systems (JIS), Structural Survey (SS) and Journal of Civil Engineering and Management (JCiEM) are included in the list of journals during Stage II of the searching process. Finally, 558 articles which consist of the keywords ‘productivity’ and ‘construction’ were identified.

The procedure followed in the identification of the relevant papers is shown in Figure 2-1. The contents of the 558 articles were reviewed, and the papers which investigate factors influencing productivity in construction projects were included in the final list of articles. Papers which do not address the factors which either negatively or positively affect productivity in construction projects were excluded from the final list (Figure 2-1). Finally, a total of 102 articles were included in the final list, and the detailed review was conducted to identify the knowledge gap.

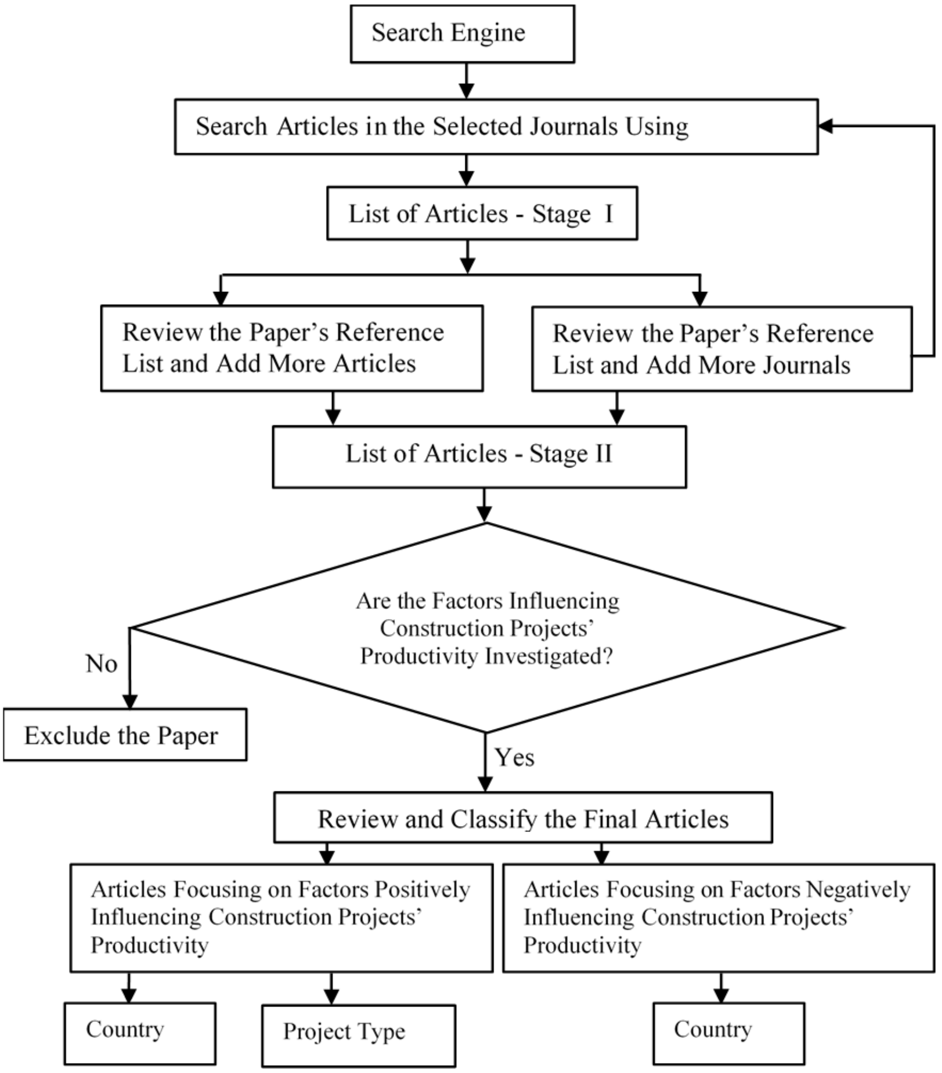


Figure 2-1 Flow Chart for the Systematic Review of Literature

The final articles were then analysed based on project type, country and the focus of the paper, and the results are presented in Table 2-4. As summarised in the table, in both Australian and international contexts, none of the researchers has identified the management practices that have the potential to enhance productivity in building construction projects and developed a tool to measure the practices. Furthermore, no research has been conducted on how to develop a tool which can be used to predict the probability of exceeding baseline productivity based on a score of the management practices. In the international context, two studies have identified the management practices that could enhance productivity in industrial and infrastructure projects and developed management practices scoring tools for these project types (Caldas et al., 2014, Nasir et al., 2015).

Table 2-4 Summary of the Systematic Review of Literature

I. Research Identifying Factors Influencing Construction Projects' Productivity		
Country	Australia	International
No of Papers	5	95

II. Research Identifying Management Practices That Have the Potential to Enhance Productivity in Construction Projects and Developing Tools to Measure the Practices						
Country	Australia			International		
Project Type	Building	Infrastructure	Industrial	Building	Infrastructure	Industrial
No of Papers	-	-	-	-	1	1

III. Research Developing Tool for Predicting Probability of Exceeding Baseline Productivity Based on a Score of Management Practices						
Country	Australia			International		
Project Type	Building	Infrastructure	Industrial	Building	Infrastructure	Industrial
No of Papers	-	-	-	-	-	-

The finding of the literature review shows that most previous studies focused on the investigation of factors which deter construction projects' productivity, and these factors are described in Section 2.5. Studies conducted in the Australian context and addressing construction productivity issues are summarised in Section 2.4.

Figure 2-2 indicates the number of articles focusing on the factors influencing productivity in construction projects based on countries or contexts. Figure 2-3 shows the numbers of research papers according to their authors. In the figure, the authors who published more than three articles are presented.

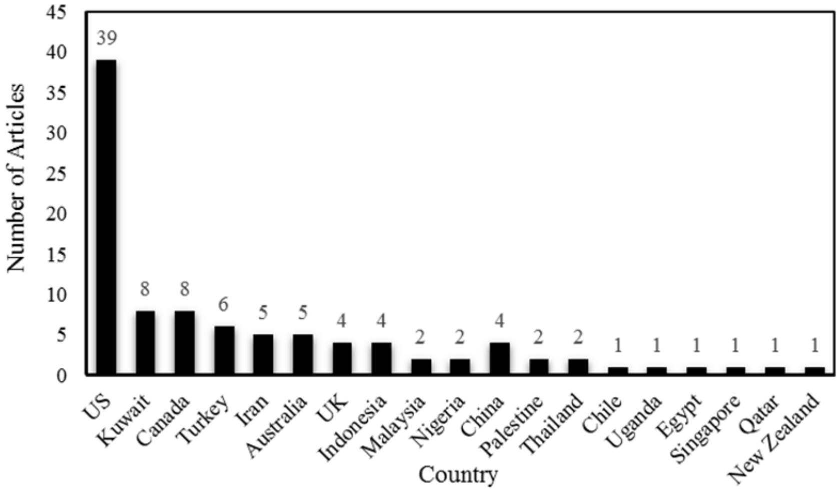


Figure 2-2 Classification of Research Articles Based on Countries

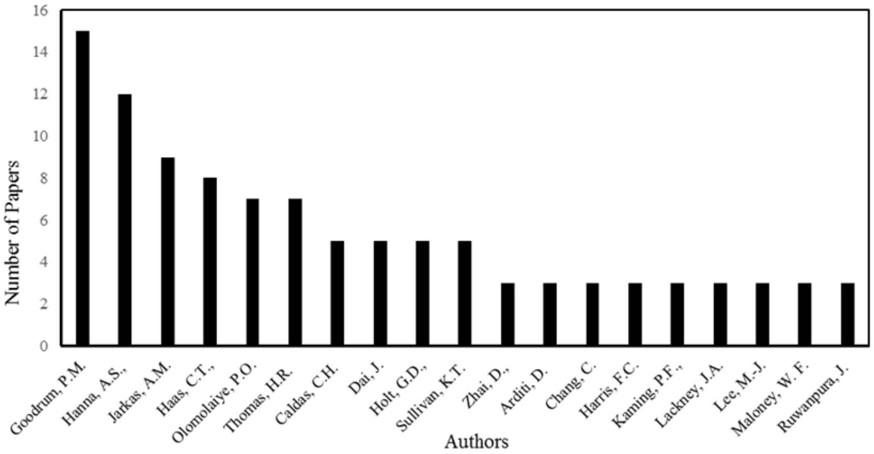


Figure 2-3 Classification of Research Articles Based on Authors

2.4 Overview of Australian Construction Industry Productivity Studies

Most previous studies, in the context of Australia, conducted at construction projects level focus on identifying the factors which hamper construction labour productivity (Chalker and Loosemore, 2016, Loosemore, 2014, Hughes and Thorpe, 2014). However, the previous researchers do not identify and prioritise the construction management practices that have the potential to enhance productivity in multi-storey building construction projects. Doloi (2008) identified three factors which positively influence productivity in building projects. These include project planning, incentives, and job satisfaction. However, materials management, equipment management, safety and health practices and other practices which could influence productivity were not investigated. Moreover, no research has been conducted on how to develop a technique to measure, plan, monitor, and evaluate the practices in the context of building projects in Australia.

Previous studies indicated that management-related problems are negatively influencing construction projects' productivity in Australia. The Business Council of Australia (BCA) found that the main contributing factors for low construction productivity in Australia include the inefficiency in scheduling projects with multiple tasks, unexpected leaving of skilled staff, lack of critical machinery on site when it is needed, and lack of flexibility in the workplace (BCA, 2012). Loosemore (2014) investigated the determinants of Australian construction productivity and found that low quality of relationships with principal contractors; lack of opportunity for early involvement in design; poor or not transparent tender practices; poor administration and document control, and design management; lack of project management and supervisory skills, particularly in planning, scheduling and coordination; and industrial relations (IR). Hughes and Thorpe (2014) found that rework, incompetent supervisors, and incomplete drawing are the three most critical problems that reduce construction projects' productivity in the Australian context.

Construction productivity studies conducted at the construction industry level in Australia can be summarized under: (1) the significance of improving the productivity of Australian construction industry to the national economy (Walker, 1995, Industry Commission, 1997, PWC, 2013), (2) comparison of Australian construction industry productivity with other developed countries' construction industry productivity (Toner et al., 2001, Loosemore and McGeorge, 2002), and (3) estimation of the total factor productivity (Li and Liu, 2010), and (4) drivers of Australian construction industry productivity (Chancellor, 2015). However, these studies did not investigate the management practices influencing productivity at construction project level.

Previous studies have addressed the importance of increasing construction industry productivity to Australia's economy. Walker (1995) described that improving construction industry productivity is essential for promoting national competitiveness, for enhancing living standards and for achieving a satisfactory rate of growth. The Industry Commission (1997) report also indicated that productivity enhancement is the key ingredient in promoting sustainable economic growth and in improving the living standards of Australians. According to the report, the influence of productivity growth on living standards can come over long periods of time, and small improvements in productivity growth will make a substantial difference for future generations. The report showed that increase in productivity of about half percent could raise average real incomes by an additional 30 percent over the subsequent 40 to 50 years. Moreover, the Commission estimated that productivity growth has accounted for about two-thirds of the improvement in the average real incomes of Australians over the past three decades prior to 1996. Accordingly, the real Gross Domestic Product (GDP) increased from 145 billion Australian Dollars (AUD) in 1964/65 to AUD 430 billion in 1995/96; and the productivity growth had accounted for about AUD 140 billion from the total of AUD 285 billion increase (Industry Commission, 1997). Therefore, improvement in the productivity of multi-storey building construction projects is significant for the economic growth of the country.

A study conducted by PWC (2013) indicated that increasing productivity is fundamental to the Australia's economy. According to the research, over long periods of time, small differences in rates of productivity growth can compound like interest in a bank account and make an enormous difference to a society's prosperity. Moreover, the study showed that higher construction industry productivity implies lower construction costs, higher savings in production costs, and consequently an increase Australia's GDP. The study also concluded that the performance of Australian construction industry in terms of productivity is low, and the research estimated that 1% increase in the productivity of Australian construction industry would result in the national benefit of about AUD1.252 billion. Therefore, increasing the productivity of multi-storey building construction projects can also lower the construction costs, increase profit margins of the contractors, and contributes to the national economy. Moreover, the owners of the projects can be benefited if the productivity of the projects is improved as the contractors' offer could be lower.

Previous researchers made international comparisons of Australian construction industry productivity. However, there are opposite views about the status of the productivity performance of Australian construction industry when compared to other developed countries. Some of the previous researchers argue that Australia's construction industry productivity is high while others claim that it is low. A study conducted by Loosemore and McGeorge (2002) indicated that, in value added per hour, Australia's construction industry productivity is on a par with Japan's and Germany's construction industry productivity and performing slightly better than France and the UK, but lagging behind the US, Canada, and Singapore. Similarly, a report by Young et al. (2008) indicated that Australian construction industry productivity is less than USA's construction industry productivity. According to the report, the proportion of the Australia's construction productivity was 95.9%, 77% and 51.9% of the USA's construction industry productivity in the year 1990, 2000 and 2005 respectively. Likewise, the study conducted by the Business Council of Australia (BCA) indicated that, in Australia, it takes 1.3 hours to execute work that would take 1.0 hour in the USA (BCA, 2012). The study concluded that Australian construction projects have lower productivity, and they are 40% more costly than similar projects in the USA. However, Best (2012) argued that construction projects in Australia might not be costly if purchasing power parities are utilised instead of the exchange rates when comparing construction projects in the USA and Australia. Although there is no consensus among the previous researchers regarding the status of Australia's productivity, it is desirable to investigate the mechanisms of increasing the productivity of multi-storey building projects as the increment contributes to the economic growth of a country.

The drivers of Australian construction productivity at industry level were identified by previous researchers. Chancellor (2015) found that wage growth, research and development expenditure are the drivers of productivity at the national level. The study also found that increasing the number of apprentices and expenditure on research and development are the main drivers of construction industry productivity in Victoria State, Australia. However, the study did not investigate the productivity drivers at the construction project level. In next section, the review of the factors which deter productivity of construction projects is presented.

2.5 Factors Negatively Influencing Construction Projects' Productivity

Based on the review of previous studies, factors which negatively influence construction projects' productivity can be broadly categorised into construction materials, construction equipment and tools, preconstruction activities, construction methods, human resource management, and safety and health. This section presents the review these factors.

Productivity Problems Related to Construction Materials Management

Previous researchers estimated the adverse effect of the factors related to construction materials on construction projects' productivity. Thomas et al. (1989) conducted a case study of a five-story commercial building and estimated that 18% of the time overruns is attributed to the poor materials management practices. Similarly, Thomas and Sanvido (2000) investigated the effect of inefficient materials management on productivity using three building projects as case studies and found the schedule slippage between 50% and 129%. The factors related to construction materials and reducing construction projects' productivity include the lack of construction materials, delay in delivering materials, poor quality of materials, and improper handling of materials.

Lack of construction materials has been identified by previous researchers as the most critical problem that affects productivity in construction projects. The lack of construction materials was found to be the among the top three factors which reduce construction projects' productivity (Olomolaiye et al., 1987). Zakeri et al. (1996) found the shortage of materials as the critical factor deterring productivity of construction projects. Kaming et al. (1997) identified that the lack of construction materials, which is caused by on-site transportation difficulty and excessive paperwork, is one of the most critical productivity problems. Liberda et al. (2003) identified non-availability of construction materials as the third management related problems that are influencing construction productivity. The shortage of materials due to liquidity problems of the contractors and lack of coordination between the project site and contractor's head office is identified among the major productivity problems (Makulsawatudom et al., 2004). Abdul Kadir et al. (2005) identified material shortage caused by the inaccessibility of items and excessive travel to get them as the most critical factor causing low productivity in residential building construction projects. In the UK, the blue-collar workers mentioned the unavailability of materials and their components among the factors that could potentially reduce their productivity (Chan and Kaka, 2007). According to the survey conducted by Dai et al. (2009b), crafts in the United States responded that the lack of construction materials reduced their productivity. Rivas et al. (2011) concluded that shortage of materials is the most significant impediments to construction productivity. The shortage of materials is also cited as productivity problem in the construction industry of Kuwait (Jarkas and Bitar, 2012). The unavailability of materials is also found to be one of the main factors which hinder the increment of construction projects' productivity (El-Gohary and Aziz, 2014). In Australia, Hughes and Thorpe (2014) identified the shortage of construction materials among the top five productivity problems. The findings of the above studies indicate that material unavailability is one of the major productivity problems in both developed and developing countries. Although the previous studies identified the productivity problems, the materials management practices that could enhance the productivity of the multi-storey building construction projects were not identified and prioritised. Problem identification alone might not improve productivity unless the problem is integrated with the respective solutions (practices).

Delay in delivering construction materials is found to be another factor which reduces the productivity of construction projects. Work stoppage due to delay in delivery of materials to a construction site was perceived as the most significant factor in Singapore construction industry (Lim and Alum, 1995). Thomas and Sanvido (2000) found that unsequenced deliveries of construction materials caused unnecessary crane movements and rework. Late delivery of materials and coordination problem with suppliers were identified as the major determinants (Abdul Kadir et al., 2005). Similarly, poor procurement plan and delayed payments to the suppliers or sub-contractors led to the delayed delivery of materials and loss of productivity in construction projects (Ghoddousi and Hosseini, 2012). Delay in ordering materials was mentioned among the barriers to increasing the productivity performance (El-Gohary and Aziz, 2014). Thus, the materials management practices that should be implemented to counteract the loss of productivity due to the delay in delivering the materials needs to be identified in the context of multi-storey building construction projects.

The use of poor quality construction materials which leads to rework is also among the significant factors which negatively influence construction projects' productivity. Dai et al. (2009b) found that poor materials quality is among the main problems influencing the productivity of construction projects. Ghoddousi and Hosseini (2012) identified that rework due to the failure of construction materials or construction works to pass tests were among the major impediments to productivity in construction projects. Furthermore, the authors stated that errors in fabrication, which should be rectified by rework, had an adverse impact on the progress of the work. Although quality related issues were mentioned by previous researchers, which materials management practices are suitable to reduce quality related problems were not identified.

Improper handling of construction materials, which results in breakage and loss of the materials, is also mentioned by previous researchers as productivity problems. Thomas et al. (1989) identified multiple handling of materials, improper sorting or marking materials, and errors in fabrication as adverse conditions for productivity. Improper allocation of materials and lack of storage facilities were considered as a major productivity problem in urban high-rise construction sites in Singapore (Kaming et al., 1997). Moreover, Dai et al. (2009b) found that difficulty in tracking materials on site as one of the factors that reduce construction productivity. Rivas et al. (2011) concluded that locating on-site materials storage areas far from the working areas had reduced the productivity of construction projects. The problems associated with the ease of handling materials is also identified as the third critical determinants of construction productivity (El-Gohary and Aziz, 2014). In the context of Victoria State, Australia, the issue of materials handling could be one of the productivity problems in the construction of multi-storey building projects which needs the implementation of appropriate materials management practices.

Productivity Problems Related to Construction Equipment Management

Construction equipment and tools related problems were identified among the critical factors that negatively influence the productivity of construction projects. The major productivity problems which are frequently cited by previous studies include lack of equipment, tools, and consumables on construction sites; and breakdown of equipment and tools.

Lack of appropriate construction equipment and tools has a significant influence on the production rates of the crews. Olomolaiye et al. (1987) identified lack of proper tools as the third main hindrance to craftsperson productivity. The finding of the study indicated that up to 3.5 hours per person per week could be lost in steel fixing activity due to unavailability of steel bending machine. The authors concluded that poor quality of tools, improper maintenance, and outright shortages were the main causes of the unavailability of tools. Moreover, Makulsawatudom et al. (2004) identified lack of tools and equipment as the fourth deterrent for productivity increment in Thailand. The main reasons cited by the authors were the insufficient supply of tools and equipment; lack of maintenance of tools and equipment which ultimately lead to the use of old and inefficient machinery and its spare part; and error in estimation of the capacity of the equipment that resulted in the purchase of inefficient machines. Furthermore, Dai et al. (2009a) found that unavailability of the crane, forklifts, man lifts (hoists), consumables and tools; and misplacement of tools were the critical factors reducing the productivity of craftsmen. Some of the previous studies indicated that lack of tools and equipment is caused by various factors such as shortage of funds, concurrent construction of various projects leading to an increase in the demand for equipment, failure to report broken down tools and equipment; and lack of organized, safe and secure storages in construction sites (Hughes and Thorpe, 2014, Ghoddousi and Hosseini, 2012).The construction of multi-storey building projects in Victoria could also face the problem of unavailability of construction equipment and tool; the tradesmen could spend much time in waiting for the delivery of the required materials due to the unavailability of the equipment such as forklift, crane or hoists; and, in some circumstances, tools could also be misplaced and difficult to find them. Thus, investigation of good construction equipment and tools management practices is essential to alleviate the problems in Victorian context.

Breakdown of tools and equipment is another major productivity problem that reduces productivity in construction projects. Olomolaiye et al. (1987) explained that, on top of poor initial quality, handling problems and lack of maintenance such not oiling at appropriate intervals and replacing worn parts are the main cause of the breakdown of the machinery. Similarly, Alinaitwe et al. (2007) found that the frequent breakdown of equipment such as water pumps and vibrators due to poor maintenance and lack of service affect the productivity of construction projects in Uganda. Moreover, various researchers have concluded that equipment breakdown is the critical factor which reduces productivity (Kaming et al., 1997, Makulsawatudom et al., 2004, Ghoddousi and Hosseini, 2012, Hughes and Thorpe, 2014). Breakage of construction equipment and tools could also be one of the productivity problems in the construction of multi-storey building projects in Victoria, and investigation of the most suitable construction equipment management practices is significant for counteracting the adverse effect of these problems.

Productivity Problems during Pre-Construction Phase

Previous researchers identified the factors which have negative impacts on construction projects' productivity and related to pre-construction phase activities. These factors include inadequate planning, disruption of utilities, lack of contracting strategies, frequent changes, the complexity of designs, incomplete project information, and delay in permits.

Inadequate or lack of construction plan is one of the major factors which are frequently mentioned by previous researchers as impediments to construction projects' productivity. Zakeri et al. (1996) explained that the lack of proper work plan by site managers could lead to project delay since priorities might not be given to the execution of activities on the critical path. Durdyev and Mbachu (2011) found the inadequacy of planning as one of the constraints to on-site construction productivity in New Zealand. Ghoddousi and Hosseini (2012) identified lack of construction planning, and improper planning and sequencing of the tasks as the most critical factors that have adverse effects on the construction projects' productivity in Iran. The absence of construction planning as an impediment to construction projects' productivity was also identified by El-Gohary and Aziz (2014). In the construction of building projects in Victoria State, Australia, if the construction tasks are not clearly planned and sequenced to the lowest possible execution level or a daily activity, then there could be project delay as the crews might not fully understand what activities to execute and when they should be started and completed.

Disruption of utilities such as power and water is also among the critical factors which negatively influence productivity. Lim and Alum (1995) found that stoppage of utilities has an adverse effect on productivity. The authors explained that the main causes of the disruption of power were the damage to the underground cables by excavators, and the reason for water interruption was the bursting of water pipes during excavation works. Alinaitwe et al. (2007) also identified disruption of power and water services as factors that negatively affect construction productivity. Moreover, disruption of power and water services are considered as the main factors which negatively influence the productivity of construction projects in Iran (Ghoddousi and Hosseini, 2012). In the context of Victoria, Australia, the lack of water can delay activities that need water during their placement. For instance, if a project is using in-situ concrete, then the lack of water affects the production of concrete, and the concrete crew will be idle. Consequently, there could be the loss of productivity. Power disruption could also have a similar effect on activities that need power in their production and fixing such as welding of door and windows, trusses, and other related tasks.

The use of inappropriate contract types is also mentioned as one of the impediments to construction productivity. Lim and Alum (1995) described that work stoppages due to the insolvency of subcontractors were the main causes of the loss of the construction projects' productivity. Durdyev and Mbachu (2011) identified the type of procurement adopted as the productivity constraints in New Zealand. In the context of multi-storey building projects in Victoria, the lack of investigating and adopting suitable project delivery or contracting strategies could lead to project delays, cost overruns, and disputes. For instance, if the contract is awarded to a subcontractor without examining its technical and managerial capacity, the consequence could be the loss of productivity due to the lack of the capability of the subcontractors. Besides the contract types, insufficient considerations of the delivery methods such as ‘design and construct’ or ‘construct only’ during the planning stage could affect productivity. For example, if the adopted project delivery model is ‘construct’ only, then the subcontractor has to wait for a designer who has the authority to make amendments to the design.

Another productivity problem that is frequently cited by previous researchers is the changes in design, drawing, specification and scope of works. Rojas and Aramvareekul (2003) identified that change in the scope of works is one of the most critical factors that negatively influence productivity. Alinaitwe et al. (2007) found that change in design is one of the main problems influencing construction productivity in Uganda. In New Zealand, Durdyev and Mbachu (2011) mentioned the frequency of design changes as one of the constraints of productivity. Ghoddousi and Hosseini (2012) concluded that rework due to changes in design, drawings or specifications is the most critical factor that affects productivity. El-Gohary and Aziz (2014) found that work interruptions due to design changes are some of the productivity problems in the construction projects in Egypt. Other researchers also found that change order due to errors in design affects workers morale, causes rework, disrupts the sequence of activities and ultimately decreases construction productivity (Zakeri et al., 1996, Makulsawatudom et al., 2004, Abdul Kadir et al., 2005, Jarkas and Bitar, 2012). The issue of the incomplete document that is subject to numerous revisions and changes could be one of the productivity problems in multi-storey building construction projects in Victoria, Australia. These frequent changes can cause rework, idleness, and dispute between the principal contractor and subcontractors.

The complexity of designs and provision of less emphasis on the constructability issues can also negatively influence productivity. Alinaitwe et al. (2007) found that the complexity of designs hampers the productivity performance of Ugandan construction projects. Enshassi et al. (2009) mentioned the effect of project complexity as the major problems in construction projects in Gaza. Durdyev and Mbachu (2011) also identified project complexity as an internal constraint to on-site productivity in New Zealand. Jarkas and Bitar (2012) indicated that the complex nature of the design could result in rework and loss of productive working hours. El-Gohary and Aziz (2014) found that the lack of integration between design and construction or lack of consideration for constructability issues is one of the most critical factors which negatively influences productivity in construction projects, and the study concluded that there is a serious lack of cohesion between the design and construction teams in Egyptian construction industry. If a design of multi-storey building project in Victoria is complex, it could take a longer time to understand and implement the design, and productivity could be affected. Furthermore, if the design of the multi-storey building is not buildable by using the existing construction methods, the project's productivity performance can also be affected.

Provision of incomplete information such as work order, specification and drawings to crew members can also negatively influence the productivity of construction projects. Olomolaiye et al. (1987) found that instruction delay reduced the productive time of the operatives as they wait for work order from the supervisor. An incomplete design was considered to be the second most significant factor in Thailand, and the main reason mentioned by the authors was the inability of the client to provide sufficient time and budget for the designer to complete the design (Makulsawatudom et al., 2004). According to Alinaitwe et al. (2007), poor communication due to inaccurate instructions and drawings highly influenced productivity as the level of literacy of construction operatives were low. The study revealed that most communications were verbal which could not be as accurate as the written ones. Similarly, El-Gohary and Aziz (2014) identified lack of clarity of instructions and information exchange in construction projects in Egypt. Furthermore, slow in responding to questions regarding drawings, errors in drawings and availability of drawings were mentioned as productivity problems in US construction projects (Dai et al., 2009b, Dai et al., 2009a). Added to this, Rivas et al. (2011) revealed that lack of construction experiences of the designers is one of the reasons for poor drawings, and for the wastages of time in the interpretation of design during the construction phase. By the same token, delay in responding to request for information (RFI) is among communication gaps leading to low productivity (Jarkas and Bitar, 2012). Finally, the Australian construction projects' productivity is also negatively affected by the lack of complete design (Hughes and Thorpe, 2014).The study explained that the reason for the incomplete design was insufficient details provided by designers, inadequate examination of completed drawings and inadequate time provided to draftsperson. Thus, in the context of Australia, an investigation of the management practices which have positive impacts on productivity and counteract the adverse effect of the lack of complete project information on productivity is essential.

Delays in getting permits as well as stoppage of works due to the breach of regulatory requirements are some of the causes of the loss of construction projects' productivity. Lim and Alum (1995) explained that work stoppage orders due to infringement of government regulations affected productivity in the construction projects in Singapore. Moreover, Dai et al. (2009a) found that waiting for the work permits such as hot work permit and confined space permit delayed the productivity of construction projects. Other researchers also revealed the influence of regulatory requirement on productivity (Alinaitwe et al., 2007, Chan and Kaka, 2007, Durdyev and Mbachu, 2011). As there are various regulatory requirements in the building and construction industry of Victoria, failure to comply with these requirements could also lead to loss of productivity in building construction projects.

Productivity Problems Related to Human Resource Management

Previous studies have identified the problems that hamper construction projects' productivity from the human resource perspective. These factors include lack of skilled supervisors and craftsmen; absenteeism; lack of motivation and employee turnover; inadequate allocation of workers and frequent change of employees; and unfairness in payment.

The skill deficiency of operatives and supervisors has a negative impact on the productivity of construction projects. Olomolaiye et al. (1987) found that supervisors' incompetence was one of the contributing factors for low productivity of operatives. The study revealed that a high proportion of inspection delays could have been avoided if the supervisors had provided clear instruction and understood the project details. Makulsawatudom et al. (2004) ranked the presence of incompetent supervisors as the third critical factor which reduces construction projects productivity. The study suggested that the incompetent supervisors might be responsible for the defective works, and for inappropriate application of tools and equipment. El-Gohary and Aziz (2014) explained that the most common characteristics of unskilled operatives are the presence of low and faulty outputs coupled with unreasonably high inputs. Similar studies indicated the adverse impact of the lack of skill and experience of construction workers on productivity (Liberda et al., 2003, Alinaitwe et al., 2007, Chan and Kaka, 2007, Dai et al., 2009b, Ghoddousi and Hosseini, 2012, Jarkas and Bitar, 2012, Hughes and Thorpe, 2014). In the construction of multi-storey building projects in Victoria, the shortage of skill and experience of the workforce can affect productivity as well as the quality of the works. If the operatives do not have the required level of skills, then they might perform poor quality works which can be subjected to rejection by supervisors. As a result of this, contractors can do reworks to rectify the defects, and the productivity of the projects is affected.

Absenteeism is also often mentioned by previous researchers as one of the factors related to human resource and negatively influencing the productivity of construction projects. Lim and Alum (1995) mentioned that absenteeism is the fourth critical factor curtailing productivity of construction projects in Singapore. Similarly, Makulsawatudom et al. (2004) ranked absenteeism as the fifth factor reducing productivity in the construction projects in Thailand. Rivas et al. (2011) identified that the main causes of absenteeism are sickness, fatigue, alcoholism, personal problems and time for personal activities. Furthermore, many studies mentioned the effects of absenteeism on construction projects' productivity (Olomolaiye et al., 1987, Kaming et al., 1997, Durdyev and Mbachu, 2011, Hughes and Thorpe, 2014). In the multi-storey building construction projects in Victoria, absenteeism which could be unavoidable due to ill health or deliberate absence to search for more lucrative jobs could hamper productivity. Thus, the progress of the building works could be delayed due to unavailability of operatives on the scheduled date. It could also lead to the lag of an overall project completion date if the delay occurs on the critical path.

The lack of motivation by workers to work with full potential is also one of the factors which have negative impacts on productivity. Liberda et al. (2003) identified that the lack of motivation is the second critical factor, under human resource category, which impinged productivity of construction projects in Canada. Durdyev and Mbachu (2011) identified the level of motivation or commitment of the workforce as one of the factors influencing productivity in New Zealand. Jarkas and Bitar (2012) found that reduced motivation of labour is ranked first among the labour related factors which hamper construction productivity. The study indicated that if operatives are motivated, they are more enthusiastic and initiative; they work harder and respond faster to instructions; they feel satisfied and responsible; and they are more productive than demotivated workers. Similarly, if construction employees in the multi-storey building projects in Victoria are not motivated, they could exert minimal effort which can reduce the potential to get maximum possible productivity.

Employee turnover is the other factor which negatively influences productivity in construction projects. Kaming et al. (1997) revealed that the principal causes of turnover in the construction projects in Indonesia are the lack of adequate work volume, better pay from other projects, distance from home to the site, lack of better working environment and the presence of less challenging works. Similarly, Rivas et al. (2011) found that high turnover occurs due to the expectation of better salary by employees and the company do not provide them; personal problems and preference for working close to home; lack of incentives; short-term contracts; and supervisor's mistreatment. Other studies also investigated and revealed the negative impact of turnover on construction productivity (Makulsawatudom et al., 2004, Alinaitwe et al., 2007, Chan and Kaka, 2007, Durdyev and Mbachu, 2011). By the same token, if the rate of employee turnover in multi-storey building projects in Victoria is high, then there could be a disruption to construction progress as the employees leave with their knowledge and skill that they have acquired from the project.

The frequent change of staff and inappropriate allocation of workers in their respective crews are mentioned as some of the determinants of construction projects' productivity. Olomolaiye et al. (1987) found that changing the crew members were one of the productivity problems in Nigerian construction projects. Zakeri et al. (1996) identified changing crew size as one of the impediments to construction productivity in Iran. Abdul Kadir et al. (2005) revealed that an allocation of an inadequate number of workers is one of the major causes of delay in Malaysian construction projects. Alinaitwe et al. (2007) found that the change of Foremen and other crew members affect the productivity of building projects in Uganda. Dai et al. (2009b) concluded that pulling people off a task before it is completed has an adverse impact on productivity. Other similar studies indicated the impact of the change in both management staff and labour on productivity (Kaming et al., 1997, Liberda et al., 2003, Ghoddousi and Hosseini, 2012, Jarkas and Bitar, 2012). In the context of Victoria, Australia, there could also be a frequent change in the multi-storey building construction projects' employees which can negatively influence the productivity of the projects.Thus, investigation of the most suitable human resource management is significant to reduce the loss of productivity due to the frequent changes of the workers.

The inconsistency in payment schemes is another human resource related factor which negatively influences the productivity of construction projects. Abdul Kadir et al. (2005) found that workers strike due to unpaid work are some of the determinants of construction projects' productivity in Malaysia. Likewise, Dai et al. (2009a) identified the uses of different pay scales and per diem rates for the same job on the same project have negative effects on the performance of the construction workers. El-Gohary and Aziz (2014) mentioned that the payment scheme for labourers such as paying on a daily wage basis or paying a lump sum for a certain task has an impact on productivity. The issue of untimely payment of wages to the construction workers in Victoria could also reduce the productivity of building projects, and implementation of the most appropriate human resource management is essential to enhance productivity.

Productivity Problems Related to Construction Methods

Based on the findings of the previous studies, the factors which reduce construction projects productivity and related to construction methods include improper sequencing of works, excessive shift works or overtime, lack of adequate instruction and supervision, poor site layout, and lack of management commitment to investigate new technologies.

Improper sequencing of the works of subcontractors is found to be one of the factors reducing productivity in construction projects. Rojas and Aramvareekul (2003) found that the lack of subcontractor integration is one of the main productivity determinants in construction projects. Chan and Kaka (2007) identified that lack of sequencing and interference is one of the productivity problems in the UK construction projects. Similarly, Dai et al. (2009b) concluded that out of sequence work assignments is one of the main reasons for low productivity performance in the US construction projects. Other researchers such as Motwani et al. (1995), Liberda et al. (2003), Alinaitwe et al. (2007), Rivas et al. (2011), Jarkas and Bitar (2012) and El-Gohary and Aziz (2014) also investigated the impact of poor sequencing of works on productivity. As the construction of multi-storey building project in Victoria involves many subcontractors, inappropriate sequencing of the works of the subcontractors could result in loss of productivity. The crews of the subcontractors could interfere which leads to a slow progress of the project.

The lack of suitable working schedule strategies is another factor identified as productivity problem. Jarkas and Bitar (2012) ranked working overtime as the sixth critical factor influencing productivity in Kuwait. The study suggested that the operatives could lose their strength and moral due to the prolonged working hours; as a result, there could be low productivity and rework due to poor workmanship. Similarly, Hughes and Thorpe (2014) identified work overload as the fourth critical factor influencing the productivity of construction projects in Australia. The study suggested that working continuously for seven days per week has more negative impact on productivity than working overtime during the normal working days. Other studies also confirmed the effect of long working hours on productivity (Liberda et al., 2003, Ghoddousi and Hosseini, 2012, El-Gohary and Aziz, 2014). Therefore, the use of excessive shift length, unscheduled breaks, and working overtime could be practised in Victorian multi-storey building construction projects, and investigation of the appropriate management practice is significant to reduce the loss of productivity. The use of excessive shift length, for instance, can increase workload to the workers and cause physical tiredness which in turn leads to the reduced efficiency.

Inadequate instruction and supervision are some of the critical problems which reduce productivity in construction projects. Zakeri et al. (1996) concluded that repeating construction activities due to poor instruction and supervision, and delays in the inspection are the most critical factors that hinder construction productivity in Iran. Kaming et al. (1997) found that rework due to poor instruction is the second most significant problem that reduces the craftsmen's productivity in Indonesia. Liberda et al. (2003) identified supervision problems as one of the factors which negatively affect productivity in Alberta, Canada. Alinaitwe et al. (2007) identified inspection delay as one of the factors which decrease productivity in Ugandan building projects. In the US, Dai et al. (2009b) identified the inadequate instruction by supervisors as a critical productivity problem. Rivas et al. (2011) found that waiting for inspections, lack of preplanning of quality control and not notifying the quality controlling procedure in advance are the major problems of construction projects productivity in Chile.

Ghoddousi and Hosseini (2012) mentioned the stoppage of works due to inspection delays in construction projects in Iran. The inspection delay by site management is also concluded as a major impediment to productivity in Kuwait (Jarkas and Bitar, 2012). In Victorian multi-storey building construction projects, the lack of adequate inspection by contractors' supervisors could lead to rework and overall project delay. Furthermore, the productivity of the contractors could be hampered due to the lack of appropriate instruction.

Poor job site layout is another factor that negatively influences construction projects' productivity. Kaming et al. (1997) concluded that overcrowding on a construction site is among the major factors that reduce construction projects' productivity. Liberda et al. (2003) identified that congested work areas, poor site layout, and insufficient parking and other facilities on site are the major factors which reduce construction projects' productivity in Canada. Chan and Kaka (2007) mentioned that congestion of construction site is also one of the main factors influencing construction productivity in the UK. Alinaitwe et al. (2007) found that poor access and overcrowding on the site are the main factors reducing the productivity of construction projects in Uganda. According to the survey conducted by Dai et al. (2009a), long travel time due to the size of a project and the location of storage space being far from the working areas are some of the factors which reduce crafts' productivity in the US construction projects. Rivas et al. (2011) identified that overcrowded working area due to lack of coordination among supervisors and allocation of an excessive number of workers is the main productivity reducing factor in construction projects in Chile. In New Zealand construction projects, poor site layout is identified as the major productivity problem (Durdyev and Mbachu, 2011). Ghoddousi and Hosseini (2012) found that poor job site layout and overcrowding are the factors reducing the productivity of construction projects in Iran. Jarkas and Bitar (2012) identified unsuitability of storage location, site access, confinement of working space and poor site layout as the main factors which negatively influence construction projects' productivity in Kuwait. In the Australian context, poor site layout and overcrowding are also found to be some of the problems influencing construction projects' productivity (Hughes and Thorpe, 2014).Therefore, investigation of the techniques which reduce the loss of productivity of the Victorian multi-storey building construction projects due to poor site layout is significant.

The lack of management commitment to assess and implement new technologies is also identified as a factor which influences the productivity of construction projects. Chan and Kaka (2007) identified that the lack of investigation of prefabrication and standardisation as the productivity determinants in the UK construction projects. Durdyev and Mbachu (2011) found that technology and process related issues such as inadequacy of method of construction, resistance to accepting new technologies, insufficiency of technology, lack of awareness or training in new technologies, inadequate IT infrastructure and its application in the construction industry are the factors reducing construction projects' productivity in New Zealand. Ghoddousi and Hosseini (2012) found that utilising the traditional construction methods instead of modern technology has reduced productivity in construction projects in Iran. El-Gohary and Aziz (2014) identified poor construction technology as one of the factors negatively influencing construction projects' productivity in Egypt. In multi-storey building projects in Victoria, the lack of implementation of appropriate technology during planning and construction of the projects might also influence productivity.

Productivity Problems Related to Safety and Health

Previous researchers have identified factors which are related to safety and health and hamper construction projects' productivity. These factors include the occurrence of accidents in construction projects, unsafe work conditions, lack of cleanliness of construction sites, alcohol and substance abuse, and health condition of the employees.

Accidents in construction projects are some of the main factors that can reduce the productivity of the construction projects. Lim and Alum (1995) found that the occurrence of accidents that resulted in a death of an employee led to the issuance of stop-work orders by the government authorities, and productivity was negatively affected. Enshassi et al. (2007) identified three types of accidents which influence productivity in the construction projects.The first one is the accident that results in the death of an injured worker and the stoppage of work for several days. The second one is an accident that causes an injured labourer to be hospitalised for at least 24 hours and decreases the productivity of a crew in which the affected employ belongs. The third one is a minor accident that results from objects such as nails and steel wires and has a minor effect on the productivity of a crew. Kazaz and Ulubeyli (2007) described that occupational injuries at construction sites have an adverse effect on the reputation of a company, decrease productivity and result in a huge cost. Other researchers also mentioned that accidents in construction sites are the major deterrents to productivity (Makulsawatudom et al., 2004, Abdul Kadir et al., 2005, Alinaitwe et al., 2007, Jarkas and Bitar, 2012, Hughes and Thorpe, 2014). Therefore, to minimise the occurrence of accidents and reduce the negative impacts of the accidents on the productivity of multi-storey building projects in Victoria, investigation of appropriate safety and health practices is essential.

Unsafe work conditions such as noise, dust, radiation, poor ventilation, low lighting, limited access, unavailability of personal protective equipment and other work-related conditions have adverse effects on construction projects' productivity. Liberda et al. (2003) identified that noise, dust and radiation are some of the causes for the decrement of construction projects' productivity in Canada. Enshassi et al. (2007) found that insufficient lighting, inadequate ventilation and working at height are the three critical factors influencing construction projects productivity. Ghoddousi and Hosseini (2012) described that high level of dust and noise, low lighting, and ventilation affect the productivity of operatives in construction projects in Iran. El-Gohary and Aziz (2014) mentioned that working at heights is one of the problems affecting productivity in Egypt's construction projects. Since the working conditions of most construction projects in different countries could be similar, the multi-storey building construction projects in Victoria State, Australia, might also face productivity problems due to unsafe working conditions.

Lack of cleanliness of construction sites, alcohol and substance abuse, as well as the health conditions of employees, can significantly affect productivity in construction projects. Lim and Alum (1995) indicated that alcoholism and health issues such as mosquito breeding due to poor housekeeping are some of the factors that influence productivity. Alinaitwe et al. (2007) identified alcoholism, drug abuse, and poor health of workers such as sickness and general weakness as the problems impinging productivity in building construction projects in Uganda. Ghoddousi and Hosseini (2012) also mentioned that poor housekeeping is one of the productivity constraints in construction projects in Iran. Other researchers such as Chan and Kaka (2007) and Durdyev and Mbachu (2011) also mentioned the issue of the health of the workforces on productivity. The construction workers involved in multi-storey building construction projects in Victoria, Australia, might use alcohol and drugs which could affect their productivity. Thus, the practices of how these issues are controlled or minimised worth investigation. In next section, review of the management practices that have the potential to enhance productivity in industrial and infrastructure projects are described.

2.6 Management Practices Enhancing Productivity in Industrial and Infrastructure Construction Projects

Project Level Versus Activity Level Management Practices

Construction management practices that could improve productivity at project level can also enhance productivity at an activity level. However, practices which could improve the productivity of an activity might not necessarily increase the productivity of a construction project. For instance, locating cranes in most appropriate location for the construction of many work packages can improve the productivity of a project or group of activities such as concrete work, façade, and structural steel works. However, positioning a crane in the most suitable position for only one activity could enhance the productivity of that activity, for instance, façade work, but might not improve the productivity of other groups of activities or a project. Similarly, procurement of a crane by considering the maximum weight to be lifted in a single work package can affect the productivity of other work packages as these work packages might have the heaviest materials which the procured crane could not lift. Thus, focusing on activity level management practices might not increase the overall project productivity.Therefore, this research focuses on productivity improvement at the project level.

Previous researchers have identified project level management practices that have the potential to improve productivity in industrial and infrastructure construction projects and developed scoring tools for these project types in North America (Nasir et al., 2015, Caldas et al., 2014, CII, 2013b, CII, 2013a, Nasir, 2013).

Management Practices Enhancing Productivity in Industrial Construction Projects

The management practices that could improve productivity in industrial projects in North America have been identified and organised into elements, sections, and categories. There are 53 elements which are grouped into 18 Sections and 6 Categories (Table 2-5). The six Categories have been defined based on the experience of the panel of experts (Caldas et al., 2014).

Table 2-5 Elements, Categories and Sections of the Best Practices for Industrial Projects (adapted from Caldas et al. (2014) and CII (2013a))

Categories	Sections	Elements	Weights
I. Materials Management	A. Material Management Systems	A1. Project Team Material Status Database	36
		A2. On-site Material Tracking Technology	45
		A3. Material Delivery Schedule	59
		A4. Procurement Plan for Materials and Equipment	56
	B. Receipt and Inspection of Materials	B1. Material Inspection Process	63
		B2. Material Inspection Team	48
		B3. Post receipt Preservation and Maintenance	50
II. Equipment Logistics	A. Site Tool Management	A1. Site Tool and Consumables Management Strategy	38
		A2. Tool Tracking Systems	29
		A3. On-site Tool Maintenance	28
		A4. Control System for Tool Delays	25
	B. Machinery Availability	B1. Construction Machinery Productivity Analysis	67
		B2. Equipment Maintenance	106
III. Craft Information Systems	A. Short Interval Planning	A1. Short Interval Planning	74
	B. Workface Planning	B1. Well Defined Scope of Work	19
		B2. Utilization of Software to Assist in Generating Work packages	11
		B3. Project Model Requirements	12
		B4. Dedicated Planner	15
		B5. Identify Required Permitting	13
		B6. Engineering Work Packages (EWP)	14
		B7. Construction Work Packages (CWP)	15
		B8. Installation Work Packages (IWP)	15
	C. Constructability Review	C1. Design Readiness for Construction	67
		C2. PPMOF Evaluation	40
IV. Human Resources Management	A. Training and Development	A1. Trades Technical Training	47
		A2. Career Development	33
	B. Behaviour	B1. Nonfinancial Incentive Programs	24
		B2. Financial Incentive Programs	28
		B3. Social Activities	16
	C. Organizational Structure	C1. Maintain Stability of Organizational Structure	32
		C2. Clear Delegation of Responsibility	36
	D. Employment	D1. Retention Plan for Experienced Personnel	46
		D2. Exit Interviews	21
V. Construction Methods	A. Sequence and Scheduling of Work	A1. Integrated Schedule	47
		A2. Work Schedule Strategies	30
		A3. Schedule Execution and Management	46
	B. Start-up, Commissioning, and Turnover Plan	B1. Planning for Start-up	36
		B2. Testing Procedures	28
		B3. System Turnover Procedure	34
	C. New Technology Investigation	C1. New Equipment Investigation	20
		C2. New Information System Investigation	16
		C3. New Materials Technologies Investigation	18
	D. Site Layout Plan	D1. Dynamic Site Layout Plan	38
		D2. Site Security Plan	29
		D3. Equipment Positioning Strategy	36
VI. Environment, Safety, and Health	A. Job Safety	A1. Zero Accident Techniques	38
		A2. Task Safety Analysis	36
		A3. Identification of Potential Hazards	34
		A4. Housekeeping	31
		A5. System Test Hazards Planning	24
	B. Substance Abuse Programs	B1. Substance Abuse Programs	88
	C. Safety Training and Orientation	C1. OSHA Compliance Training	62
		C2. Toolbox Safety Meeting	81
		Total Weight	2000

The 18 sections are further organised into 6 categories: (1) Materials Management, (2) Equipment Logistics, (3) Craft Information Systems, (4) Human Resource Management, (5) Construction Methods, and (6) Environment, Safety, and Health (Caldas et al., 2014). Each practice is assigned a weight based on the relative importance of the practice in improving the productivity of industrial construction projects in North America. The total weight is 2000 points (Table 2-5).

Scoring Tool for Management Practices Enhancing Productivity in Industrial Construction Projects

The scoring tools for the 53 practices have been developed by the Construction Industry Institute (CII, 2013a). The tool has been validated by collecting productivity and management practices data from 33 industrial projects in North America.The scoring tool for one of the practices, On-site Materials Tracking Technologies, is indicated in Table 2-6. Accordingly, if a contractor plans to implement Level 2 or "the materials are assigned a laydown and storage area and the information is recorded," then the score for this practice will be 12. Using similar procedure, other practices are scored, and a total score for an industrial project in North America is computed. For the sake of brevity, the scoring tools for the other 52 practices are not presented here.

Table 2-6 The Levels and Weights of On-site Materials Tracking Technologies in the Context of Industrial Projects (adapted from CII (2013a))

	Practice: On-site Materials Tracking Technologies	*Weights*
Level 0	On-site materials tracking technology is not applicable.	0
Level 1	No tracking is done on site beyond receivables	1
Level 2	Materials are assigned a laydown and storage area and the information is recorded.	12
Level 3	Continuation of level 2, plus the location information is kept updated in a software system, and well-defined processes for establishing lay down area grids, developing pick lists, flagging, warehouse organization (if applicable), and other necessary functions.	23
Level 4	Continuation of level 3, plus the system is supported by tracking software and also supplemented by barcode, GPS, or RFID systems for automated location tracking.	34
Level 5	Continuation of level 4, plus the tracking system is completely automated and integrated with other project processes.	45

Management Practices Enhancing Productivity in Infrastructure Construction Projects

Previous researchers identified 61 management practices that have the potential to improve productivity in infrastructure projects (Nasir et al., 2015). The 61 practices are grouped into 20 sections, and the sections are organised into six categories: (1) Materials Management, (2) Construction Machinery and Equipment Logistics, (3) Execution Approach, (4) Human Resources Management, (5) Construction Methods, and (6) Health And Safety (Table 2-7).

Table 2-7 Elements, Categories and Sections of the Best Practices for Infrastructure Projects (adapted from Nasir et al. (2015), CII (2013b))

Categories	Sections	Elements	Weight
I. Materials Management	A. Procurement Strategy	A1. Procurement Procedures and Plans for Materials and Equipment	35
		A2. Long-Lead/Critical Equipment & Materials Identification	49
		A3. Procurement Team	19
	B. Materials Management Systems	B1. Project Team Materials Status Database	30
		B2. On-Site Material Tracking Technology	8
		B3. Materials Delivery Schedule	20
	C. Receipt and Inspection of Materials	C1. Materials Inspection Process	9
		C2. Materials Inspection Team	6
		C3. Post Receipt Preservation & Maintenance	5
II. Construction Machinery and Equipment Logistics	A. Construction Machinery and Equipment Availability	A1. Procurement Procedures & Plans for Construction Machinery	37
		A2. Construction Machinery Productivity Analyses	59
		A3. Construction Machinery and Equipment Maintenance	59
	B. Tools and Equipment Management Best Practices	B1. Site Tools and Equipment Management Strategy	36
		B2. Tools & Equipment Tracking	49
		B3. On-site Tools Maintenance	9
		B4. Construction Machinery & Equipment Utility Requirements	9
III. Execution Approach	A. Planning	A1. Short Interval Planning	22
		A2. Well defined scope of work	30
		A3. Use of Software	9
		A4. Dedicated Planner	37
		A5. Construction Work Packages (CWP)	18
	B. Constructability Reviews	B1. Design readiness for construction	41
		B2. Utility Alignment & Adjustments	39
		B3. Contract Types/Strategies	38
		B4. Model Requirements/3D Visualization	8
	C. Acquisition Strategy	C1. Right of Way, Land, and Utilities Acquisition Strategy	9
		C2. Contracts & Agreements with Agencies	13
		C3. Utility Agreements	24
		D1. Environmental Requirements	51
		D2. Regulatory Requirements/Permitting Requirements	44
IV. Human Resources Management	A. Planning	A1. Crews Composition/Crew Formation	54
		A2. Skills Assessment and Evaluation	50
	B. Training and Development	B1. Employees / Trades Technical Training	49
		B2. Career development	35
	C. Behaviour	C1. Nonfinancial Incentive Programs	32
		C2. Financial Incentive Programs	40
		C3. Social Activities	48
	D. Organizational Structure	D1. Maintain Stability of Organization Structure	7
		D2. Clear Delegation of Responsibility	21
	E. Employment	E1. Retention Plan for Experienced Personnel	31
		E2. Exit Interview	33
V. Construction Methods	A. Project Schedule Control	A1. Integrated Schedule	35
		A2. Work Schedule Strategies	10
		A3. Schedule Execution and Management	6
	B. Site Layout Plan	B1. Dynamic site layout plan	53
		B2. Traffic Control Plan	28
		B3. Site security plan	8
		B4. Machinery and Equipment positioning strategy	19
	C. Design/Construction Plan and Approach	C1. Communications, Coordination, & Agreements	50
		C2. Project start-up plan	18
		C3. Project Completion Plan	30
		C4. Innovations & New Technologies	60
		C5. Housekeeping	42
VI. Health and Safety	A. Job Site Safety	A1. Formal Health and Safety Policy	64
		A2. Health and Safety Plans/Zero Accident Techniques	64
		A3. Task Safety Analysis	56
		A4. Hazards Analysis	57
		A5. Hazards Planning	60
	B. Substance Abuse Program	B1. Drugs and Alcohol Testing Program	13
	C. Health and Safety Training and Orientation	C1. Health and Safety Training Programs	60
		C2. Toolbox Safety Meetings	45
		Total Weight	2000

The weight for each practice was assigned based on the relative significance of the practices in improving productivity in infrastructure projects. The total maximum score for a certain infrastructure project is 2000 (Table 2-7). In this research context, the term management practices or practices is used to refer to the elements.

Scoring Tool for Management Practices Enhancing Productivity in Infrastructure Construction Projects

The scoring tools for the 61 practices that have the potential to improve productivity in infrastructure projects have been developed by Construction Industry Institute (CII, 2013b). The tool has been validated by collecting and analysing productivity and the management practices data from 31 infrastructure projects in North America. In Table 2-8, the scoring tool for the practice, On-site Materials Tracking Technologies, is indicated for comparison with the scoring tool of the same practice in the context of industrial projects. For the sake of brevity, the scoring tools for the other 60 practices are not presented here.

Table 2-8 The Levels and Weights of On-site Materials Tracking Technologies in the Context of Infrastructure Projects (adapted from CII (2013b))

	Practice: On-site Materials Tracking Technologies	*Weights*
Level 0	On-site materials tracking technology is not applicable.	0
Level 1	No tracking is done on site beyond receivables	1
Level 2	Materials are assigned a laydown and storage area and the information is recorded manually on paper.	3
Level 3	Continuation of level 2, plus the location information is kept updated in a software system, and well-defined processes for establishing lay down area grids, developing pick lists, flagging, warehouse organization (if applicable) are established and followed.	5
Level 4	Continuation of level 3, plus the system is supported by tracking software and also supplemented by barcode, GPS, or RFID systems for automated location tracking.	7
Level 5	Continuation of level 4, plus the tracking system is completely automated and integrated with other project processes.	8

Comparison of Management Practices and Scoring Tools for Industrial and Infrastructure Construction Projects

The findings of the previous studies indicate that some of the practices which are suitable for enhancing productivity in industrial projects are not suitable for infrastructure projects. Under materials management category, the practices Long-Lead/Critical Equipment and Materials Identification, and Procurement Team are not identified as the practices which could enhance productivity in industrial projects. Under Equipment Logistics category, the practice Control System for Tool Delays is not considered as good practice for infrastructure projects; and Procurement Procedures and Plans for Construction Machinery, and Construction Machinery and Equipment Utility Requirements are found to be not suitable for industrial projects. Under execution approach/ craft information systems category, the practices Engineering Work Packages (EWP); Installation Work Packages (IWP); and Prefabrication, Preassembly, Modularization and Offsite Fabrication (PPMOF) Evaluation are considered as practices that could not enhance productivity in infrastructure projects. The practices Utility Alignment and Adjustments; Contract Types/Strategies; Right of Way, Land, and Utilities Acquisition Strategy; Contracts and Agreements with Agencies; Utility Agreements; and Environmental Requirements are not suitable for industrial projects.

The practices Crews Composition/Crew Formation, and Skills Assessment and Evaluation are some of the human resource management practices which are not included in the list of practices that could increase productivity in industrial projects. In the construction methods category, the practices Testing Procedures, and System Turnover Procedure are not suitable for enhancing productivity in infrastructure projects. Traffic Control Plan; Communications, Coordination, and Agreements are found to be the practices which are not appropriate to improve productivity in industrial projects. The practice Formal Health and Safety Policy is found to be a practice which is not included in the list good practices for industrial projects in the Safety category. The findings of the previous studies suggest that projects are not homogeneous when considering the practices which could enhance their productivity. Thus, multi-storey building construction projects would have different practices that could enhance their productivity.

The relative importance or weight of the practices which are common to both project types are also different. In the materials management category, Project Team Materials Status Database is one of the most important practices for improving productivity in infrastructure projects whereas the same practice is found to be least important for enhancing productivity in industrial projects. Similarly, Short Interval Planning is found to the most critical practice for industrial projects under Craft Information System category, but the practice is not given more weight in improving productivity in infrastructure projects. Clear Delegation of Responsibility is the least important human resource management practice for enhancing productivity in infrastructure projects whereas the practice is one of the most important practices for industrial projects. Under construction methods category, Integrated Schedule is found to be the most critical practice in industrial projects whereas Innovations and New Technologies is the most important practice in the context of infrastructure projects. The practice Substance Abuse Programs is the most critical safety and health practice for industrial projects whereas the practice is the least essential for infrastructure projects. Thus, the findings of the previous studies show that management practices are not equally important in improving the productivity of construction projects. Hence, the relative importance of the practices in enhancing productivity in multi-storey building projects in the context of Victoria State, Australia would be different.

Due to the difference in the weights of the practices, the scoring tools of the management practices are not interchangeable. As indicated in Table 2-6 and Table 2-8 above, although the verbal description of the levels of implementation of the practice ‘On-site Materials Tracking Technologies’ is the same in both project types, different scoring tools have been used for measuring the practice in the context of industrial and infrastructure projects. The weight assigned to each level is different in the two project types. Thus, if a contractor involved in industrial construction plans to implement level 2 or “the materials are assigned a lay down and storage area and the information is recorded,” then the score will be 12 points. However, if a contractor involved in the construction of infrastructure project plan to implement the same level in the industrial construction project, the score will be 3 points. This indicates that although the scoring tools are validated for industrial and infrastructure construction projects in similar environment, North America, the tools are different. Therefore, the existing tools cannot be directly used for measuring management practices in multi-storey building projects in Victora as the type of practices as well as their relative weights would be different in the context of Australia.

2.7 Summary

The loss of productivity in construction projects can lead to project delays, liquidated damage, additional cost and reduction in the profit margins of contractors. Previous researchers, both in Australia and international contexts, identified the factors which negatively influence construction projects productivity. These productivity deterrents can be classified into problems related to construction materials, equipment and human resource management; problems related to construction methods, and safety and health; and pre-construction phase productivity problems. However, as most of these factors are related to the management of the construction projects, they can be minimised by adopting practices which are suitable for a specific project type (building, industrial and infrastructure) in a certain environment or country. Moreover, a tool which is used to measure, plan, monitor, and evaluate the practices is essential to improve productivity.

A systematic review of the literature has been conducted to identify the knowledge gap. Accordingly, previous studies did not identify the management practices that have the potential to enhance productivity in the context of multi-storey building projects, prepare scoring tools for measuring these practices, and develop tools for predicting the probability of exceeding baseline productivity based on a score of the practices. The Construction Industry Institute (CII) has developed two scoring tools for infrastructure and industrial projects in North America. Analysis of the existing tools indicates that the scoring tools are not interchangeable. Some practices which are suitable to improve productivity in industrial projects are not important for infrastructure and vice versa. The relative importance of the practices which are common in industrial and infrastructure projects is also different. Thus, the practices for improving productivity in building projects would be different, and the relative weights of the practices would also be different; consequently, new scoring tools should be prepared and validated. The conceptual frameworks of productivity and the management practices in the context of multi-storey building projects in Victoria are presented in the next chapter.

CHAPTER THREE

3 CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter provides the conceptual framework for the study. First, the neoclassical economic growth theory (the growth accounting framework) is described in Section 3.2. Following this section, the preliminary conceptual frameworks for the study have been developed based on the context of the research and the review of relevant literature (Section 3.3 to Section 3.8). The preliminary conceptual frameworks of productivity and construction materials management practices, construction equipment management practices, pre-construction phase management practices, management practices related to construction methods, human resource management practices, and safety and health practices are described in Section 3.3, Section 3.4, Section 3.5, Section 3.6, Section 3.7 and Section 3.8 respectively. Finally, the summary of the chapter is presented in Section 3.9.

3.2 Growth Accounting Framework

This research investigates the under-researched areas (the management practices aspects) of the growth accounting framework. The framework states that capital deepening, technological progress and management practices can increase the labour productivity. The growth accounting framework originates from the neoclassical theory of economic growth formulated by Solow (1956). The theory explains that the increase in labour force, capital accumulation, and technological progress lead to the rise in output. According to the theory, the rise in the labour force and capital will result in a temporary increment in the output because of the diminishing returns to capital and labour. Diminishing returns refers to the decrease in the rate of growth of output when one of the factors of production (for instance, capital) increases while the amount of another factor (labour) stays constant and vice versa. For example, in the context of construction, consider a certain building project having an insufficient number of concrete workers and sufficient equipment for the concrete production and placing. If more workers are employed, the in-situ concrete production will increase at the beginning of the process. However, after all the required concrete crew members are deployed, adding more workers might not increase the rate of the concrete production and placement. Similarly, the supply of additional concrete equipment might not increase the production and placement of concrete as the required machinery is already provided to the crew.

Figure 3-1 and Figure 3-2 are plotted to explain the Solow economic growth model. As shown in Figure 3-1, at the beginning of the production process, increasing the capital per worker (k) from k_1 to k_2 leads to an increment in the output per worker (y) from y_1 to y_2 and the rate of growth of the output per worker is high or the slope of the production function is steep. However, due to the diminishing returns to capital, the increment of capital per worker will not lead to a continuous increment of output per labour (refer point k_3, k_4, y_3, y_4 in Figure 3-1). The rate of growth of output per worker after y_3 is very low or insignificant.

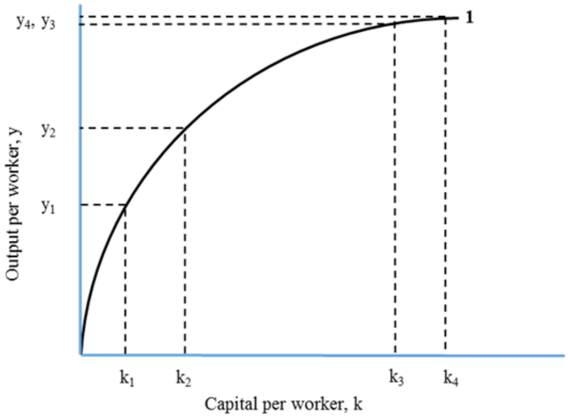


Figure 3-1 Relationship between Capital per Worker and Output per Worker (adapted from Solow (1956))

In Figure 3-2, the effect of technological progress on output per worker (y) is presented. Due to the technical change in the production process, the production graph shifts from the original position 1 to new position 2. The output per worker (y) also increases from point y_4 to point y_5 without a change in capital per worker (k_4).

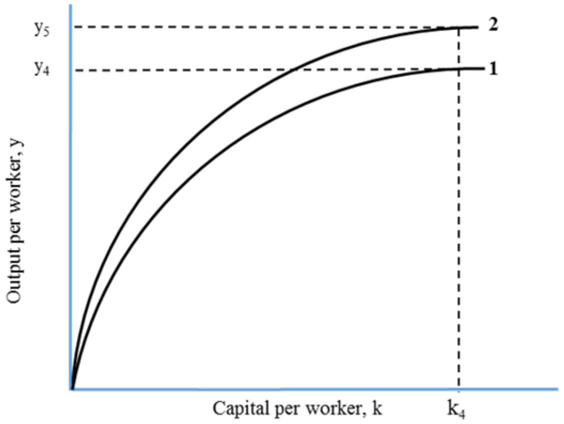


Figure 3-2 The Effect of Technical Progress on Output per Worker (adapted from Solow (1957))

Based on the neoclassical economic growth theory, the growth accounting framework has been developed. The framework states the importance of management practices besides the technological progress in improving labour productivity (Organisation for Economic Co-operation and Development, 2001, Productivity Commission, 2013, Australian Bureau of Statistics, 2015a). The growth accounting framework describes that the labour productivity growth can be achieved through capital deepening and technical progress which includes management practices (Australian Bureau of Statistics, 2015a). Capital deepening or capital intensity refers to changes in capital to labour ratio and increased capital deepening implies that each labour has more capital to work with to produce certain output (Productivity Commission, 2016). According to Australian Bureau of Statistics (2015b), besides the technological advancement, the technical progress which could increase labour productivity include changes in the management practices, economies of scale and scope, and reallocation of capital and labour. Productivity Commission (2013) also indicated that apart from technological progress and innovations, the increment of labour productivity could occur due to changes in the management practices. However, which types of management practices, in which sector or context, are not investigated. Thus, this research explores the practices in the context of multi-storey building construction projects.

The construction management practices that have the potential to enhance labour productivity in construction projects could be categorized into (1) construction materials management practices, (2) construction equipment and tools management practices, (3) management practices related to construction methods, (4) pre-construction phase management practices, (5) human resource management practices, and (6) safety and health practices (CII, 2013a, CII, 2013b). The preliminary conceptual frameworks for the six categories of the construction management practices are presented in the subsequent sections.

3.3 Conceptual Framework of Construction Materials Management Practices and Productivity

The preliminary conceptual framework of productivity and the construction materials management practices is presented in Figure 3-3. The suitability of the practices shown in the hypothetical framework for improving the productivity of multi-storey building projects will be investigated during Phase I of this research and the validated conceptual framework will be developed.

Procurement Plans for Construction Materials

Procurement plan for construction materials could be one of the materials management practices that could enhance productivity in multi-storey building projects. Arditi (1985) mentioned the importance of materials procurement plan as the potential area for productivity improvement in the US construction projects. Arditi and Mochtar (1996) concluded that to achieve maximum project efficiency, the timely procurement of materials is crucial. According to the survey conducted by the authors, improving the procurement practices were given higher priority to enhance construction projects' productivity in Indonesia. Nasir (2013) found that materials procurement plan is one of the best materials management practices for improving productivity in infrastructure projects. Caldas et al. (2014) confirmed that materials procurement plan can enhance productivity in industrial projects. In the context of multi-storey building projects in Victoria, preparing the procurement plans for both critical (long-lead items) and non-critical materials could improve productivity by reducing the project delay due to the unavailability of building materials.

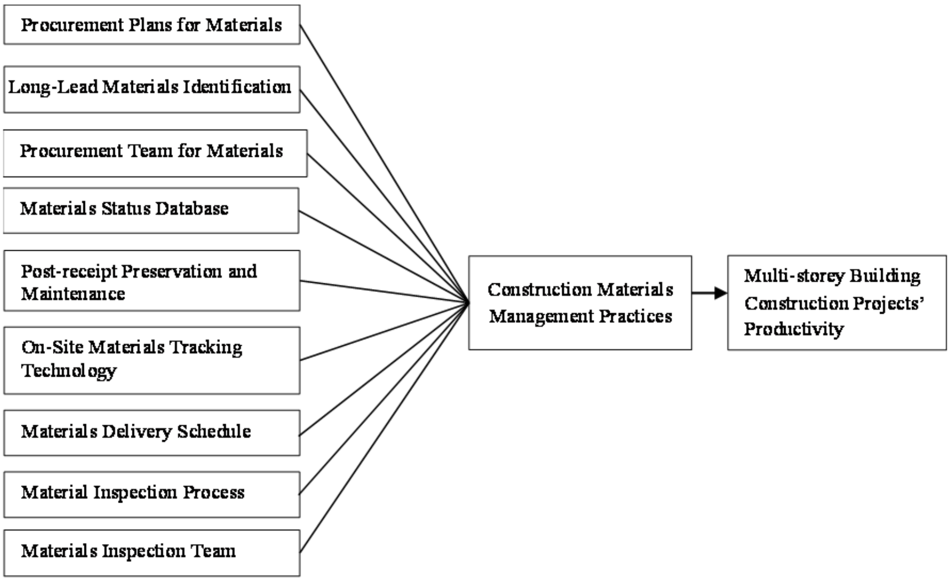


Figure 3-3 Preliminary Conceptual Framework of Construction Materials Management Practices and Productivity

Long-lead Materials Identification

Identification of long-lead (critical) materials could also be one of the practices that have the potential to increase productivity in multi-storey building projects. Abdul

Kadir et al. (2005) recommended that to enhance productivity the project management team should plan ahead to ensure that the critical materials are identified, procured and available on site every time. Jergeas (2009) also suggested that to improve productivity in oil and gas capital projects in Alberta, Canada the project team should ensure the availability of critical materials. The author concluded that look-ahead procurement and logistics plans for these materials are essential for enhancing productivity (Jergeas, 2009). Long-lead materials identification is also considered as the best materials management practice for improving productivity in infrastructure projects in North America (Nasir, 2013). Identification of the long-lead materials and preparation of procurement plan for these materials might also improve the productivity of multi-storey building construction projects in the context of Victoria State, Australia since most of the critical materials are imported from overseas. If these materials are not identified early, then the project could be delayed. According to Wheeldon (2012), most building materials are purchased from abroad due to the rising costs of manufacturing in Australia. Figure 3-4 shows the manufacturing price indexes of architectural aluminium, paint and coatings, ceramics, and glass products from 2002 to 2016. Accordingly, the prices of the selected building materials are increasing. The proposition that long-lead materials identification is one of the potential areas for the enhancement of the Victorian multi-storey building construction projects' productivity will be verified.

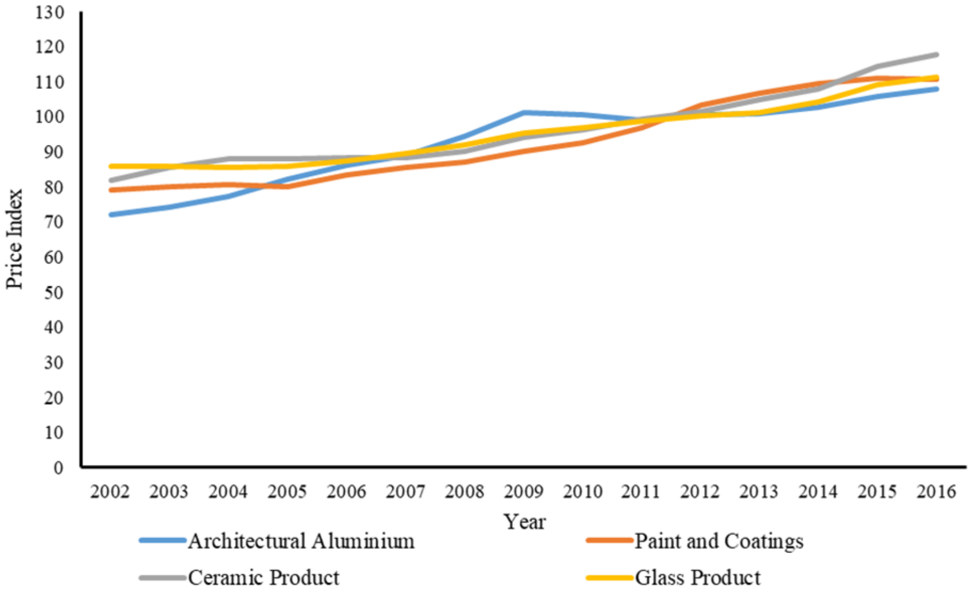


Figure 3-4 The Manufacturing Price Indexes of Selected Building Materials (Plotted using data obtained from Australian Bureau of Statistics (2017))

Materials Procurement Team, Materials Status Database, and Post-Receipt Preservation

Assigning the materials procurement team, controlling the status of materials on site, and maintenance of the received materials could also be considered as some of the materials management practices that could enhance productivity in building projects. Jergeas (2009) recommended that dedicated follow-up of the materials procurement activities is essential to improve productivity since the practice can reduce the workers' idleness. Nasir (2013) concluded that forming materials procurement team; keeping track of the quantity of the utilised materials and identifying the remaining materials; and preservation of the received materials on construction sites are the practices that have the potential to improve productivity in infrastructure projects. Furthermore, Caldas et al. (2014) identified that materials status database and preservation of construction materials are the best practices for increasing productivity in industrial construction projects in North America. In the context of Victorian multi-storey building construction projects, as the majority of the building materials are imported from overseas, the assignment of materials procurement team could be essential to follow up the procurement process. Furthermore, the preservation and maintenance of the construction materials on multi-storey building construction sites in Victoria could also be essential. If the materials are not maintained and damaged on site, it could take a long time to procure and replace the damaged materials. As a result, the productivity of the project could be affected.

On-site Materials Tracking Technology

The use of materials tracking technology on multi-storey building construction sites could also be one of the potential areas where productivity gain could be obtained. Grau et al. (2009) assessed the impact of materials tracking technologies on crafts' productivity and quantified the impact of automating, identifying and localising engineered components on productivity in industrial projects. The results of the study indicated that materials tracking technologies can significantly improve productivity. Nasir et al. (2010) confirmed that the implementation of on-site material tracking technology on industrial projects such as refineries and power plants can improve productivity. Similarly, the implementation of materials tracking technology has been confirmed as one of the best practices that enhance productivity in infrastructure and industrial projects (Nasir, 2013, Caldas et al., 2014). For multi-storey building projects in Victoria, the use of materials tracking technologies could also help contractors to identify where a particular material or its components are located on building sites. Consequently, the time spent by the workers to search the materials can be reduced, and productivity could be improved.

Materials Delivery Schedule

The preparation of materials delivery schedule could also be one of the materials management practices that could improve productivity in multi-storey building projects. Arditi (1985) mentioned that materials delivery plan and schedule are among the potential areas for productivity improvement in construction projects in the US. Bell and Stukhart (1987) identified materials planning as one of the most critical materials management systems (MMS). Nasir (2013) confirmed that materials delivery schedule is the best materials management practices for improving productivity in infrastructure projects. Caldas et al. (2014) also confirmed that materials delivery schedule is the best practice for enhancing productivity in industrial projects. Likewise, El-Gohary and Aziz (2014) suggested the importance of materials delivery plan in increasing the construction projects' productivity in Egypt. In the context of multi-storey building projects in Victoria, materials delivery schedule could also be an important practice to improve productivity. If the materials delivery schedule is prepared, and the materials are supplied to a site as per the schedule, disruptions to other schedules such as crane usage schedules can be minimised. For instance, in the absence of materials delivery schedule, many materials might be delivered to a building site at the same time; consequently, some materials might not be lifted to the required working level due to the disruption of the crane schedule. Furthermore, the project site can be overcrowded, and productivity could be influenced.

Materials Inspection Process and Materials Inspection Team

Developing materials inspection process and formation of materials inspection team for a certain multi-storey building project could improve its productivity. Makulsawatudom et al. (2004) suggested that careful inspection of construction materials could be one of the potential areas where productivity can be gained in the construction projects in Thailand. Arditi (1985) mentioned the significance of checking the product availability and standardisation as a potential for increasing construction projects' productivity.

Similarly, materials standardisation and checking the product availability by the designer are identified as factors which have positive impacts on construction projects' productivity in Indonesia (Arditi and Mochtar, 1996). El-Gohary and Aziz (2014) also recommended the preparation of painstaking documentations for materials specifications to reduce the adverse effects of factors affecting productivity. The preparation of materials inspection strategy and the formation of inspection teams for multi-storey building construction projects in Victoria might also improve productivity. Inspecting the critical materials during the manufacturing process as well as before they are supplied to a building site can reduce the project delays due to the rejection of non-conforming materials during the construction phase.

3.4 Conceptual Framework of Construction Equipment Management Practices and Productivity

Based on a review of previous studies, a preliminary conceptual framework of the construction equipment and tools management practices and productivity in multi-storey building projects is developed (Figure 3-5). The framework will be modified based on the findings of Phase I of the study in which the relevant independent variables (construction equipment and tools management practices that improve productivity in multi-storey building projects in Victoria State, Australia) are identified.

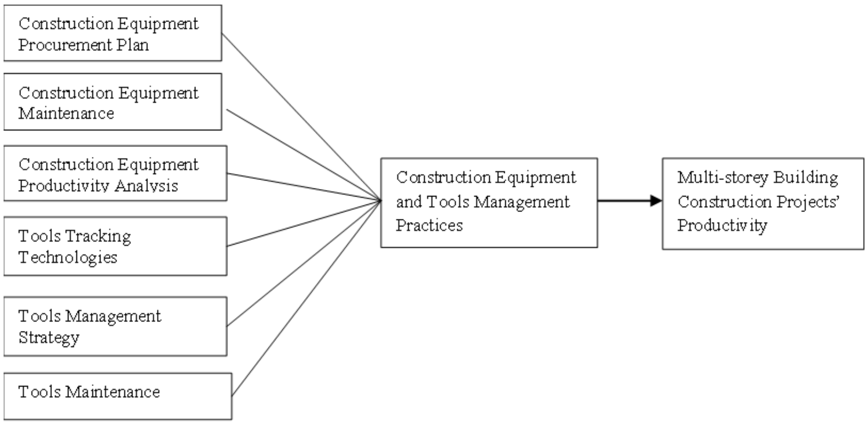


Figure 3-5 Preliminary Conceptual Framework of Construction Equipment Management Practices and Productivity

Construction Equipment Procurement Plan

Construction equipment procurement plan could be one of the construction equipment management practices that could enhance the productivity of multi-storey building construction projects. According to Prasertrungruang and Hadikusumo (2007), good equipment acquisition strategy is one of the success factors in construction projects.

Stewart (2002b) recommended the preparation of equipment procurement plan to reduce productivity loss due to the shortage of equipment on construction projects. Stewart (2002a) suggested that when there are many projects in the industry and/or when there is high workload on a certain construction project, the construction equipment should be leased for a longer time to reduce the loss of productivity. Procurement procedures and plans are also found to be the best practices that have the potential to improve productivity in industrial projects (Caldas et al., 2014). Thus, construction equipment procurement planning might also be one of the practices that could increase productivity in multi-storey building projects in the context of Victoria as the practice might help to reduce stoppage of building construction works due to shortage of construction equipment in the state.

Construction Equipment Maintenance

Preventive maintenance of construction equipment could also be one of the equipment management practices that could enhance the productivity of multi-storey building construction projects. Wireman (2005) described that equipment maintenance has the potential to increase the profitability of contractors by increasing the availability of equipment and by reducing the number of unexpected breakdowns or service interruptions. According to the author, preventive maintenance activities such as lubrication program, routine inspections, and adjustments should be conducted to avoid potential problems that can be corrected before they happen. Arditi (1985) concluded that machinery maintenance is one of the possible areas where productivity gain could be obtained in the US construction projects. Similarly, Arditi and Mochtar (1996) identified maintenance of construction equipment as one of the potential areas where productivity improvement can be attained in the construction projects in Indonesia. For multi-storey building construction projects in Victoria, equipment such as cranes and hoists might need preventive maintenance as their stoppage could influence activities on a critical path whose delay might affect an overall projects' progress. Thus, implementation of this practice could improve productivity.

Construction Equipment Productivity Analysis

Analysing the performance of construction equipment could be another equipment management practice that could increase the productivity of multi-storey building construction projects. Crespo Márquez and Sánchez Herguedas (2004) described that good record keeping during the operation of the equipment helps contractors to analyse the performance of the machinery and to take corrective actions. Nasir et al. (2015) found that construction equipment productivity analysis is one of the best practices that could improve productivity in infrastructure projects. Analysing the performances of various equipment and choosing the most suitable construction machinery for a certain multi-storey building project in Victoria could help contractors to reduce unnecessary cost and increase productivity.

Tools Tracking Technologies

The use of tracking technologies such as bar codes and radio frequency identification (RFID) could also have important applications in tools management. The technology can be used to identify the location of tools, the date when the item is checked out, and the person who took the tool. Morse (1990) recommended the tracking technology to reduce theft and to track the location of the tools. Goodrum et al. (2006) explained the significance of tools availability for improving productivity and developed a tool tracking and inventory system which is capable of storing operation and maintenance data using RFID tags. As the construction of multi-storey building projects might involve numerous tools, tracking technology could be necessary to enhance their productivity.

Tools Management Strategy and Tools Maintenance

Tools management strategy and tools maintenance could be other tools management practices that could enhance productivity in multi-storey building construction projects. Morse (1990) found that authorising the tool manager to purchase some tools is one of the efficient tool management systems. Similarly, tools and consumables management strategy are recommended as the potential area for productivity improvement in industrial projects (Caldas et al., 2014). Finally, conducting onsite tool maintenance is found to be one of the best practices for improving productivity in infrastructure projects (Nasir, 2013). The author suggested that pre-maintenance activities such as identification of the tools which need maintenance, planning the date when maintenance will be conducted, and assigning qualified personnel are essential practices. Efficient tools management systems could also be important for multi-storey building projects in Victoria as the damage or loss of the tools might influence the productivity of the projects.

3.5 Conceptual Framework of Management Practices Related to Construction Methods and Productivity

Project management methods are defined as a system of practices, techniques, procedures, and rules used by those who work in the discipline (PMI, 2013). In construction projects, the techniques of integration of different schedules; schedule controlling methods; mechanisms used in the preparation of site layout; project start-up and completion procedures; and investigation of suitable technologies could be some of the methods that could enhance productivity in multi-storey building construction projects. The preliminary conceptual framework of the management practices related to construction methods and productivity is shown in Figure 3-6. The framework will be validated before conducting Phase II of this research.

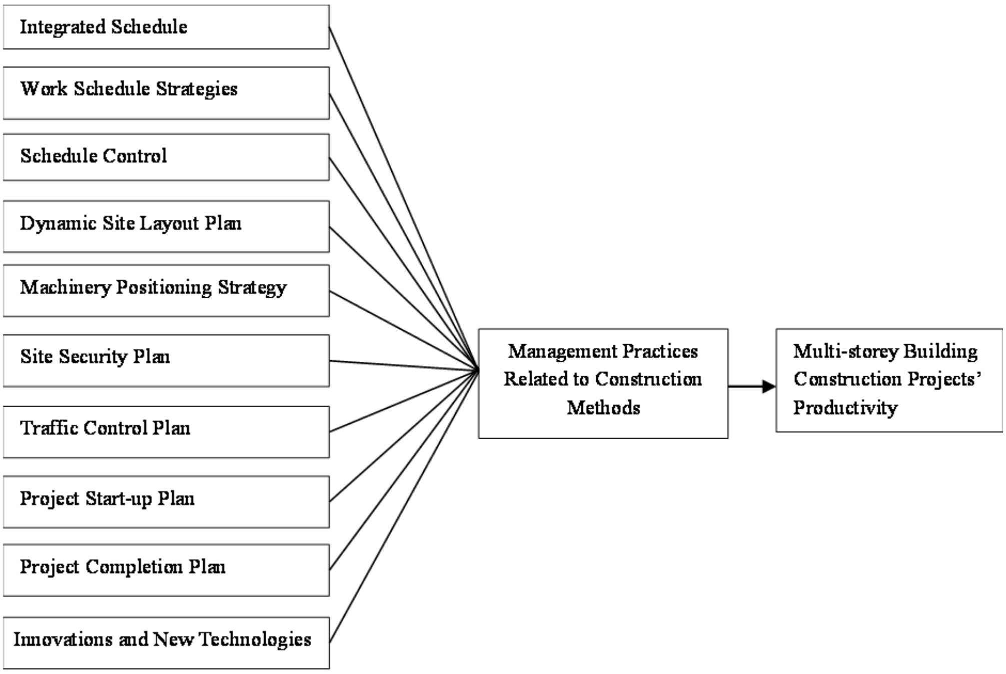


Figure 3-6 Preliminary Conceptual Framework of Management Practices Related to Construction Methods and Productivity

Integrated Schedule

The use of integrated schedule during construction period could be considered as a good practice to increase productivity in multi-storey building construction projects. Arditi and Mochtar (1996) suggested integration of management functions is one of the areas where productivity gain could be obtained. The study indicated that combination of cost and schedule control is one of the critical success factors in completing the project on time. Caldas et al. (2014) confirmed that integrated schedule is one of the best practices for improving productivity in industrial projects. The integration of work schedule, materials procurement and delivery schedule, budget and other information required for the execution of multi-storey building projects in Victoria could be essential for enhancing their productivity. If all the required information is found on the same page or interconnected, then the project team can easily track and control the progress of the construction of a multi-storey building project.

Work Schedule Strategies

The practices of adopting different working hours strategies could also be another potential area for productivity improvement in multi-storey building projects. Hanna et al. (2008) found that shift schedule is effective as compared to overtime and overmanning in reducing the project duration. The authors opined that the use of shift schedule reduces physical fatigue and site congestion that could occur if overtime and overmanning practices are implemented. Scheduled overtime is also suggested as a practice that has a positive impact on productivity as it builds the morale of employees (CII, 2013a). According to the Environmental Protection Authority of Victoria (EPA), the normal working hours for most projects should be between 7:00 am and 6:00 pm on weekdays (EPA, 2016). Contractors in Victoria are also required to work as per the calendar prepared by the Construction, Forestry, Mining and Energy Union (CFMEU) which is typically 36 hours per week (CFMEU, 2016a). Given the working hours restrictions set by authorities such as Environmental Protection Authority and the CFMEU, adopting various working hours strategies such as scheduled overtime for critical and nearly critical tasks could be essential practices for delivering multi-storey building projects within the contract time.

Schedule Control

The use of appropriate project schedule controlling techniques for different activities is another area where multi-storey building projects' productivity gain could be obtained. The controlling techniques include the methods used to measure the work progress, to analyse the data, to report the status and to take corrective actions. Some of the techniques of measurement include units completed, incremental milestone, start/finish, and manager or supervisor judgment (Neil and Knudsen, 1990, Attalla, 1997). According to the authors, the units completed is recommended for tasks that can be measured easily such as concrete, steel, and excavation; the incremental milestone method is suitable for an activity with different sub-activities, for example, three coats of cement sand plastering, that should be handled in sequence and each sub-activity is allocated certain percentage upon their completion; the start/finish technique is suitable for tasks that do not have clearly defined intermediate milestone and/or the time required for their execution is difficult to estimate, for instance, testing lift; and subjective judgment of the supervisor is appropriate technique when the task is minor in nature such as installing architectural trim. Some of the analysis techniques include the progress curve or S-Curve and time variance analysis (Attalla, 1997). In the context of multi-storey building projects in Victoria, delay in the progress of an activity on a critical path could affect the progress of other activities and lead to overall project delay. Thus, implementation of the suitable schedule controlling techniques might be an important practice to monitor the execution of the activities as per their schedules and to reduce delays.

Dynamic Site Layout Plan

The implementation of the practice dynamic site layout could also enhance productivity in multi-storey building projects. Dynamic site layout refers to a sequence of layouts each of which is used for a discrete time interval or for a certain project phase, and together covering the entire duration of a construction project (Tommelein and Zouein, 1993). Previous researchers developed a dynamic site layout models and indicated the significance of implementing the techniques to enhance productivity (Tommelein et al., 1992, Tommelein and Zouein, 1993, Elbeltagi et al., 2004). As most multi-storey building construction projects in the central business district of Melbourne, Australia, have restricted working spaces, the use of dynamic site layout plans could help contractors in reducing congestion on sites. By using the dynamic site layout plan some parts of a building, which is under construction, can be used as a store, office and other temporary facility allowing early start of the external works.

Machinery Positioning Strategy, Site Security Plan, and Traffic Control Plan

Construction machinery positioning strategy might also be an important practice that has the potential to enhance productivity in multi-storey building projects. Choi and Harris (1991) proposed a mathematical model for determining the most suitable tower crane location for building projects. Similarly, Zhang et al. (1999) developed a computer model to optimise the location of a group of tower cranes. Safe Work

Australia prepared a code of practice to assist contractors in preparing good traffic management plans by providing information about traffic signs, the distance between pedestrians and vehicles, and vehicles movement (Safe Work Australia, 2014c). Investigation of the most appropriate location for a crane could also be significant to increase productivity in multi-storey building projects in Victoria. If the crane is positioned wrongly, its relocation cost could be high, and productivity could be lost. Thus, developing a strategy to position the crane using different models might be an essential practice. The integration of the traffic control plan and site security plan with the site layout plan could also be significant to enhance the productivity of the multi-storey building projects. Since most construction materials in Australia are imported from overseas, any loss or damage to them could incur the loss of productivity due to unavailability of the materials locally. Thus, site security plans might be an important practice to reduce theft and loss of materials. Traffic control plans could also be an essential practice as there are various local traffic regulations such as Road Safety (Traffic Management) Regulations 2009 that could suspend the construction of multi-storey projects due to noncompliance with the regulation.

Project Start-up and Project Completion Plans, and New Technologies

Project start-up plan and project completion plan might also be some of the management practices that have the potential to enhance productivity in multi-storey building projects. Fangel (1984) recommended that to reduce delays related to project start-up, the project team should prepare a project management manual that contains the details of pre-commencement activities. The author also suggested project start-up meetings prior to commencing a construction project. Kerzner (2010) proposed project kick-off meetings as one of the best practices that should be included in the project start-up process. Nasir (2013) found that project start-up plan, project completion plan, and innovations and new technologies are some of the best practices to enhance productivity in infrastructure projects. In the context of multi-storey building projects in Victoria, since various subcontractors could finish their works at different times, the principal contractor should plan when to receive certificates of the completed works by each subcontractor. Thus, completion plans could be a noteworthy practice to facilitate the handover of a multi-storey building project to the client. New technologies might also be essential in multi-storey building construction projects. For instance, to detect clashes among engineering services, the software could be used to develop 3D models which help to visualise the services lines.

3.6 Conceptual Framework of Pre-Construction Phase Management Practices and Productivity

The preliminary conceptual framework of productivity and preconstruction phase management practices is presented in Figure 3-7. The suitability of the independent variables (the preconstruction phase management practices) to improve the productivity of multi-storey building projects will be confirmed during Phase I of this research, and the framework will also be validated.

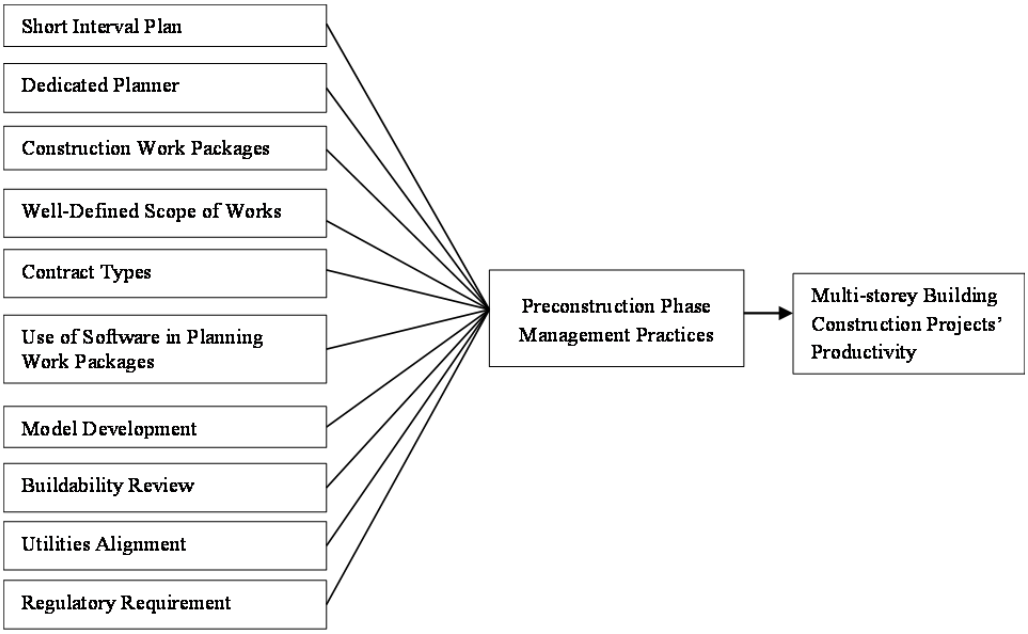


Figure 3-7 Preliminary Conceptual Framework of Preconstruction Phase Management Practices and Productivity

Short Interval Plan

The preparation of short interval plan could be one of the construction management practices that could enhance productivity in multi-storey building projects. According to Hamzeh et al. (2008), look ahead planning (short interval planning) denotes the production planning having a time frame which usually spans between two to six weeks in which activities are broken down into the level of operations. Hadavi and Krizek (1993) concluded that the implementation of short-interval goals which consists of a day to day activities of the craftsmen can lead to higher construction projects' productivity. Waly et al. (1999) described that the short interval plans can increase productivity by reducing the nonproductive hours due to waiting for the resources. The authors have also developed a model that is used to generate the short interval schedules (SIS). Tucker (1986) recommended that planning is the most important practice to improve construction productivity. Doloi (2008) found that increasing the level of preplanning and programming is the most critical factor to increase the productivity of construction projects. Huang et al. (2009) mentioned planning as an important management practice that could positively affect productivity. For multi-storey building construction projects in Victoria, the preparation of the short interval plan could also enhance their productivity since the plan can help the contractors' project managers to clearly identify the day to day activities including the resources required for the execution of the activities. The construction materials delivery schedule and crane utilisation schedule can also be prepared based on the short interval construction work schedule, and the loss of productivity due to waiting for the construction materials could be minimised.

Dedicated Planner

The assignment of a dedicated planner for a certain multi-storey building project could also be one of the practices that could enhance its productivity. COAA (2013b) recommended the assignment of a dedicated planner for the increment of on-site productivity since the dedicated planner can prepare detailed installation work plans which are subjected to minor revisions during the implementation phase. CII (2013b) identified the employment of committed planners as the potential areas for improving the productivity of infrastructure projects. The preparation of master work schedule and short interval work schedules for the construction of multi-storey building projects in Victoria by dedicated planners could also be essential to increase productivity. The planners might have sufficient data and experience that enable them to prepare schedules which need minor revisions.

Construction Work Packages

The preparation of manageable construction work packages (CWP) could be one of the preconstruction phase management practices that have the potential to improve the productivity of multi-storey building projects. According to the Construction Owners Association of Alberta (COAA), construction work package is defined as 'an executable construction deliverable that defines in detail a specific scope of work and includes a budget and schedule that can be compared with actual performance' (COAA, 2013a).

The Construction Industry Institute (CII) identified that the preparation of manageable construction work packages is one of the best practices for enhancing productivity in industrial and infrastructure projects (CII, 2013a, CII, 2013b). Nasir (2013) also verified that the implementation of the practice construction work package can enhance productivity in infrastructure projects in North America. In Australia, since the 'managing contractor' is the commonly practised delivery model in multi-storey building projects (Austroads, 2014), the principal contractors need to prepare a manageable and complete work package by considering the capacity of the local subcontractors.Thus, the implementation of the practice 'construction work packages' could be essential to enhance the productivity of the multi-storey building projects.

Well-Defined Scope of Works

Well-defined scope of works could also be one of the practices that have the potential to increase the productivity of multi-storey building projects. Defining the scope refers to the development of a common understanding as to what to include or exclude from a certain work package (Turbit, 2005). PMBoK (2000) recommended that the project scope needs to include all the necessary works and only the essential works to complete the project successfully. Jergeas (2009) found that clearly defining the scope of works in oil and gas projects in Canada is a good practice to enhance the performance of the projects. Liao (2008) concluded that industrial projects with better scope definition also have better construction productivity. For multi-storey building construction projects in Victoria, defining the scope of works could improve productivity since the practice can reduce the interference among the craftspersons or subcontractors. If the scope of works is well-defined, the conflict between the crews (subcontractors) that execute successive tasks can be minimised, and those who carried out the defective works or missed the execution of a certain activity can easily be identified and corrective actions can be taken accordingly.

Contrat Types

Selection of appropriate construction contract types could also be one of the preconstruction phase management practices that could enhance productivity in multi-storey building projects. Contract types such as a lump sum, unit price, and cost-plus denote the agreement of how the subcontractor is paid for the work it has executed (Gordon, 1994). Jergeas (2009) indicated that the contractual strategy adopted for a certain construction project is one of the key factors for successful completion of the project. The study suggested that the use of lump sum contracts as good practice for productivity. Arditi and Mochtar (1996) found that construction management contracting (CM) is the preferred delivery method to increase productivity in Indonesian construction projects. Lavender (2014) suggested that ‘construction management’ is the delivery method that is preferred for completing projects early, and the method allows the involvement of a client. The choice of suitable contract types by the contractors operating in Victoria could assist them to enhance the productivity of their multi-storey building construction projects. For instance, if the main contract (the contract between the client and principal contractor) is lump sum type, the principal contractor could also choose the lump sum subcontract type to share the risks (cost overruns and project delays) with the respective subcontractors. Furthermore, if the main contract allows the principal contractor to carry out design revisions or minor amendments, including the statements which authorise the subcontractors to make minor design modifications in the subcontract agreements could be essential to reduce the loss of productivity related to the designs.

Use of Software in Planning Workpackages and Model Development

The use of software in preparing the construction work packages and the development of 3D models could be some of the potential areas where productivity of the multi-storey building projects could be increased. Kang et al. (2008) and O’Connor and Yang (2004) concluded that there is a strong correlation between schedule performance and the use of IT. Rojas and Aramvareekul (2003) recommended the enhanced use of IT systems in construction projects as one of the potential areas for productivity improvement. Arditi and Mochtar (1996) identified the application of computer in scheduling as the practice which could increase productivity. Thomas et al. (2001) concluded that as the implementation of three-dimensional (3D) modelling using computer-aided design (CAD) increases, the schedule performances of the projects also increase. Caldas et al. (2014) identified the ‘utilisation of software in generating work packages’ and ‘project model development’ as the best practices that improve productivity in industrial projects. For multi-storey building construction projects in Victoria, the use of software in planning can help to reduce the human errors in breaking down of the works and in defining the activities as well as their sequences appropriately. Thus, productivity could be enhanced as the interference between the subcontractors or construction crews decreases due to the clarity of the sequences of the activities. Furthermore, the use of 3D models in multi-storey building projects, which involve the intertwining of different engineering services such as mechanical, electrical and planning, could help the project team to reduce the overlapping of the services and to improve on-site productivity.

Buildability Review

Conducting buildability review before the implementation of the building designs could also be important practice to enhance the productivity of the multi-storey building projects. Poh and Chen (1998) confirmed the positive relationship between productivity and buildability. The authors investigated the buildability of 37 building projects in Singapore and found that projects with higher buildability reviews also have higher productivity. El-Gohary and Aziz (2014) suggested that increasing the buildability level of design is the first step in improving productivity in Construction projects in Egypt. Jergeas (2009) mentioned that conducting the buildability reviews on a regular basis throughout the project phases can increase the project performance. Therefore, the implementation of the practice buildability review in multi-storey building projects in Victoria could also improve the projects’ productivity. The involvement of construction team in the design process could help to reduce the loss of productivity due to the design problems.

Utilities Alignment and Regulatory Requirement

Prior identification and adjustment of the utility lines such as water, electricity, gas and telecommunication, and the identification of the regulatory requirements can be some of the practices that could increase productivity in multi-storey building projects. Nasir (2013) and CII (2013b) confirmed that the adjustment of utility lines and the identification of the regulatory requirements are some of the potential areas for productivity improvement in infrastructure projects. In the context of Victoria, since contractors are required to obtain various permits, the prior identification of the regulatory requirements could help them to reduce the loss of productivity associated with the suspension of the projects. For instance, the contractors working in the City of Melbourne should get their construction management plan (CMP) approved. Also, they need to get many permits such as a permit to erect a gantry, construction zone permit, working outside prescribed hours permit and others (City of Melbourne, 2005). Thus, early identification of the type of permits and getting approvals from the concerned authority could help to reduce the chance of stopping the construction activities due to the non-compliance with the local regulatory requirements. Similarly, as the damage to the public utilities during excavation works could result in the suspension of the construction of projects, identification and protection of the existing utility lines before commencing the construction works could be an essential practice.

3.7 Conceptual Framework of Human Resource Management Practices and Productivity

In Figure 3-8, the hypothetical conceptual framework of productivity and the human resource management (HRM) practices is presented. The suitability of the proposed HRM practices in the context of multi-storey building projects in Victoria will be verified after collecting and analysing the qualitative data.

Financial Incentive Programs

The amount and timeliness of remuneration, as well as the incentive schemes, could be one of the human resource management practices that could enhance productivity in multi-storey building projects. Maloney (1983) identified that sharing the profit obtained from a project is one of the effective programs for construction productivity improvement. Kazaz and Ulubeyli (2007) concluded that incentive payments, the adequacy of the workers' payment as compared to others who are working on similar projects and making payment on time are the most important factors that increase workers' motivation. Dai et al. (2009a) mentioned the importance of equal pay in the same geographical area as one of the factors influencing productivity. Furthermore, Jergeas (2009) investigated the importance of sharing the incentive or bonus among the tradesmen, foremen and management staff for increasing project performance. Therefore, motivating the construction workers involved in multi-storey building construction projects in Victoria by providing financial incentives could improve the projects' productivity since the motivated workers could exert high levels of efforts which help them to achieve a higher level of productivity.

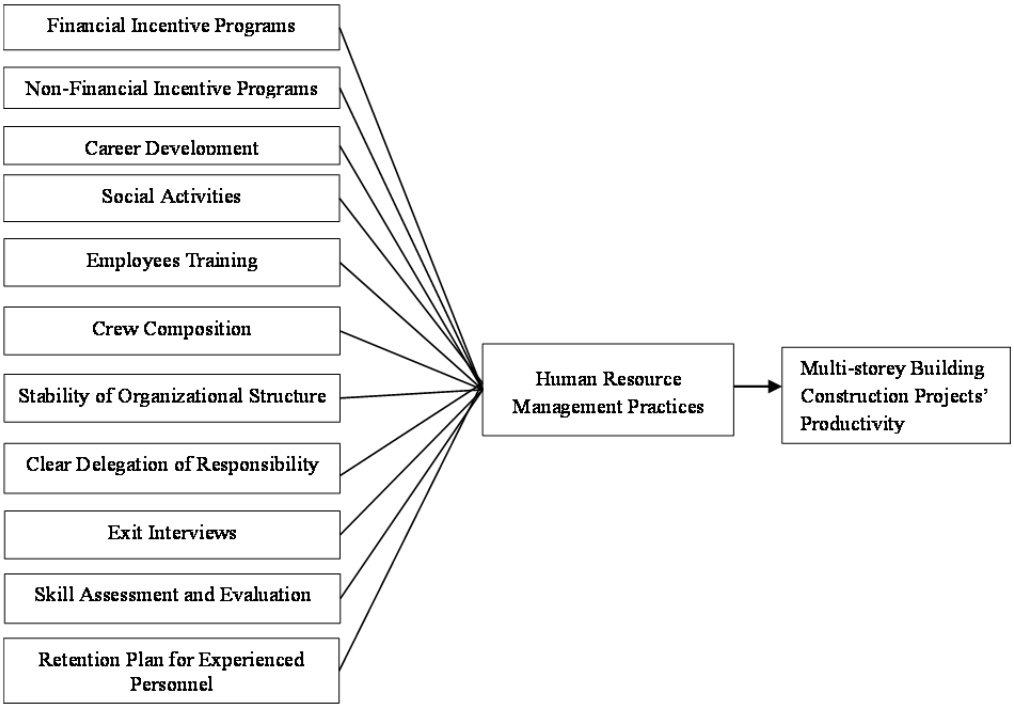


Figure 3-8 Preliminary Conceptual Framework of Human Resource Management Practices and Productivity

Non-financial Incentive Programs

Besides the financial incentives, provision of non-financial incentives to construction workers could also be an essential practice that could enhance the productivity of multi-storey building construction projects. Luthans (2000) concluded that recognition is one of the most effective leadership tools that improve the performance of employees. Graham and Unruh (1990) cited in Luthans (2000), suggested the mechanisms for operationalization of the non-financial reward systems include congratulating an employee for a job well done; writing a personal note and publicly recognising an employee for good performance; and conducting morale-building meetings to celebrate successes. Fagbenle et al. (2004) compared the performances of construction projects that have implemented non-financial incentives with projects that have not implemented the incentives schemes and found that the productive time of bricklayers who received non-financial incentive is improved significantly. For multi-storey building construction workers in Victoria, providing non-financial incentives such as job recognition and appreciation by the contractors could also play a vital role to build the morale of employees and to achieve better performance.

Career Development Plan and Social Activities

Organising social activities and preparing the career development plans for construction workers can be some of the human resource management practices that could enhance productivity in multi-storey building construction projects. Hewage et al. (2011) concluded that the construction productivity cannot be improved by not only working hard and fast but also by developing the social skills of workers. Kazaz and Ulubeyli (2007) identified social activity as one of the socio-psychological factors that influence construction projects' productivity in Turkey. Tabassi et al. (2012) described that a well-organized human resource development program is an essential strategy for construction firms as human capital play a significant role in the success of an organisation. In the context of multi-storey building construction projects in Victoria, the use of social activities could enhance the productivity of the projects as these events can help to increase the team spirit among the crew members. Similarly, the career development plans could motivate employees and enhance their performance.

Employees Training

Employees training is also one of the human resource management practices that could increase productivity in multi-storey building construction projects. Wang et al. (2010) found that training craftsmen can increase productivity by 5%, decrease absenteeism by 2.5% and reduce turnover by 10%. Allmon et al. (2000) suggested that training employees to be multi-skilled workers can enhance productivity in construction projects. Rojas and Aramvareekul (2003) found that activity-specific training is the second major productivity driver in the manpower category. The authors recommended that before commencing execution of any task, formal education and training or site-specific training should be provided to the construction workers. Jergeas (2009) recommended that training the low-level supervisors and site staff as well as investing in apprentice training programs are essential practices that should be implemented to enhance project performance. By the same token, various studies identified employees training as an essential practice for productivity (Arditi, 1985, Arditi and Mochtar, 1996, Hewage et al., 2011, Tabassi et al., 2012). Therefore, training construction workers involved in multi-storey building construction projects in Victoria can also be one of the practices that could enhance the productivity of the projects. The training can help the employees to execute good quality works which might not be rejected by their supervisors. Consequently, reworks can be minimised and the time spent to rectify the defects can be saved.

Crew Composition, Organisational Structure and Clear Delegation of Responsibilities

Crew formation, maintaining the stability of the organisational structure and clearly specifying the duties and responsibilities of construction workers can also be some of the human resource management practices that could increase productivity in multi-storey building construction projects. Maloney (1983) mentioned that team building practice is one of the approaches which enhance the forces acting to increase the productivity of labour. Liberda et al. (2003) also identified crew composition and team spirit as the most significant practices under human and management category. Caldas et al. (2014) identified the stability of organisational structure as the best practice that has a potential to increase the productivity of industrial projects. Likewise, CII (2013b) recommended that to keep the organisational structure stable, changes in key personnel should be avoided; plans on how to incorporate any unusual staff changes have to be prepared; and clauses which prohibit or reduce the replacement of key personnel should be included in the contract document. Nasir (2013) identified clarifying the delegation of the responsibilities of personnel as one of the best practices for enhancing productivity in infrastructure projects. In the context of Victorian multi-storey building construction projects, the formation of construction crews that have different skill levels, clarification of the employees' roles and maintaining the stability of the projects' organisational structure could also help to enhance the projects' productivity. These practices can assist the project managers to have crews having necessary skills and experience. The practices could also help workers to know the persons who are responsible for resolving specific problems that hamper their performances. Additionally, the knowledge and skills obtained from the particular project could be retained.

Exit Interviews and Skill Assessment

Conducting exit interviews and skill assessment could be some of the practices that could enhance productivity in multi-storey building projects. Kazaz and Ulubeyli (2007) described that conducting regular interviews and understanding the problems of the construction workers are some of the socio-psychological factors that influence the productivity of construction projects. According to CII (2013a) and CII (2013b), exit interviews, and skill assessment and evaluation are the best human resource practices for increasing productivity in infrastructure and industrial projects. Dai et al. (2009a) mentioned the importance of conducting construction workers' performance reviews and taking corrective actions to enhance the productivity of construction projects. Moreover, Nasir (2013) found that doing skill assessment and evaluation by checking employees' previous experience and certificates before commencing the execution of any task can help the project manager to form better crews. In multi-storey building construction projects in Victoria, conducting exit interviews could assist contractors to get information regarding the problems that hamper the productivity of their projects. Employees who quit their jobs could provide reasons which demotivate them. Based on the identified problems, the contractors can take corrective actions which help to enhance the productivity of the projects.

Retention Plan for Experienced Personnel

Retention plan for experienced personnel can also be an important practice to increase the productivity of multi-storey building projects. Employee retention is a process of encouraging employees to stay with the organisation for maximum possible time (Narang, 2013). According to Hong et al. (2012), effective human resource management practices such as employee empowerment, training and development, appraisal system and compensation are the principal factors for employee retention. Kakar et al. (2015) confirmed that employee retention is positively associated with employee empowerment, training and development; and compensation. In multi-storey building construction projects in Victoria, the practice 'retention of experienced employees' could be important as it helps to retain the knowledge and skills gained during the construction of the specific projects. The knowledge, in turn, helps contractors to be more competitive and productive.

3.8 Conceptual Framework of Safety and Health Practices and Productivity

The preliminary conceptual framework of productivity and safety and health practices is shown in Figure 3-9. Eight independent variables (safety and health practices) which will be verified during Phase I of this research are proposed based the review of the literature.

Safety and Health Policy

Preparation of safety and health policy for multi-storey building construction projects could be important practice to enhance their productivity. According to Worksafe Tasmania, a safety and health policy is a written statement which shows the commitment of a construction company's management and workers to reduce the risks to the safety and health of construction workers, visitors, and others who might be affected during the construction process (Worksafe Tasmania, 2016). Sawacha et al. (1999) found that organisational policy on safety is the most dominant factor that influences the safety performance of construction projects in the UK. The authors recommended that contractors employing five or more personnel must have a safety policy. Jergeas (2009) concluded that ensuring safety program at the project site is crucial in providing a safe work environment. Furthermore, the preparation of formal health and safety policy at a project level is identified as a good safety practice that could increase productivity in construction projects (CII, 2013b). Therefore, preparing safety and health policies for multi-storey building construction projects in Victoria could help to reduce the likelihood of the occurrence of accidents which negatively affect the productivity of the projects.

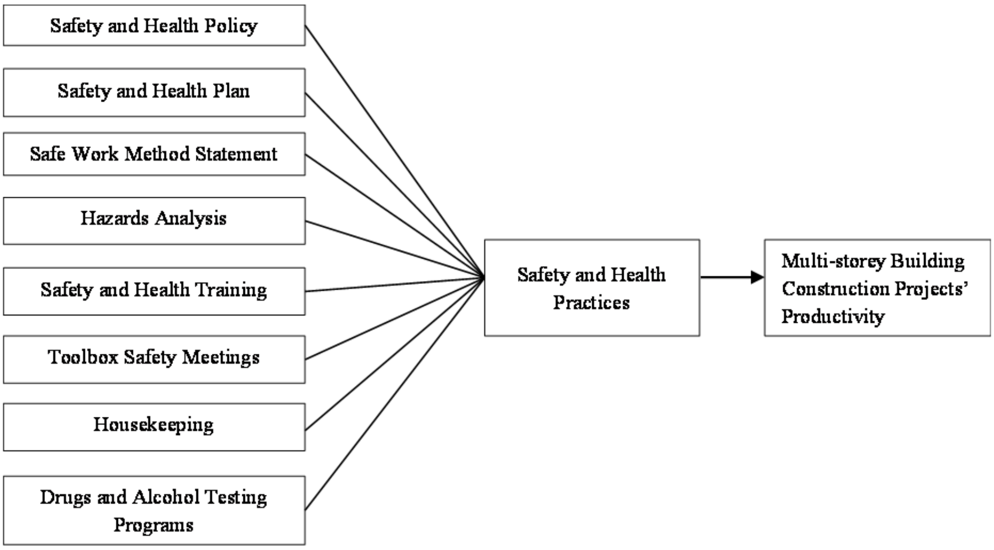


Figure 3-9 Preliminary Conceptual Framework of Safety and Health Practices and Productivity

Safety and Health Plan

Preparation of safety and health plan to reduce the number of accidents on multi-storey building construction projects could also be one of the safety and health practices that could enhance their productivity. According to Safe Work Australia (2011), a workplace health and safety (WHS) plan is ‘a written plan that sets out the arrangements for managing the site health and safety matters.’ The plan includes project-specific safety and health rules and procedures to be followed in receiving, assessing, monitoring and reviewing the safe work method statements (Safe Work Australia, 2011). CII (2013a) found that health and safety planning techniques such as pre-task planning for safety, safety orientation and training, safety incentive programs, alcohol and substance abuse programs, and accident investigations are the best practices that have the potential to improve productivity in industrial projects. Nasir (2013) and CII (2013b) confirmed that zero accident techniques are among the best safety and health practices which could increase productivity in infrastructure projects. In the context of multi-storey building construction projects in Victoria, preparation of project-specific safety and health plan which outlines procedures and techniques to be used in managing safety at the construction sites could help contractors to reduce the occurrence of accidents and to increase the productivity of the workers.

Safe Work Method Statement and Hazard Analysis

The preparation of the safe work method statement (SWMS) for high-risk construction activities and conducting hazard analyses for activities with no SWMS could also be some of the practices that could improve the productivity of multi-storey building construction projects. Hazard is a ‘situation or thing that has a potential to harm a person’, and hazard analysis involves identification of the hazards, assessing the risks and devising the controlling mechanisms (Safe Work Australia, 2011). Accordingly, the use of ladders, incorrectly erected equipment, unguarded holes, falling objects, welding fumes, the presence of asbestos, and hazardous manual tasks are some examples of hazards. Caldas et al. (2014) found that task safety analysis is the practice that has the potential to enhance productivity in industrial projects. Nasir et al. (2015) confirmed that hazard analysis is one of the safety and health practices that can improve productivity in infrastructure projects. For multi-storey building projects in Victoria, analysis of the hazard associated with both high-risk and low-risk construction activities might lead to enhanced productivity since the analysis could minimise the likelihood of the occurrence of accidents on the construction sites. Furthermore, the occupational health and safety regulations in Australia oblige contractors to prepare the Safe Work Method Statement (SWMS). For instance, Work and Health Safety Regulations 2011

Part 6.3 Article 299 and 300 stipulate the obligations of contractors to prepare SWMS. The regulation also specifies the associated penalty of up to 30,000 AUD for the non-compliance. Thus, preparation of SWMS could help contractors to reduce the suspension of their projects and to avoid the penalty.

Safety and Health Training, and Safety Meetings

Providing safety and health training and conducting toolbox safety meetings could be some of the essential practices that have the potential to increase the productivity of the multi-storey building construction projects. Jergeas (2009) concluded that safety training can play a significant role to improve productivity in oil and gas projects in Canada. Dai et al. (2009b) also mentioned the impact of health and safety training on productivity.Toolbox safety meeting is found to be one of the best practices that can positively influence productivity in industrial and infrastructure construction projects (CII, 2013b, CII, 2013a). In the context of Victoria, to ensure the safety of construction workers, WorkSafe Victoria obliges contractors to make sure that the safety training is provided to all employees involved in construction projects (Worksafe Victoria, 2016). Thus, to comply with the regulatory requirements and to reduce the rate of accidents in multi-storey building construction projects, providing safety training as well as conducting regular safety meetings could be essential.

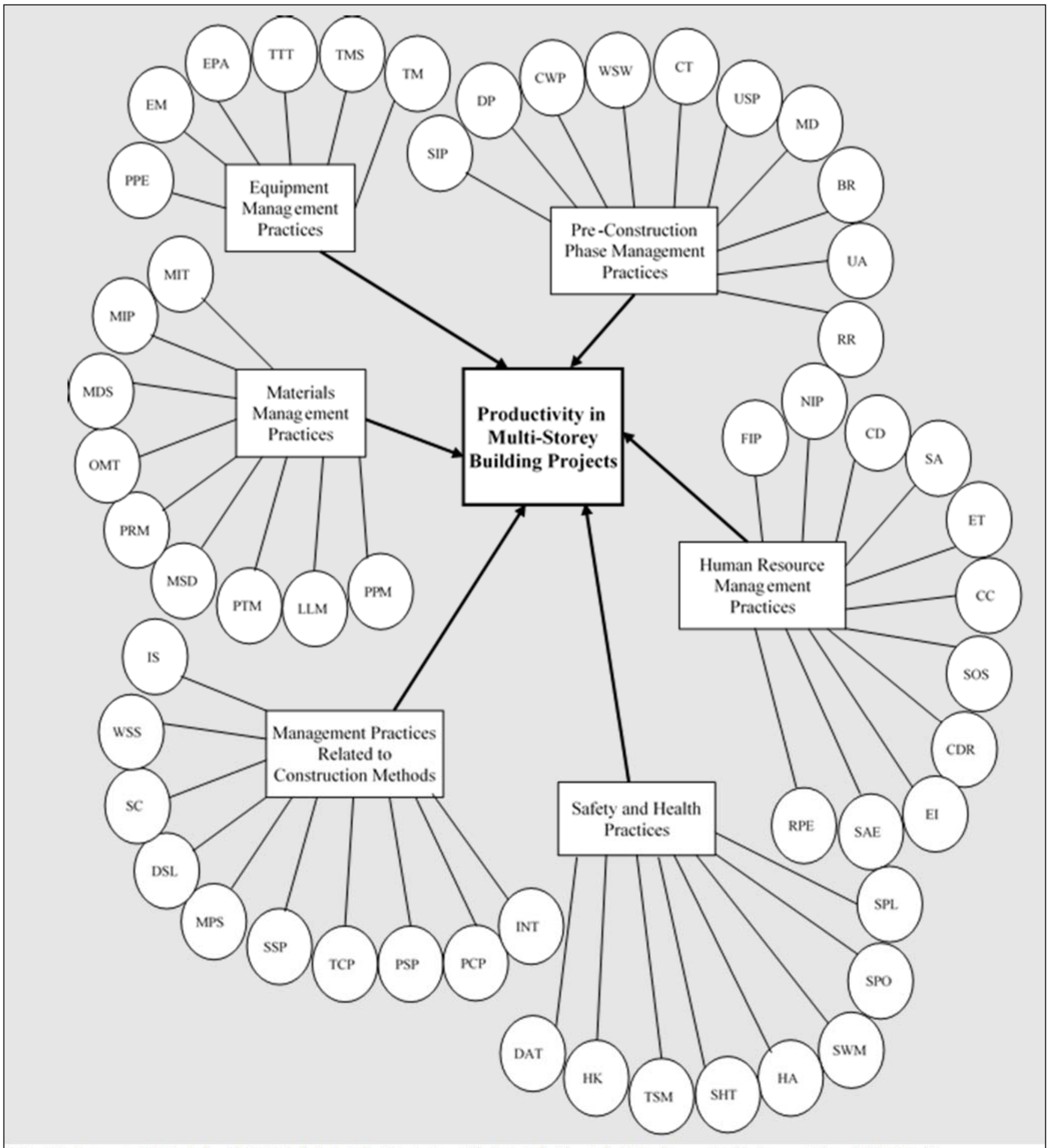
Housekeeping and Alcohol Testing Program

Regular housekeeping, and alcohol and substance abuse testing programs can also be some of the safety and health practices that could enhance productivity in multi-storey building projects. According to CII (2013a), housekeeping involves scheduling a suitable time either weekly or bi-weekly to ensure that the workface is organised and all materials, tools, and equipment are properly stored, cleaned up and disposed of the site. Jergeas (2009) found that neat and clean work environment is essential to ensure safety and to increase the productivity of construction projects. Hinze and Wilson (2000) confirmed that conducting alcohol and substance abuse programs is one of the mechanisms to achieve zero accidents in construction projects.The study indicated that implementing good safety practices improves safety performances which are measured in terms of lost time injury rates. According to Standards Australia (1990), lost time injury is any occurrence which results in a permanent disability and/ or time lost from work by one day or a shift or more as well as a fatality. The lost time injury frequency rates (LTIFR) are the number of occurrences of injury in a specified period for one million hours worked (Standards Australia, 1990). In other words, the LTIFR is computed by dividing the number of occurrences in a given period, say a year, by the number of hours worked in that specific period. Since the ratio could be small, the output is multiplied by one million (Standards Australia, 1990). In the construction of multi-storey building projects in Victoria, the implementation of the practice housekeeping could help to keep the construction sites clear and reduce the rate of accidents which negatively influence the productivity of the projects. Furthermore, alcohol and drugs testing programs can assist to minimise the construction workers' injuries. If employees execute construction activities after consuming alcohols and drugs, the rate of accidents on project sites could increase.

3.9 Summary

Six preliminary conceptual frameworks of the construction management practices that have the potential to enhance productivity in multi-storey building construction projects have been developed based on the growth accounting framework and findings of the previous studies. The conceptual frameworks will be validated after conducting Phase I of this research. The materials management practices' framework relates nine independent variables (the materials management practices) to the productivity of multi-storey building projects. The conceptual framework of the construction equipment practices links six independent variables (the equipment and tools management practices) and one dependent variable (productivity).

The framework for management practices related to construction methods relates ten independent variables (the management practices related to construction methods) and one dependent variable (productivity). Similarly, ten independent variables (pre-construction phase management practices) and one dependent variable (productivity) are linked in the conceptual framework of the pre-construction phase management practices. The human resource management framework relates eleven independent variables (the human resource management practices) and one dependent variable (productivity). Finally, eight safety and health practices (the independent variables) are related to the productivity (dependent variable) of multi-storey building construction projects using the preliminary conceptual framework of safety and health practices. Overall, 54 potential management practices that could enhance productivity in multi-storey building projects in Victoria State, Australia, are related to productivity (Figure 3-10).



Note: IS= Integrated Schedule; WSS=Work Schedule Strategies; SC=Schedule Control; DSL= Dynamic Site Layout Plan; MPS=Machinery Positioning Strategy; SSP=Site Security Plan; TCP=Traffic Control Plan; PSP=Project start-up plan; PCP=Project Completion Plan; INT=Innovations and New Technologies; PPM= Procurement Plans for Materials; LLM=Long-Lead Materials Identification; PTM= Procurement Team for Materials; MSD=Materials Status Database; PRM= Post-Receipt Preservation and Maintenance; OMT= On-site Materials Tracking Technology= Material Inspection Process; MIT=Materials Inspection Team; PPE=Procurement Plans for Construction Equipment; EPA= Construction Equipment Productivity Analysis; EM=Construction Equipment Maintenance; TTT=Tools Tracking Technologies; TMS=Tools Management Strategy; TM= Tools Maintenance; SIP=Short Interval Plan; WSW=Well Defined Scope of Work; USP=Use of Software in Planning Work Packages; DP=Dedicated Planner; CWP=Construction Work Packages; BR=Buildability Review; UA =Utilities Alignment; CT=Contract Types; MD=Model Development; RR=Regulatory Requirement; CC= Crew Composition; SAE=Skill Assessment Evaluation; ET=Employees Training; CD=Career Development; NIP=Non-Financial Incentive Programs; FIP=Financial Incentive Programs; SA=Social Activities; SOS= Stability of Organization Structure; CDR=Clear Delegation of Responsibility; RPE=Retention Plan for Experienced Personnel; EI=Exit interviews; HK=Housekeeping; SPO=Health and Safety Policy; SPL=Health and Safety Plan; SWM= Safe work Method Statement; HA=Hazards Analysis; SHT= Safety and Health Training; TSM=Toolbox Safety Meetings; and DAT= Drugs and Alcohol Testing Programs.

Figure 3-10 The Conceptual Framework of the Management Practices and Productivity

The next chapter presents the research design and methodology adopted to achieve the objectives of this study.

CHAPTER FOUR

4 RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

This chapter presents the research design and methodology adopted to achieve the objectives of the study. Section 4.2 describes the research design and presents the flow chart of the research process. Section 4.3 discusses the research approach which includes the philosophical assumptions of the study and the mixed methods research approach. In Section 4.4, the research strategy and activities, as well as the associated inputs and outputs, are described. The two phases of the research and the corresponding research questions and objectives are also explained in Section 4.4. Section 4.5 discusses the data analysis strategy used in Phase I and Phase II of the study. The qualitative data analysis methods, the units of analysis and units of observation for the second phase of the research, and the descriptive and inferential statistical analysis techniques such as correlation, linear and logistic regression analyses are described in Section 4.5. Finally, the summary of the chapter is presented in Section 4.6.

4.2 Research Design

The research design is a systematic and a logical plan prepared for directing a research study, and it stipulates the objectives of the study, the methodology, and techniques to be adopted for achieving the objectives (Krishnaswami and Satyaprasad, 2010). Accordingly, it forms a blueprint for the measurement, collection, and analysis of data. It is the plan, structure, and strategy of the investigation conceived so as to obtain answers to research questions. This study uses exploratory sequential mixed methods research design which involves the combination of qualitative and quantitative data in two phases. Amaratunga et al. (2002) explained the importance of mixed methods research design in built environment studies as it focuses on the strengths of both qualitative and quantitative methods. The schematic diagram of the research activities that are designed to answer the research questions is indicated in Figure 4-1.

This research commenced with a review of the literature to provide information regarding the context of the study and to identify the knowledge gap. After the preliminary literature review, the research problem was stated. Following the problem identification, an extensive literature review was conducted to identify the construction management practices that have the potential to improve productivity in construction projects, and preliminary conceptual framework was developed. The first phase of the research was then begun by conducting face-to-face in-depth interviews with professionals who have experience in delivering multi-storey building construction projects in Victoria State, Australia. The qualitative data analysis reached a saturation point, the management practices that are suitable to the local context were identified, the instrument used to measure the practices was verified, and the preliminary conceptual framework was validated during Phase I.

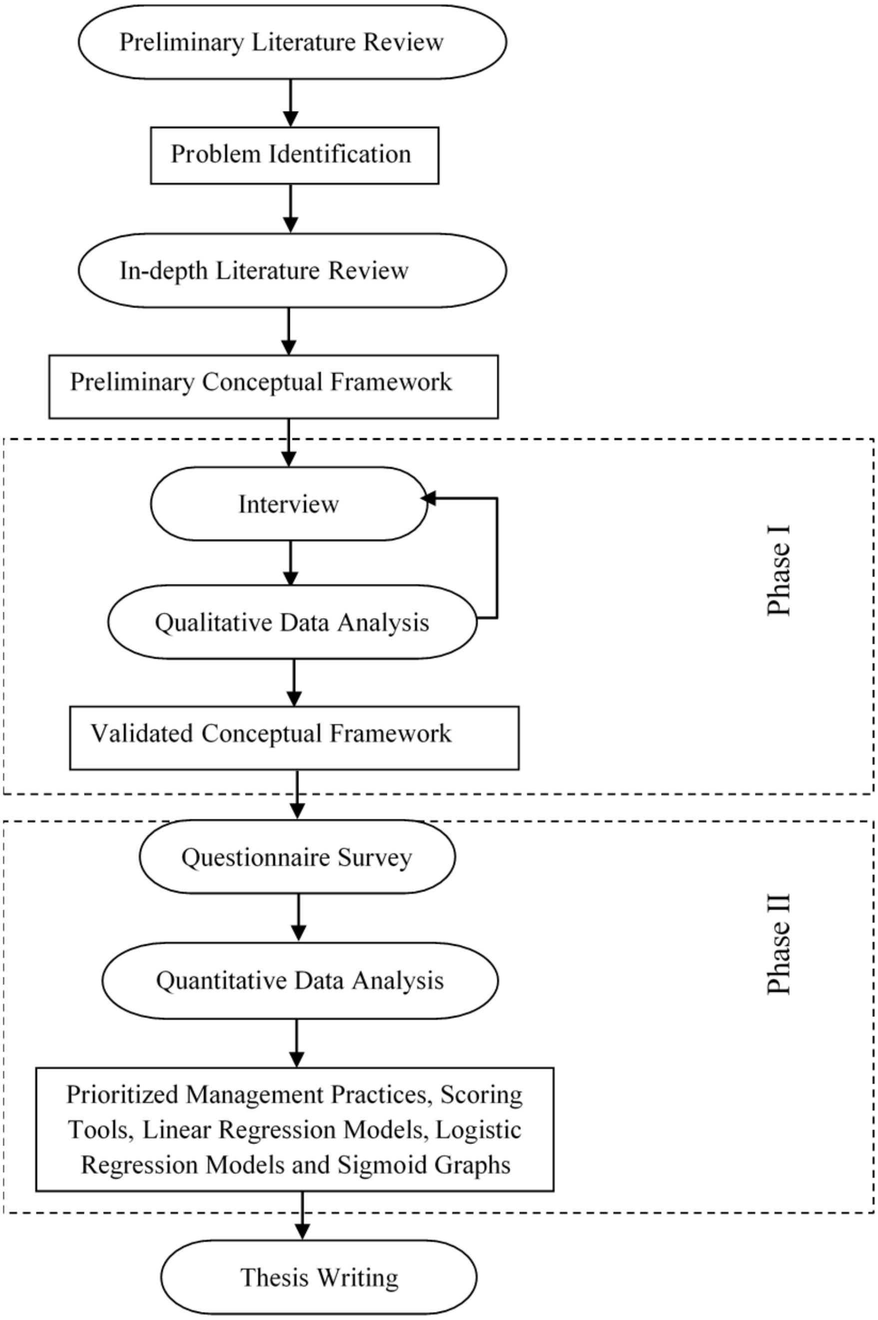


Figure 4-1 Flowchart of the Research Process

Based on the findings of Phase I, Phase II of the research was conducted. During this stage, quantitative data were collected using interview questionnaire survey whereby the survey was self-administered; the quantitative data were analysed; the management practices were prioritised; the scoring tools and logistic regression models were developed; and the probability graphs were plotted. Detailed descriptions of the methods of collecting and analysing data for Phase I and Phase II are presented in Section 4.4 and 4.5.

4.3 Research Approach

4.3.1 Philosophical Assumptions

This research uses the mixed methods research approach which is based on pragmatism worldview. There are four research paradigms that may be used in any research: post-positivism, constructivism, transformative, and pragmatism (Creswell, 2013). Post-positivists reflect a deterministic philosophy about research in which causes probably determine effects or outcomes. The problems studied by post-positivists reflect issues that need to identify and assess the causes that influence the outcomes. Social constructivists hold the assumption that individuals seek understanding of the world in which they live and work. Individuals develop subjective meanings of their experiences, meanings directed toward certain objects. Transformative worldview holds that research inquiry needs to be intertwined with politics and a political change agenda to confront social oppression and social justice at whatever levels it occurs (Mertens, 2010).

Pragmatism as a philosophy arises out of actions, situations, and consequences. In this paradigm, there is a concern with applications that work in certain situation and solutions to problems. Thus, instead of focusing on methods, researchers emphasise the research problem and use all approaches available to understand it (Creswell, 2013). Talisse and Aikin (2008) described that pragmatists are driven by the desire to achieve their ends; and they have little interest in idealisation, nit-picking argument, abstraction, or theory of any sort. Pragmatism worldview is considered most suitable for this research because the study focuses on the problems leading to the loss of productivity in multi-storey building construction projects, and it explores appropriate solutions or practices that could improve the productivity. Management practices vary according to project types and contexts and the solutions in one context might not be effective in another. Thus, this study explored context-specific construction management practices as some of the solutions to the productivity problems.

There are three major research approaches that could be used in any research: qualitative, quantitative, and mixed methods (Creswell, 2013). The quantitative research approach is more suitable for the positivism paradigm, and qualitative research approach is adopted for the constructivism paradigm (Rose et al., 2014). The research approach suitable for pragmatism worldview is mixed methods research (Creswell, 2013). Accordingly, this research used mixed methods research approach.

4.3.2 Mixed Methods Research Approach

Mixed research designs have been classified into three categories: convergent parallel, explanatory sequential and exploratory sequential (Creswell, 2013). In convergent parallel mixed methods, the researcher collects both qualitative and quantitative data, analyses them separately, and then compares the results to see if the findings confirm or disconfirm each other. Explanatory sequential mixed methods involve a two-phase project in which the researcher collects the quantitative data in the first phase, analyses the results, and then uses the results to plan or build on to the second qualitative phase.

In exploratory sequential mixed methods, the researcher first begins by exploring with qualitative data and then uses the findings in a second quantitative phase. The qualitative phase may be used to build an instrument that best fits the sample under study, to identify appropriate instruments to be used in the follow-up quantitative phase or to specify variables that need to go into a follow-up quantitative study (Creswell, 2013). In this research, exploratory sequential mixed methods is used because construction management practices identified by previous studies might not be applicable to the Victorian construction industry, and there could be other practices that are specific to the local industry. Thus, exploratory study was conducted first by collecting and analysing qualitative data obtained from interviews during the first phase. The preliminary conceptual framework developed based on literature review was modified on the basis of the qualitative data. Furthermore, the instrument used to measure construction management practices was verified. To investigate the relationship between productivity and the practices, to prioritise the practices, and to develop the scoring tools and probability-based predictive models, quantitative data were collected and analysed during Phase II of the research.

4.4 Research Strategy and Activities

The two phases of the data collection and analysis, as well as the detailed descriptions of the activities, are illustrated in Figure 4-2. The research questions, research objectives, inputs, activities, and outputs of Phase I and Phase II of the study are shown in the figure.

4.4.1 Qualitative Data Collection - Phase I

Phase I of the research addressed the first research question, which states “RQ1: what are the management practices that have the potential to improve productivity in multi-storey building construction projects in the context of Victoria State, Australia?” To answer this research question, part of Objective 1 or “to identify the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia” is devised (Objective 1a in Figure 4-2). During Phase I, part of the third research question or “RQ3: how can the management practices that have the potential to improve productivity in multi-storey building construction projects be measured, planned and controlled?” is also addressed. Accordingly, part of the second objective or “to refine the scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects” is formulated (Objective 2a in Figure 4-2).

The qualitative data is typically collected through observing the behaviour or interviewing the participants (Creswell, 2013). However, observation is not suitable to collect the data regarding the management practices since they cannot be observed. Hence, interview was used as a method to collect the qualitative data in the context of this research. Nineteen professionals who have experience in delivering multi-storey building projects in Victoria were interviewed. They have a five to forty years work experience and have been working as general manager, construction manager, project manager, project coordinator, project engineer, site engineer, contract administrator, supervisor and cost manager (Table 4-1).

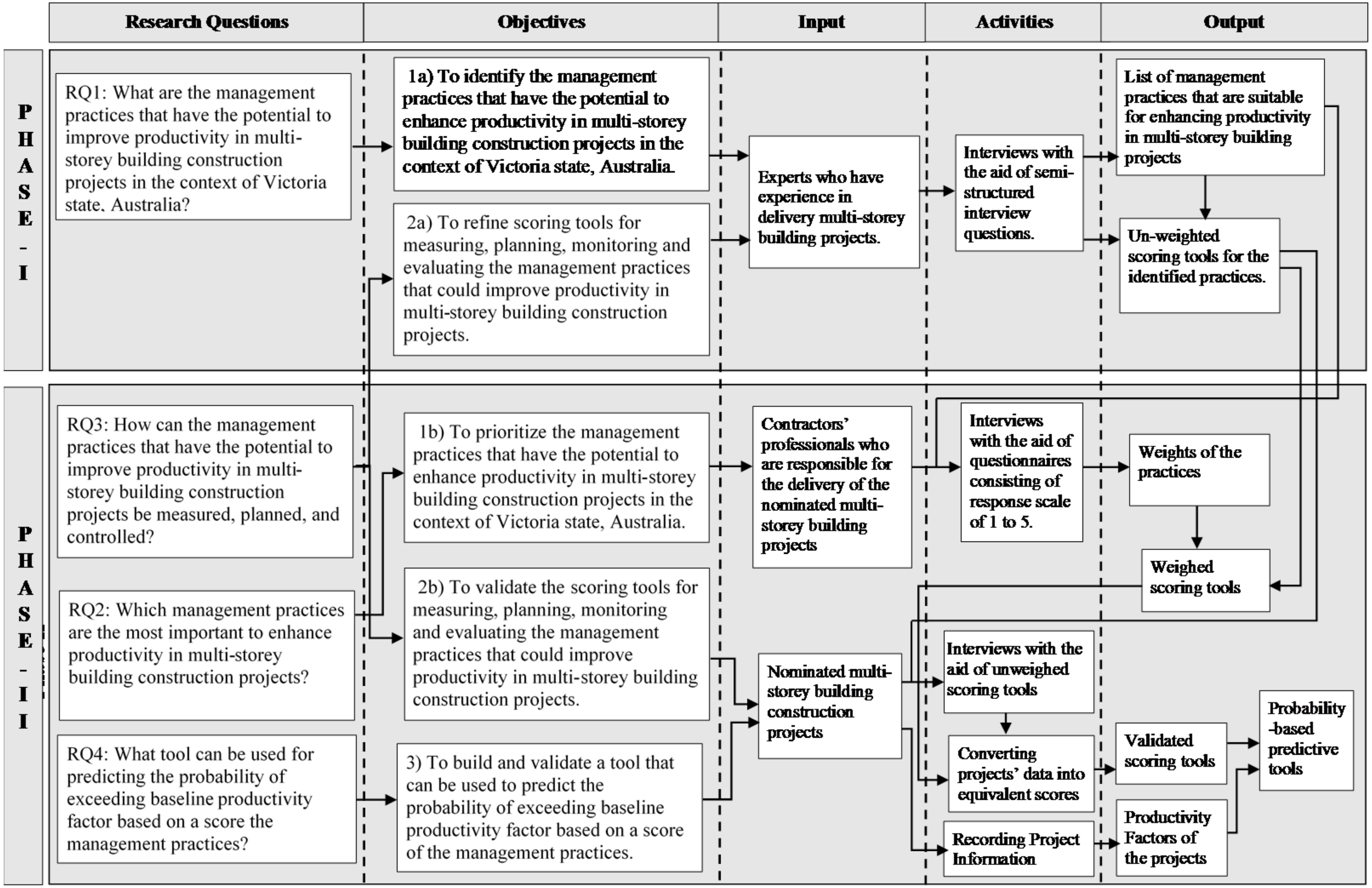


Figure 4-2 Research Strategy and Activities

Table 4-1 Profiles of the Interview Participants

Experts	*Number*	*Experience (years)*
General Manager	1	29
Construction Manager	1	26
Project Managers	6	10-40
Project Coordinators	2	6,8
Contract Administrators	2	5,10
Project Engineer	1	12
Project Planner	1	10
Site Engineers	2	7
Supervisors	2	16,25
Cost Manager	1	6
Total	**19**	

The experts were selected based on their experience in working for subcontractors and principal contractors that are involved in the construction of multi-storey building projects in Victoria State, Australia. A snowballing technique was used to select the participants for the interviews. In this technique, some experienced building construction experts were contacted first, and the researcher asked them to nominate other experienced professionals who can participate in the interviews. The semi-structured interview questions comprise lists of construction management practices that have the potential to improve productivity in construction projects. For each proposed practice, the questions include: Does this practice exist? How is it practised by local contractors? Does this practice improve productivity in multi-storey building construction projects? What other practices enhance productivity in multi-storey building construction projects? How do you measure productivity in multi-storey building projects? Each interview lasted for an average of 1.5 hours. The interviews were conducted until the data analysis reached a saturation point. Saturation refers to the point where similar reasons for accepting or rejecting a particular practice were given by the participants.

4.4.2 Quantitative Data Collection - Phase II

Phase II addressed the second research question, part of the third research question and the fourth research question. The second research question states “RQ2: which management practices are the most important to enhance productivity in multi-storey building construction projects?” To answer this research question, part of Objective 1 or “to prioritise the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia” is prepared (Objective 1b in Figure 4-2). Part of Objective 2 or “to validate the scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects (Objective 2b in Figure 4-2)" is developed to answer the third research question. The fourth research question which is " RQ4: what tool can be used for predicting the probability of exceeding baseline productivity factor based on a score of the management practices?" is answered by formulating Objective 3 or "to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices."

Survey data can be collected using mail, telephone, the internet, personal interview or group administration, and the survey can be self-administered, or an interviewer asks the questions and records the answers (Fowler Jr and Cosenza, 2009). In this research, the quantitative data were collected using interview questionnaire survey whereby the survey was self-administered.The respondents were asked the questions face-to-face and requested to write their answers. The approach can increase the response rate, and in this study it allowed the researcher to clarify issues during the interview survey.

The questionnaire consists of two parts (Appendix-1). In the first part, the respondents were asked to rate the relative importance of the construction management practices identified during Phase I. A response scale of 1 to 5 was used to achieve optimum reliability and validity (Jamieson, 2004, Lozano et al., 2008). In the rating, 1=not important; 2=slightly important, 3=somewhat important, 4=very important, and 5=extremely important practice to improve the productivity of multi-storey building projects. In the second part, the respondents were asked to provide information on a specific multi-storey building project which they have completed within last five years (2011-2016). The information includes project cost and project time among other things.The respondents were also asked to choose the level of implementation of the practices on the multi-storey building projects they nominated (Appendix 1 C). The levels of implementation of the practices were measured on the basis of a survey instrument developed as part of Phase I of the study (unweighted scoring tools in Figure 4-2). In preparing the measuring instrument, an existing instrument developed by Construction Industry Institute (CII) was used as a starting point (CII, 2013b, CII, 2013a). On that basis, a new tool was developed and validated through interviews with local experts during Phase I of the study. For instance, the survey tool (unweighted scoring tool) for the practice 'construction equipment procurement plan' is shown in Table 4-3, and the respondents were asked to choose the level of implementation of the specific practice. The validated survey tools (unweighted scoring tools) for all practices are indicated in the Appendix 1C.

Table 4-2 Sample of the Validated Survey Instrument (adapted from (CII, 2013b))

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any element unchecked.

(√)		*Procurement Plan for Construction Equipment*
	Level A	A procurement plan for construction equipment is not applicable for this building project.
	Level B	Construction equipment procurement plan is not prepared for this building project.
	Level C	Construction equipment procurement strategies such as hiring or leasing are prepared for this building project.
	Level D	Continuation of Level C and there is a procedure for identifying reputation of potential equipment suppliers
	Level E	Continuation of Level D, plus plan identifies necessary equipment and onsite resources to support delivery.
	Level F	Continuation of Level E and construction equipment schedule is integrated with other project schedules.

Before choosing the sample multi-storey building projects for Phase II of this research, a list and addresses of contractors were obtained from the registry of Victorian Department of Treasury and Finance (Department of Treasury and Finance, 2015). The Department maintains a list of contractors that are pre-qualified to provide different construction activities. They have been assessed against a range of management, technical and financial pre-qualification criteria to ensure they meet the high standards required of government suppliers. According to the Department's requirement, firms applying for pre-qualification must demonstrate that they have the management capability, qualifications, expertise, experience, technical, and financial capacity to deliver construction projects successfully. All the 39 principal contractors on the list having experience in constructing multi-storey building projects were selected. Multi-storey building projects that have been delivered by these contractors were identified from the companies' websites. The questionnaires were then distributed to the contractors. The persons directly responsible for the construction of the multi-storey building projects by these companies were contacted and were the respondents. They were construction directors, operation managers, construction managers, project managers, project coordinators, and site managers (Table 4-3). The letters explaining the objectives of the research and the benefits of participating in the research were sent to the respondents via email and in person. The researchers then sent follow-up emails and phone calls requesting the participation and setting suitable time and places for the interviews. The results of the study can be generalised because the sample size of 39 represents all potential principal contractors that have the capability to execute multi-storey building projects. Moreover, the suitability of the survey data was checked using tests such as Events per Variable (EPV) and acceptable results were found (see logistic regression section for EPV). Thus, the sample size is adequate to enable a valid conclusion to be drawn.

Table 4-3 Profiles of the Questionnaire Survey Participants

Respondents	*Number*	*Years of Experience*
Construction Director	1	20
Operation Manager	1	21
Construction Managers	4	20-43
Project Managers	18	8-41
Site Managers	2	14, 30
Project Coordinators	4	7-10
Contract Administrators	7	6-27
Project Engineers	2	7,8
Total	**39**	

4.5 Data Analysis Strategy

This section provides the methods used in analysing the qualitative data in the first subsection (4.5.1) and techniques adopted in analysing the quantitative data in the subsequent subsections.

4.5.1 Qualitative Data Analysis - Phase I

The analysis of the qualitative data is conducted in three concurrent steps: data reduction, data display, and conclusion (Rose et al., 2015). Data reduction is a form of analysis that sharpens, sorts, focuses, discards, and organises data in a way that final conclusions can be drawn (Miles and Huberman, 1994). Writing summaries, coding, and making clusters are common methods used in data reduction process. The latter two methods are more suitable when the research is entirely inductive in nature. In this study, writing summary was used as a technique to reduce the transcribed interviews. The reduced data can be displayed using matrices, graphs, charts and networks. In this research, matrix technique was used as it is suitable to display the summaries of the responses in matrix boxes. Once the data is displayed, the conclusion is drawn by either noticing the patterns of similarities and differences between categories and/or processes, clustering, making contrasts and comparisons and noting relations between concepts (Rose et al., 2015). During the analysis, the audiotaped interviews were first transcribed and a matrix was prepared in

Excel spreadsheet to match the responses of an expert and the construction management practices (Table 4-4). A summary of each interview result was written in a matrix box, and a conclusion was drawn for each practice. Similar iterative procedures were used for all the interview results. The similarity between the successive summaries was observed to find saturation point. After analysing the outcome of the fifteenth interview, similar explanations for the construction management practices that have the potential to improve productivity in multi-storey building projects were observed. Although the saturation point was reached at the fifteenth interviewee, more interviews were conducted until the nineteenth participant for the sake of validating the saturation point.

Table 4-4 presents the summary of the transcribed text for the practice 'Construction Machinery Positioning Strategy' to illustrate how the summarised data was displayed. The summaries of the interview results for all the management practices are presented in the Qualitative Data Analysis and Findings chapter (Chapter 5).

Table 4-4 Template for the Qualitative Data Analysis

Management Practices	Respondents (R)				Overall Conclusion
	R_{18}		R_{19}		
	Summary	*Conclusion*	*Summary*	*Conclusion*	
Construction Machinery Positioning Strategy	"We sit down and work out a site layout details. It is interrelated with many things such as traffic control plan, access points, the way materials could easily get into the site, the size or the footprint of the job, crane types and number requirements, the location of the cranes and other issues. For example, we locate cranes for the maximum flexibility; we place them to get as much coverage as we can. Thus, integrating and developing a strategy for positioning construction machinery is critical for productivity."	suitable	"For instance, one of the critical equipment on our site is a crane, and its location is planned by considering the weight to be loaded, the street, distance of placement and the nearby buildings. The crane needs to reach the street; it needs to reach the heaviest lift; it needs to reach the entire site. There might be another building that is taller than the building under construction, and the crane should not hit that building. All these factors are taken into account when positioning a crane and it is good practice to have a strategy for positioning construction equipment."	suitable	suitable

Finally, the output of the first phase was used as input to the second phase which comprised quantitative data collection and analysis. The construction management practices that were described as suitable to improve productivity in multi-storey building projects by the participants were included in the list for the industry-wide survey. Furthermore, the instrument used to measure the identified practices was verified.

4.5.2 Methods of Computing Relative Importance Indexes and Productivity Factors

Part one of the questionnaire was analysed to assign weights to the practices identified using the interviews (Phase I) and to rank them accordingly. Relative Importance Index (RII) and mean value can be used for ranking purpose. According to Lam et al. (2007), both methods produce similar rankings, but RII method is used to derive relative indices within the range of 0-1 which makes the relative comparisons of different variables easy. Holt (1997) explained that many researchers in construction management prefer RII as the relative comparison of variables whose indices less than or equal to one is easier to perceive. Doloi (2012) stated that the mean and standard deviations are not reliable statistics for assessing the overall ranking of the attributes, and the author used the relative importance weights as input for factor and regression analyses. This research adopted RII technique as it is suitable for ranking purpose, and it is recommended for inferential statistical analyses. The following equation (Equation 4-1) was used for RII computation (Enshassi et al., 2007, El-Gohary and Aziz, 2014). Moreover, Friedman's and Wilcoxon's tests were conducted to check the significance of the difference in the weights assigned to the practices. Finally, part of objective 1 or 'to prioritise the practices' was achieved.

$$RII=\frac{5(n_5)+4(n_4)+3(n_3)+2(n_2)+n_1}{5(n_5+n_4+n_3+n_2+n_1)} \qquad \text{(Equation 4-1)}$$

The number of respondents who selected 1 for 'not important,' 2 for 'slightly important,' 3 for 'somewhat important,' 4 for 'very important,' and 5 for 'extremely important' practice to improve productivity in multi-storey building projects are shown as n_1, n_2, n_3, n_4, and n_5 respectively.

The second part of the questionnaire was analysed to compute the productivity factors of the 39 multi-storey building projects nominated by the 39 participating contractors. The construction projects' productivity can be expressed in either absolute or relative term. In absolute term, the units of measure of both output and input are shown in the productivity value. For example, productivity can be measured in tonnes of steel erected per work-hour or meters of pipe installed per work-hour or the project cost per hours worked. The relative measure or Productivity Factor (PF) refers to the ratio of the actual to planned productivity (Equation 4-4). The actual productivity is computed using project value as output and actual time as input (Equation 4-2). The planned productivity is calculated using project value as output and planned time as input (Equation 4-3).

$$\text{Actual productivity (AP)}=\frac{\text{Output}}{\text{Actual Completion Date-Project Start Date}} \quad \text{(Equation 4-2)}$$

$$\text{Planned productivity (PP)}=\frac{\text{Output}}{\text{Planned Completion Date-Project Start Date}} \quad \text{(Equation 4-3)}$$

$$\text{Productivity Factor (PF)}=\frac{\text{Actual Productivity (AP)}}{\text{Planned Productivity (PP)}} \quad \text{(Equation 4-4)}$$

According to Alby (1994), Productivity Factor (PF) is a useful measure to compare the productivity of different construction projects. McDonald and Zack (2004) explained that measuring productivity using productivity factor is more significant in substantiating claims for the lost labour productivity. Nasir (2013) concluded that the use of productivity factor as a metric to measure productivity is more beneficial than adopting the absolute measure. According to the study, PF can be useful to measure the productivity of any project and to make a comparison with another project. Moreover, the weighted average of projects' productivity can be computed since PF is independent of the units of measurement. Caldas et al. (2014) validated the use of PF to measure productivity in industrial projects. In this research, PF is adopted as it is suitable to measure and compare the productivity of different multi-storey building construction projects.

4.5.3 Techniques of Preparing the Scoring Tools

Figure 4-3 shows the procedures used in preparing the 'validated and weighted scoring tools' which can be used for measuring, planning, monitoring and evaluating the management practices in the context of multi-storey building projects. First, the qualitative data was analysed, and practices which are suitable to improve productivity in the context of multi-storey building projects in Victoria were identified. Then, the levels of implementation for the identified practices were prepared based on the existing tools developed by the Construction Industry Institute (CII) for industrial and infrastructure projects. The practices which are not implemented by contractors in Victoria were deleted, and terminologies which are not suitable for building construction projects were excluded. Consequently, the 'unweighted scoring tools' were prepared and validated by conducting interviews with local experts during Phase I of the study.

The validated and unweighted scoring tools were used to collect the data regarding the implementation levels of the identified practices from the multi-storey building projects (please refer Part II of the questionnaire in Appendix-1 for the survey instrument). The data concerning the relative importance of the practices were collected from contractors' experts who are responsible for the delivery of the nominated multi-storey building projects (please refer Part I of the questionnaire in Appendix-1).

During Stage I of the quantitative data analysis, the weight computed for each practice was used in the preparation of the 'weighted scoring tool' (Figure 4-3). The weights were proportionally distributed among the five levels of the practices. For instance, the weight for the practice 'construction equipment procurement plan' is 0.69, and the proportions are Level A=0; Level B=1/5 × (0.69) =0.14; Level C=2/5 × (0.69) =0.28; Level D=3/5 × (0.69) = 0.41; Level E=4/5 × (0.69) = 0.55; and Level F= 0.69 (Table 4-5). Similarly, the weight proportions for other practices were computed and the 'weighted scoring tools' were developed. The tools are presented in Summary and Conclusion chapter (Chapter 10). For the sake of brevity, the term 'scoring tools' refers to the 'weighted scoring tools.' During Stage II of the quantitative data analysis, the data collected from the multi-storey building construction projects were transformed into equivalent scores using the weighted scoring tools. The analysis was then conducted to validate the weighted scoring tools.

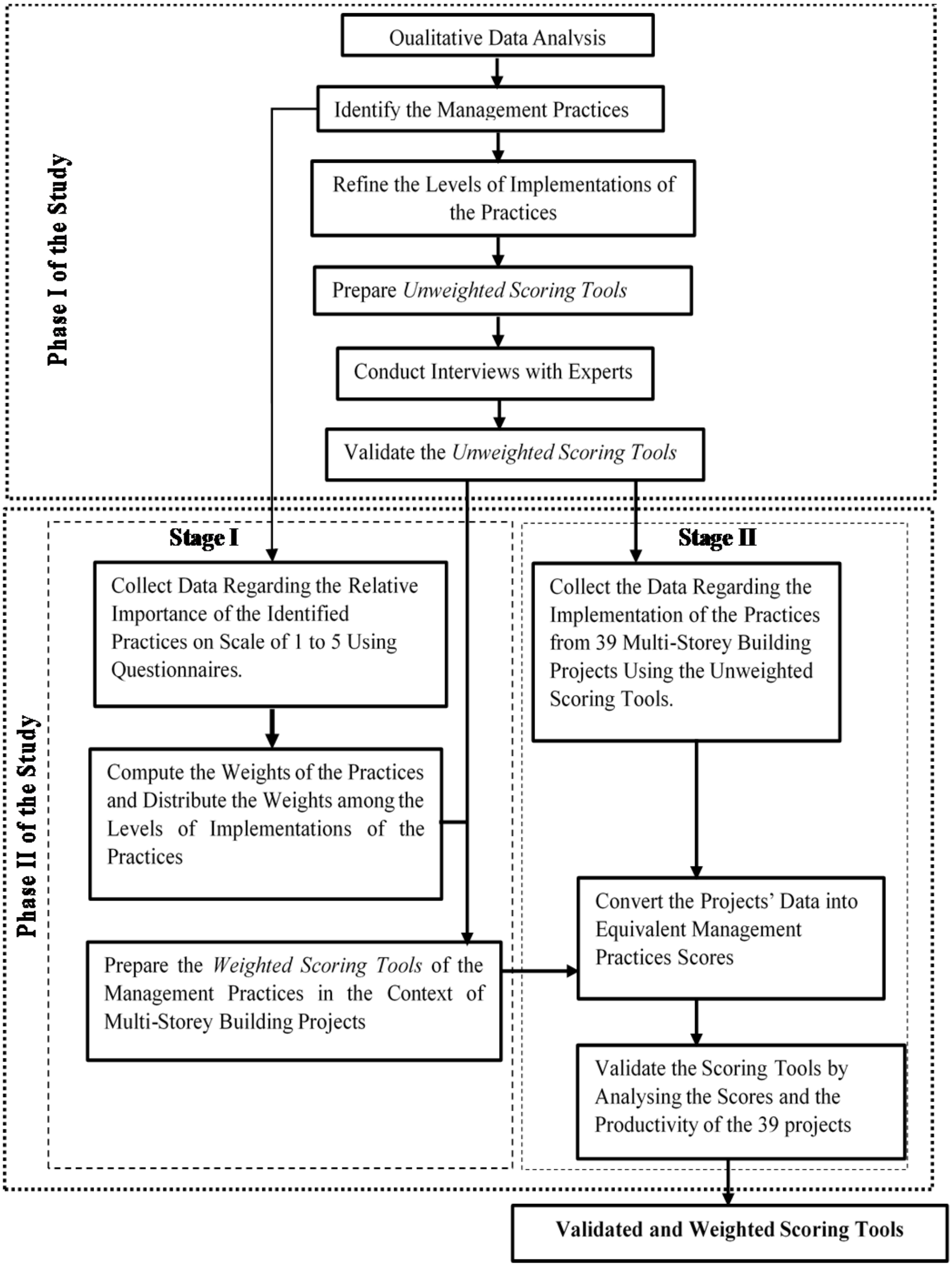


Figure 4-3 Flow Chart for Scoring Tools Preparation and Validation

Table 4-5 Sample Scoring Tool for the Practice Procurement Plan for Construction Equipment

	Planning / Implementation levels	*Weights*
Level A	A procurement plan for construction equipment is not applicable for this building project.	0
Level B	Construction equipment procurement plan is not prepared for this building project.	0.14
Level C	Construction equipment procurement strategies such as hiring or leasing are prepared for this building project.	0.28
Level D	Continuation of Level C and there is a procedure for identifying reputation of potential equipment suppliers	0.41
Level E	Continuation of Level D, plus plan identifies necessary equipment and onsite resources to support delivery.	0.55
Level F	Continuation of Level E and construction equipment schedule is integrated with other project schedules.	0.69

During validation of the scoring tools, the mean, mode, and median management practices' scores were computed to choose a baseline score for grouping the projects. If the data is not highly skewed, mean is the best measure of central tendency; otherwise, the median is the recommended value (Lurd and Lurd, 2013). According to Kim (2013), if Z-score for skewness (skewness/standard error) is less than 1.96, the distribution could be considered as normal. Projects with scores less than a central value (baseline) were classified under Group-1(low-score) and those having scores greater than the baseline were classified under Group-2 (high-score). The data that satisfied the assumptions of parametric tests such as normality were analysed using ANOVA, and the data that did not satisfy the parametric tests' assumption were analysed using Mann-Whitney U-test (non-parametric test). Finally, the difference between the two groups was investigated, and the scoring tools were validated (Chapter 7).

The internal consistency of the scoring tools was checked by running reliability test using SPSS-24. The test is essential to ensure the reliability of the dataset before conducting subsequent analyses such as correlation, linear and logistic regression analyses. Cronbach alpha (α) is the most popular reliability statistic which determines the consistency of items in a survey instrument and the recommended acceptable minimum value of the Cronbach alpha (α) is 0.70 (Santos, 1999). The results of the reliability and validity tests are presented in Chapter 7. Finally, Objective 2 of the study which is 'to refine and validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects' is achieved.

4.5.4 Correlation Analysis

Correlation analyses were conducted to investigate the association between productivity and the construction management practices. After checking the assumptions of the parametric tests such as normality, the correlation analyses between productivity and the practices identified in Phase I and prioritised in Phase II of the study were conducted. Moreover, the interrelationships among the practices were investigated. For the sake of brevity, the diagram representing the interrelationship among all the practices is not shown here. The results of the analyses are presented in Chapter 7.

Figure 4-4 shows the correlation analysis among the practices categorised under 'Construction Materials Management Practice' category.

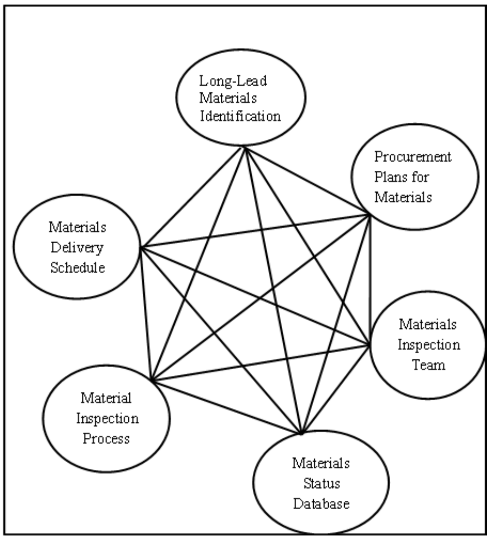


Figure 4-4 Diagram for Correlation Analyses of Construction Materials Management Practices

Figure 4-5 indicates the correlation analysis conducted among the practices categorised under the category 'Construction Equipment Management Practices.'

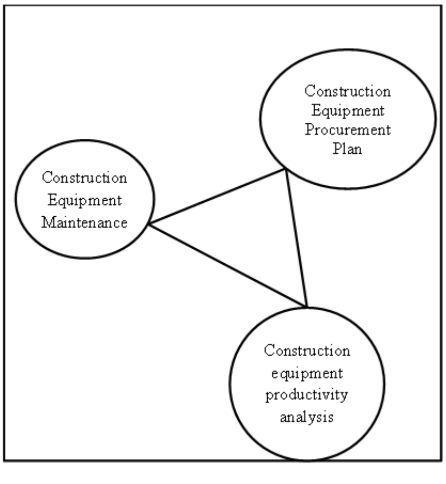


Figure 4-5 Diagram for Correlation Analyses of Construction Equipment Management Practices

In Figure 4-6, the correlation analyses for preconstruction phase management practices are shown, and the results of the analyses are presented in the quantitative data analysis and findings chapter.

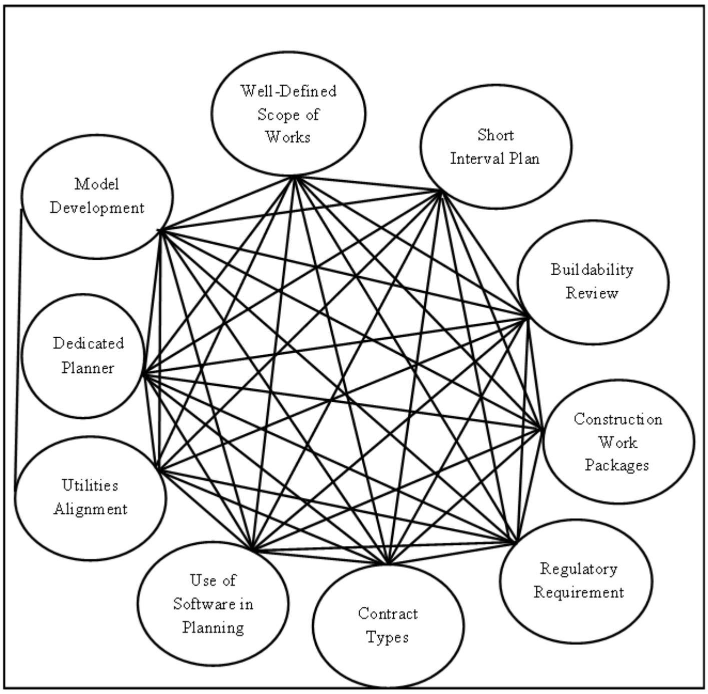


Figure 4-6 Diagram for Correlation Analyses of Preconstruction Phase Management Practices

Figure 4-7 shows the correlation analyses conducted between the practices grouped under the ‘Human Resource Management Practices’ category.

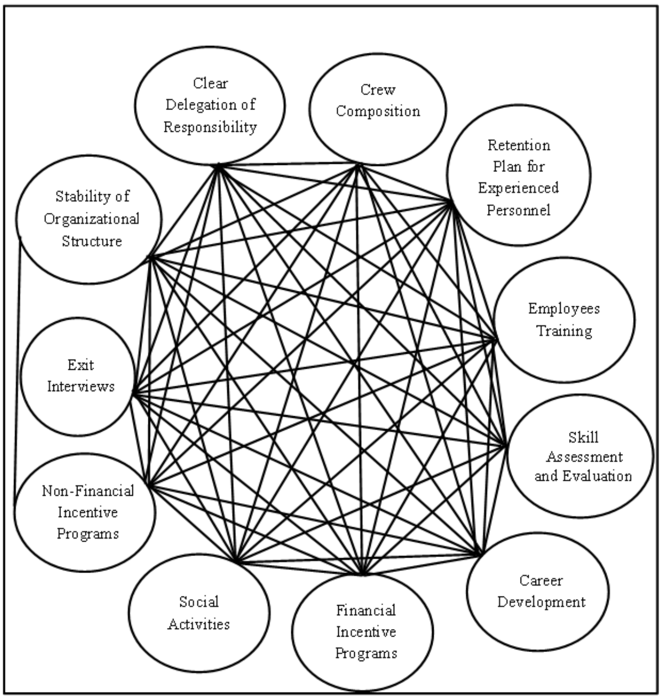


Figure 4-7 Diagram for Correlation Analyses of Human Resource Management Practices

In Figure 4-8, the correlation analyses of management practices related to construction methods are presented.

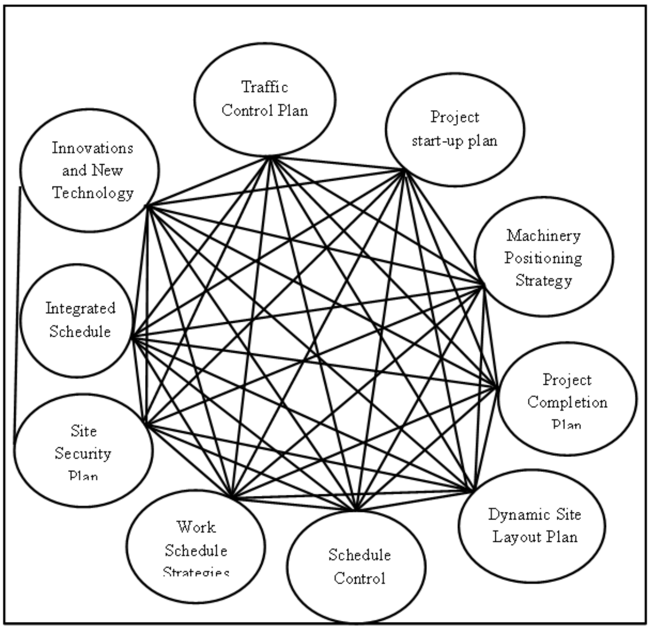


Figure 4-8 Diagram for Correlation Analyses of the Management Practices Related to Construction Methods

The correlation analyses for safety and health practices are indicated in Figure 4-9.

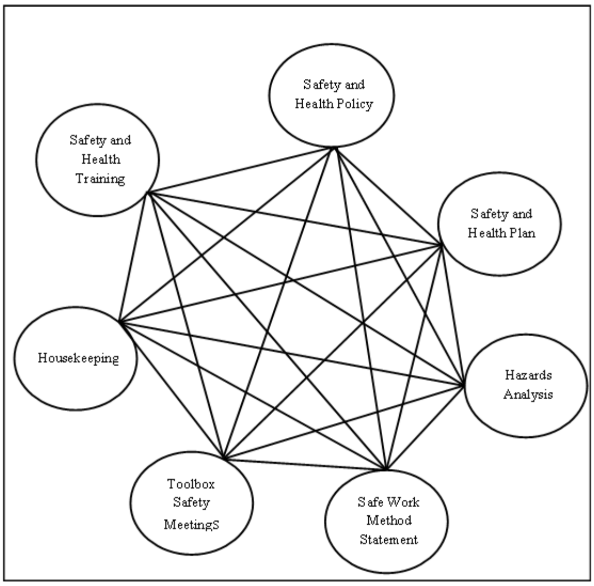


Figure 4-9 Diagram for Correlation Analyses of Safety and Health Practices

Correlation analysis was also conducted to investigate the relationship between construction management practices, project cost, project delay and company profiles (company size, company experience, and annual turnover). In the analysis, the construction companies were categorised based on the number of employees (less than 19, 20-199, and greater than 200) to determine their sizes. The classification system is adopted from the Australian Bureau of Statistics (ABS). For instance, according to ABS classification, at the end of 2015 financial year, the proportions of companies involved in building construction were 0.06%, 0.78% and 99.15% for firms employing over 200 workers, 20-199 workers, and less than 19 workers respectively (Australian Bureau of Statistics, 2016c).

4.5.5 Linear Regression Analysis

To investigate the proportion of variance in the productivity explained by the construction management practices, bivariate linear regression analysis was conducted. According to Vittinghoff and McCulloch (2007), both observational and experimental data can be analysed by using the regression analysis, and the analysis tells how the independent variables might affect the dependent variable. The author explained that if the independent variables cannot be controlled, the data is observational. On the other hand, if the factors being studied can be controlled, the data is experimental. In this research context, since the management practices of the construction projects cannot be controlled by the researcher, the data is observational.

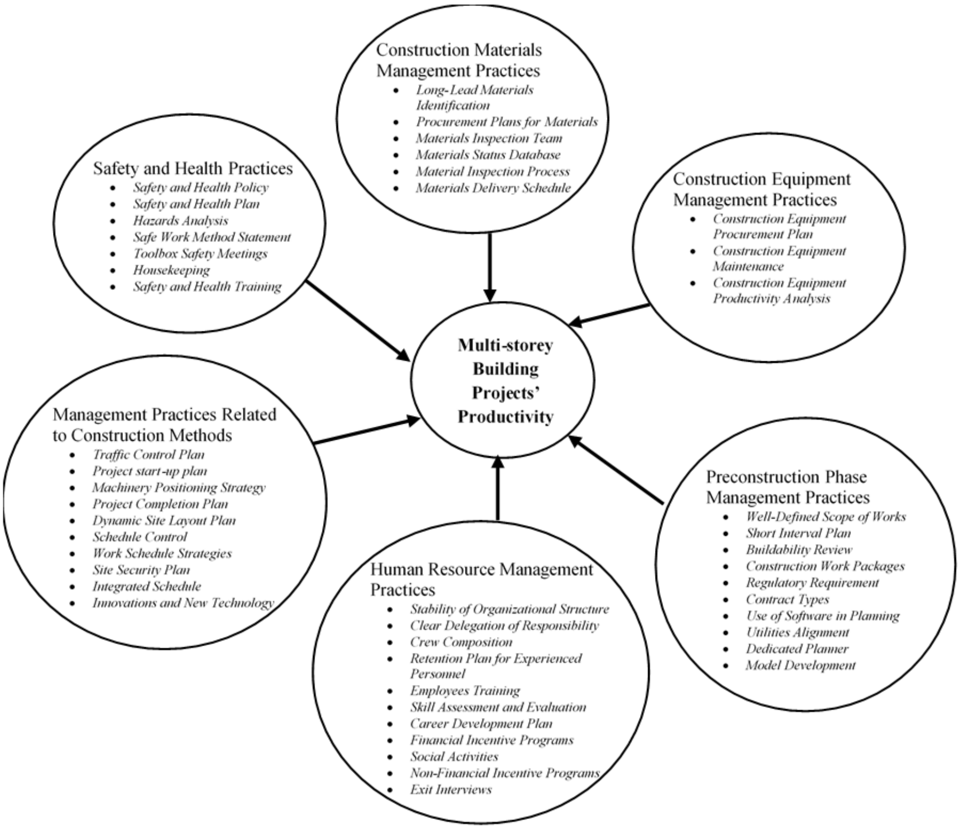


Figure 4-10 Regression Analysis between Productivity and Construction Management Practices

After testing the assumptions of the linear regression analysis such as linearity by using SPSS-24, the linear regression analyses were conducted to investigate the relationship between productivity and the six categories of the practices: construction materials management practices, construction equipment management practices, preconstruction phase management practices, human resource management practices, management practices related to construction methods, and safety and health (Figure 4-10). The linear regression analysis between productivity (the dependent variable) and the aggregated construction management practices (the independent variable) was also conducted. The results of the analyses are presented in Chapter 7.

4.5.6 Logistic Regression Analysis

Logistic regression analyses were conducted to address Objective 3 of the study which is 'to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices.' Before running the analysis, the suitability of the sample for the logistic regression analysis was checked by computing the number of events per variable (EPV). The rule of thumb for sample size for logistic regression analysis states that EPV should be greater than 10 (Peduzzi et al., 1996). Some authors argue that the minimum of 10 events per predictor is conservative (Vittinghoff and McCulloch, 2007). In this research context, the number of positive events refers to the number of projects whose productivity factors exceed the baseline productivity factor (PF); the predictor is the construction management practices (one variable); and the minimum EPV of 10 is used to develop the logistic regression models. The results of all the computed EPVs are presented in Chapter 8.

The three measures of central tendency (mean, mode and median) of the projects' productivity factors and Z-score for the skewness of the productivity factors data (skewness/standard error) were computed, and the central-PF value was fixed (Lurd and Lurd, 2013, Kim, 2013). The Events Per Variables (EPVs) were calculated using (central-PF value), (central-PF value) + 5% × (central-PF value), (central-PF value) - 5% × (central-PF value), (central-PF value) + 10% × (central-PF value), and (central-PF value) - 10% × (central-PF value) as baseline productivity factors.

After fixing the cut-off productivity factors, the datasets were divided into model building and validation. Random numbers using Microsoft Excel was assigned to each data point so that the data can be randomly distributed. Based on the random numbers, the data was sorted in ascending order before it was split into model building and validation dataset. In regression analysis, random sample splitting and K-fold cross validation techniques can be used to divide the data into model building and validation datasets (Steyerberg et al., 2001). In this research, 3-fold and 4-fold cross-validation techniques were used as they are less biased than sample splitting method (Abou-Assaleh et al., 2004). Alternative models using the 3-fold and 4-fold cross validation techniques were developed and compared before choosing the final models (Figure 4-11). The criteria for selection include the overall prediction accuracy and statistical significance of the variable in the model. The analyses and selection of the models are described in Chapter 8. Linear regression models were also developed using the cross-validation technique. Figure 4-11 indicates the flow chart for the process used in logistic regression model development and validation.

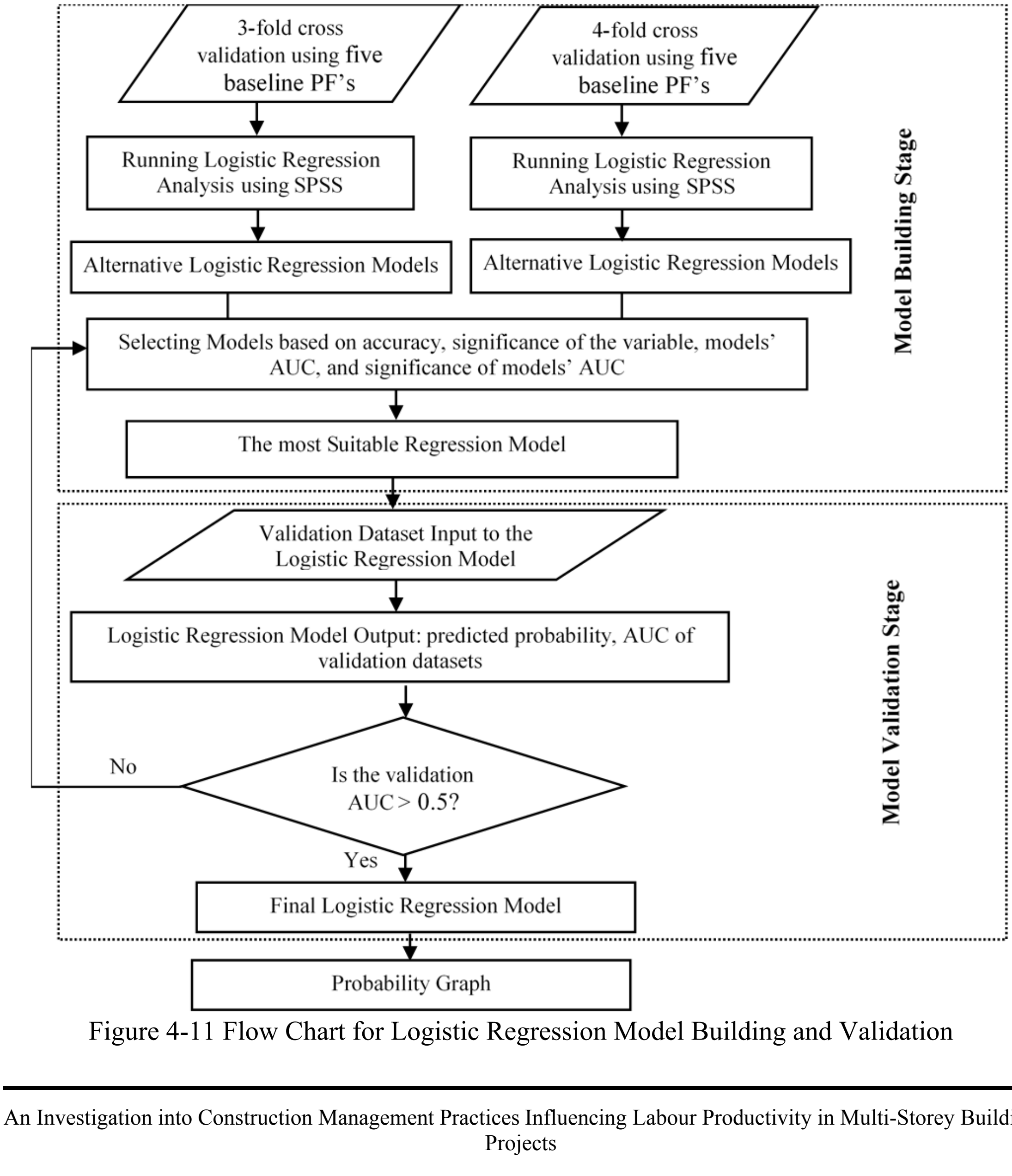


Figure 4-11 Flow Chart for Logistic Regression Model Building and Validation

To validate the logistic regression models, the probabilities of validation data sets were computed; productivity factors were predicted as binary values (1,0) and compared with the actual productivity factors; Receiver Operating Characteristic (ROC) curves were drawn and compared with the reference lines; and area under the ROC curves (AOC) were computed. According to Hanley and McNeil (1982), the AUC is interpreted as acceptable if the graph is close to the left top boundary, and AUC of 0.5 and less implies no accuracy and AUC=1 indicates perfect accuracy. To check the reliability of the logistic regression models bootstrapping using 1000 samples were conducted. Willems and Van Aelst (2005) explained that the use of 1000 or more samples provides accurate output in bootstrapping. Finally, sigmoid graphs were drawn by computing the probabilities of exceeding baseline productivity factor by using the validated model's equation.

4.6 Summary

This chapter presented the research design and methodology used in the study. The overall research process has been described using a flowchart. The philosophical assumptions of the study were explained, and the suitability of mixed methods research approach for this research has been addressed. The types of mixed methods research design have been reviewed and the 'exploratory sequential mixed methods' has been found to be suitable for this research. In the exploratory sequential mixed methods, the qualitative data is collected and analysed first, and the output of this stage is used as an input to the second stage. On the basis of the findings of the first phase, the quantitative data is collected and analysed during the second phase.

The qualitative data collection and analysis techniques such as the use of semi-structured interviews, the deployment of matrix box to display the summaries of the interviews results, and the techniques of determining the saturation point and arriving at a conclusion have been described. The quantitative data collection and analysis techniques which include the use of interview questionnaire survey in which the survey was self-administered; techniques of computing productivity factors and relative importance indexes; methods of refining and validating the scoring tools; correlation and linear regression analyses; and probability-based models building and validation techniques have been explained. In next chapter, the qualitative data analysis and findings are presented.

CHAPTER FIVE

5 QUALITATIVE DATA ANALYSIS AND FINDINGS

5.1 Introduction

In this chapter, the analyses and findings of Phase I of the study are presented. The profiles of the interview participants are described in Section 5.2. Following this section, the analysis and findings of the construction management practices are presented in six subsequent sections (from Section 5.3 to Section 5.8). Section 5.3 explains the analysis and findings of the practices categorised under ‘construction materials management practices.’ Section 5.4 describes the analysis and findings of the practices organised under ‘construction equipment management practices.’ The analyses and findings of the management practices related to construction methods, preconstruction phase management practices, human resource management practices, and safety and health practices are presented in Section 5.6, Section 5.7, and Section 5.8 respectively. Finally, Section 5.9 provides the summary of the chapter.

5.2 Profiles of the Interview Participants

The percentage distribution of the interview participants based on the areas of expertise is shown in Figure 5-1. Accordingly, 32% of the interviewees are project managers. Contract administrators, project coordinators, site engineers, and site supervisors each comprise 11% of the participants; and general manager, construction manager, project planner, project planner, and cost manager each consists of 5% of the total interviewees.

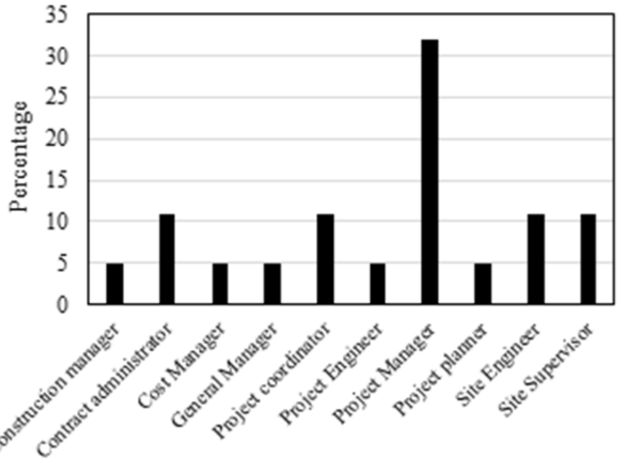


Figure 5-1 Distribution of the Interview Participants Based on Areas of Expertise

Figure 5-2 presents the percentage distribution of the interview participants based on their experience in building construction. In the analysis, the participants' experience is grouped into 0 to 4 years, 5 to 9 years, 10 to 14 years, 15 to 19 years and greater than 20 years (Figure 5-2). Accordingly, about 68% of the participants have more than ten years, 32% of them have experience between 5 to 9 years, and no participant has experience less than five years.

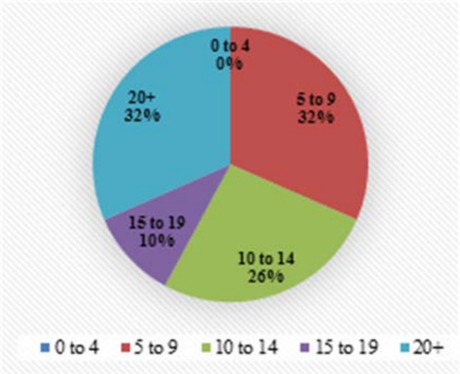


Figure 5-2 Distribution of Interviewees Based on Experience

5.3 Identification of Construction Materials Management Practices Influencing Productivity in Multi-Storey Building Projects

Six construction materials management practices that have the potential to improve productivity in multi-storey building projects are identified. These are 'Procurement Plans for Materials,' 'Long-Lead Materials Identification,' 'Materials Status Database,' 'Materials Delivery Schedule,' 'Material Inspection Process,' and 'Materials Inspection Team.' However, the practices 'Procurement Team,' 'On-site Materials Tracking Technology,' and 'Post Receipt Preservation and Maintenance' which are included in the preliminary conceptual framework of the construction materials management practices are found to be not significant to improve the productivity of multi-storey building projects in the context of Victoria State, Australia. The summary of the interview responses is indicated in Table 5-1.

Table 5-1 Summary of the Interview Results of Construction Materials Management Practices

Construction Materials Management Practices	*Summary of the Interview Responses*	*Conclusion*
Procurement Plans for Materials	"Materials procurement plan is right on the front end. The potential suppliers are identified; the required materials are estimated upfront; the tracking sheets and charts are prepared; different stages of the procurement are represented using different colours on the chart, and any changes made during the procurement process are tracked."	suitable
Long-Lead Materials Identification	"Usually the long lead times are façades, tiles, and services such as lifts, generators, and boilers. All these key primary elements have long lead time. These items are identified earlier and tabulated. The approximate lead times for these materials are also estimated; for example, item = tiles, source = Italy, duration = 8 weeks. Most items imported from overseas are categorised as long lead items."	suitable
Materials Status Database	"The contractor's project manager get information regarding the work progress from supervisors or subcontractors and prepare the material status report which comprises of the percentage of the materials utilised and the estimates of the quantities of materials required to complete the remaining works. The supervisors then monitor the work on a regular basis; they identify the remaining items and request the procurement of these materials if any."	suitable
Materials Delivery Schedule	" The materials delivery schedule is prepared based on the construction work program; the principal contractor's supervisors discuss the materials delivery dates with respective subcontractors/suppliers and prepare the schedule. The schedules are written on a whiteboard, and the materials delivery is tracked every day. Some materials such as façade are tracked during the manufacturing process; when they are on site; and after their installation."	suitable
Material Inspection Process	"The inspection is made upfront, the consultants are engaged in the inspection, and sometimes materials are inspected during the manufacturing stage. Inspection is made for various items such as reinforcement, formwork, glass and concrete test. The materials should be inspected before being installed. The subcontractors or suppliers provide the quality assurance documents for all items they bring to a site and the principal contractor's project management team conducts quality assurance checks."	suitable
Materials Inspection Team	"The project coordinators and specialist consultants are involved in the inspection process. For instance, façade expert and project coordinator or manager inspect the façade, and structural engineers take part in the inspection of reinforcement bars. Other consultants are also involved depending on the type of the materials or works."	suitable
Procurement Team for Materials	" A project coordinator or a project engineer or a contract administrator can oversee the procurement process. Forming the materials procurement team is not essential for productivity."	not suitable
On-site Materials Tracking Technology	"The materials are not stored on site; they are delivered to the site when required; thus, tracking technologies are not significant for productivity. When materials are brought to a building construction site, they are placed in a location that is very close to where they are installed."	not suitable
Post-Receipt Preservation and Maintenance	" Most building materials are not stored on sites due to the shortage of the storage areas, and the practice 'post-receipt preservation and maintenance' is not relevant for productivity improvement in multi-storey building construction projects."	not suitable

The implementation of the practice ‘materials procurement plan’ has a positive impact on the productivity of multi-storey building construction projects. The interview participants described that the building industry structure in Victoria, Australia influences the procurement strategy. They explained that most principal contractors do not directly involve in purchasing the construction materials, but they manage the procurement process of the materials. The respondents described that the materials procurement program, which is based on the main construction program, is developed by the principal contractor and provided to the subcontractors or materials suppliers. Some interviewees described that the contractors collect information regarding the location of the manufacturers (overseas / local), the time it takes to manufacture the materials, and the duration of the delivery of the materials to prepare the materials procurement plan.

The respondents explained that extra time or buffer time is allowed while preparing the procurement plan as it might take a longer time to manufacture the materials. According to the interviewees, the principal contractors monitor the procurement process to ensure the manufacturing and the delivery of the materials. The principal contractors request subcontractors or material suppliers to issue letters which confirm the manufacture of the materials; they can also request the bill of lading to make sure that materials are shipped. Some interviewees described that verifications can sometimes be made by travelling to the country where the materials are manufactured. The participants suggested that the continuous monitoring of the procurement process by conducting a weekly meeting and reviewing the available materials on site is essential to reduce the shortage of materials and to enhance productivity.

Identification of long-lead items or critical materials is found to be one of the materials management practices that have the potential to enhance productivity in multi-storey building projects. The interviewees described that identification of the long-lead items and preparation of the package leading program, a program that is prepared to suit the long lead items, prior to tendering is essential to enhance productivity. Some participants proposed that requesting the tenderers to submit the quotations for the materials including the source and lead times is essential to identify the critical materials easily. For instance, besides the price of the tiles, tenderers can be requested to provide additional information such as the tiles will be imported from Italy, and it will take eight weeks to deliver to a project site. Other interviewees explained that most building materials that are imported from abroad are categorised as long lead items. Some of these materials include tiles, light fittings, façade and lift.

The practice of preparing the material status database has been found to have a positive impact on the productivity of multi-storey building projects. The respondents explained that the principal contractor’s project manager gets a report from subcontractors regarding the progress of their works, reviews the work progress report and prepares the materials status report for each work package. Some interviewees suggested that including information such as ‘the shop drawing is prepared,’ ‘materials are in production,’ ‘materials are ready for shipping,’ ‘materials are shipped,’ ‘ETA (Estimated Time of Arrival) of the materials,’ and ‘materials' installation date’ in the material status database is essential. Other respondents described that, in some projects, it is entirely the responsibility of subcontractor or materials supplier to quantify and order the right materials that are sufficient for the job. They explained that some principal contractors provide the necessary documents to the subcontractors and transfer the risks associated with procurement of materials to them. Some interviewees stated that certain principal contractors carry out continuous monitoring of the materials and assist the subcontractors or suppliers to deliver the right quantity and quality of materials.

Preparation of construction materials delivery schedule is found to be one of the construction materials management practices that could improve productivity in multi-storey building projects. The interview participants described that the construction materials delivery schedule is commonly prepared on a weekly basis, and it is done in consultation with site supervisors. The interviewees explained that the schedule helps to avoid the delivery of various materials at the same time. The suppliers are allowed to access a building site at designated times and use cranes or lifts accordingly. They also described that the delivery schedule is shown on board at a building site where subcontractors or materials suppliers can easily get materials related information. The schedule is updated to accommodate for delays in delivery due to, for instance, inclement weather and other unforeseen conditions. Some respondents explained that the schedule is displayed on a whiteboard in a meeting room so that the project team knows which materials are delivered on a specific date. They stated that the delay in the schedule can also be shown on the board. The interviewees suggested that careful planning of the materials delivery schedule has paramount significance to reduce delays, particularly, in projects located in the central business districts (CBD) areas since delivering some materials to these projects might not be allowed during the normal working hours.

Developing a procedure for materials inspection is found to be an essential practice to enhance productivity in multi-storey building projects. Some respondents described that the best practice for the materials inspection starts from the fabrication phase. The respondents recommended that some imported materials should be inspected while they are overseas. The inspection should also be conducted after they arrive in Australia; when they are delivered to a site; and after they are installed. According to the interviews, inspection during fabrication helps to ensure that the materials are manufactured as per the required standards or quality level. Some interviewees explained that subcontractors or material suppliers provide the quality assurance documents for all items they are supplying, and the principal contractor’s project team conducts quality control checks to make sure that the materials are procured according to the specifications provided in the contract document. Other respondents described that the materials samples are kept on site until the project is completed, and the quality of the supplied materials are checked against the samples. They also stated that there are technical data or product data signed off by the specialist consultant against which quality checks are done, and the consultants make scheduled site visits to identify defects in the installed materials.

The formation of materials inspection team is found to be an important practice to enhance productivity in multi-storey building projects. The respondents explained that the project coordinators, supervisors or persons in charge of a particular trade and a project manager conduct inspections. The project coordinators track the procurement process and conduct on-site and off-site inspections with the assistance of the specialist consultants. For instance, some interviewees described that for façade materials, façade experts are members of the inspection team. Other respondents explained that preparation of an Inspection and Test Plan (ITP), which is a program for inspecting and testing of materials and works, is a good practice to assure quality and enhance productivity. According to the interviewees, the inspection checklist for each item is prepared, and the site manager or other assigned staff conduct the quality assurance as per the checklist.

Finally, based on the findings of the interviews, the nine independent variables in the preliminary conceptual framework of the construction materials management are reduced to six independent variables, and the validated framework is shown in Figure 5-3.

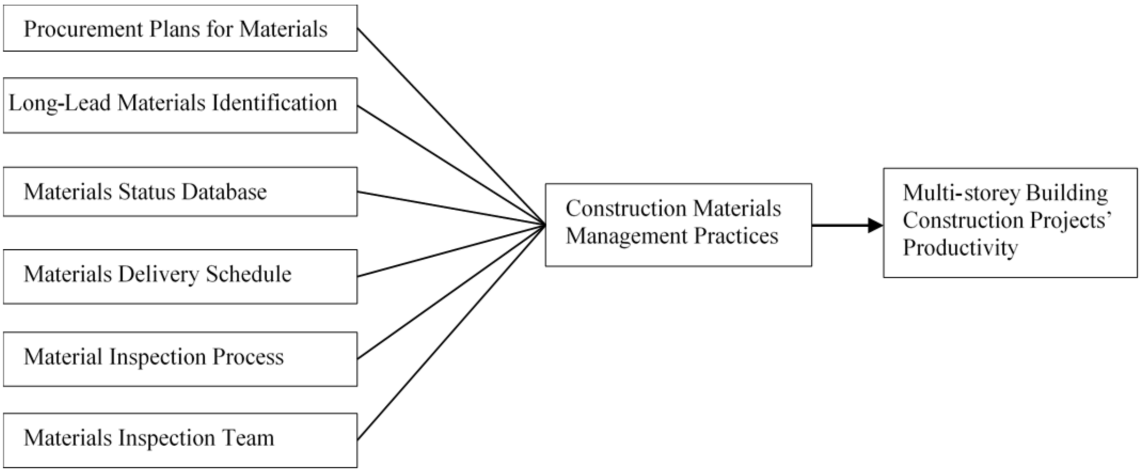


Figure 5-3 Validated Conceptual Framework of Construction Materials Management Practices and Productivity

The materials management practices such as ‘procurement team for materials,’ ‘on-site materials tracking technology,’ and ‘post-receipt preservation and maintenance’ are found to be not suitable to enhance productivity in multi-storey building projects. The interviewees described that forming the construction materials procurement teams is not essential for enhancing productivity. They explained that in most multi-storey building projects in Victoria, the projects are broken down into many packages, and supply and install contracting type is used. The interviewees described that a project coordinator or a project engineer or a contract administrator can oversee the procurement process.

On-site materials tracking technology is also found to be not important practice for improving productivity in multi-storey building construction projects. The interview participants described that as most building materials are not stored on project sites due to the shortage of storage spaces, the materials tracking technology is not required. They explained that all materials are not brought and stored on a building site. The materials are delivered when they are needed and placed close to their installation areas. Some interviewees added that to reduce the damages of the materials, they are not stored on building sites. The respondents suggested, to minimise the materials' damage on sites, the delivery of the materials one day before their scheduled installation date. According to the interviewees, if materials are delivered on the date close to their scheduled installation date and placed near their installation areas, the loss of productivity due to the mishandling of the materials can be reduced.

The practice post-receipt preservation and maintenance is also not considered as a good practice for improving multi-storey building construction projects' productivity. The interview participants explained that implementation of this practice is recommended when there are sufficient materials storage areas on project sites; however, most multi-storey building projects in the city of Melbourne do not have sufficient storage spaces, and the practice is not essential for increasing productivity.

5.4 Identification of Construction Equipment Management Practices Influencing Productivity in Multi-Storey Building Projects

Construction equipment procurement plan, construction equipment productivity analysis and construction equipment maintenance are found to be the three construction equipment management practices that have the potential to improve productivity in multi-storey building projects (Table 5-2).

The interview results reveal that preparing plan for either leasing or hiring of construction equipment has a positive impact on productivity. Some participants explained that cranes and hoists are the most frequently used equipment in multi-storey building construction projects. According to the interviewees, the lack of proper procurement procedures can negatively influence the productivity of the projects. Other interviewees explained that subcontractor involved in structure works provide equipment such as a crane, and the principal contractor negotiates on how other subcontractors use the equipment. Moreover, principal contractors can identify any equipment required for the execution of a specific task and include in the subcontract agreement so that a particular subcontractor is responsible for hiring it.

According to the interviews, the productivity of a crane, for instance, is analysed by considering its speed in lifting materials and the source of power. For example, electric crane does not make noise, and contractors can start their works early in the morning without disturbing neighbours. However, if it is a diesel crane, they could not start early as the crane's engine is noisy. The principal contractor should start work as per the permission provided to them by the city council. Cranes that have fast speed and capable of lifting maximum weight to be lifted at a particular building project are preferred. For a mobile crane, weather conditions are also considered. Contractors need to look at weather forecasts before bringing the equipment to the sites or signing an agreement with the crane hiring company.

Table 5-2 Summary of Interview Results of Construction Equipment and Tools Management Practices

Construction Equipment	*Summary of the Interview Responses*	*Conclusion*
Construction Equipment Procurement Plan	"In high-rise building projects, a crane is the major equipment that influences productivity. Sometimes there are many construction projects in Melbourne city and cranes or other construction equipment might not be available for a particular job. Thus, procurement of the equipment should be planned ahead of the commencement of a project to reduce delay.Thus, the practice ' equipment procurement plan' is vital to improve productivity."	suitable
Construction Equipment Productivity Analysis	"The practice is essential. For instance, a low-speed hoist costs less money, but it takes longer time. On the other hand, a high-speed hoist lifts materials quickly and saves construction time. For high-rise building, it is recommended to use two high-speed hoists side by side to increase productivity. The time the crane takes to place concrete panels or other items is recorded to analyse its productivity."	suitable
Construction Equipment Maintenance	"Contractors should ensure that equipment is calibrated, inspected and maintained. Induction should be provided when new equipment is delivered to a building site. In some situations, if there is no maintenance record, the equipment might not be allowed to be used on a particular project. Therefore, equipment maintenance is necessary for productivity improvement."	suitable
Tools Management Strategy	"Most of the tools used in multi-storey building construction projects are not stored on site due to a shortage of spaces. Thus the implementation of the practice 'tools management strategy' is not essential for productivity enhancement."	not suitable
Tools Tracking Technologies	"The practice is not significant to increase the productivity of multi-storey building construction projects as most tools are not stored on sites."	not suitable
Tools Maintenance	"The life span of the tool is monitored, and corrective actions can be taken, but the practice is not essential for enhancing productivity."	not suitable

In analysing the hoists' productivity, the number of stories of a building and the floor area is considered. The interview participants explained that for a high-rise building, greater than thirty stories, it is recommended to use two high-speed hoists side by side than using two low-speed hoists. The cost of a slow speed hoist is less than that of a high-speed, but it takes longer time and productivity is affected if the slow-speed is deployed. The time required to transport materials from ground to the desired working level is recorded and analysed to choose the most suitable hoist. Some respondents added that for small jobs, up to three storeys, the choice of the speed does not make any difference in productivity. However, for multi-storey buildings, the selection of appropriate hoist can make a major difference.

Construction equipment maintenance is found to be one of the practices for improving productivity in multi-storey building projects. According to some participants, crane, for instance, is commonly serviced every two weeks, and the hoist is serviced once a week. When subcontractors are responsible for hiring construction equipment, they are required to provide evidence regarding the maintenance of the equipment to the principal contractor. Other respondents added that inspecting and maintaining the construction equipment or crane, in particular, is fundamental because lifting building materials is a risky task. If materials fall while lifting due to the usage of unsafe cranes, the contractor is responsible for damages to nearby properties or persons. The respondents also described the regulatory requirement that must be fulfilled regarding the frequency of maintenance and what items should be inspected regularly.

Based on the findings of the interviews on construction equipment and tools management practices, the six independent variables in the preliminary conceptual framework of construction equipment management practices are reduced to three independent variables, and the validated conceptual framework is shown in Figure 5-4.

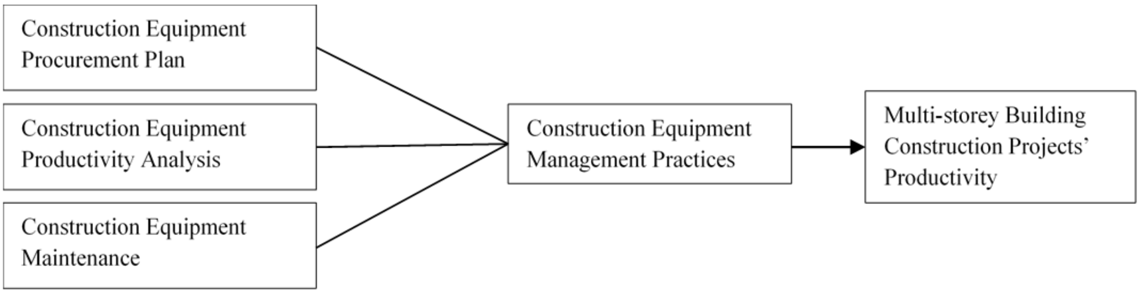


Figure 5-4 Validated Conceptual Framework of Construction Equipment Management Practices and Productivity

Tools management strategy, tools tracking technologies, and tool maintenance are found to be the practices which are not significant to enhance productivity in multi-storey building projects. The respondents explained that the majority of contractors involved in the delivery of multi-storey building projects in Victoria State, Australia are managing contractors, and they do not purchase and store the tools on building sites. Thus, the practice 'tools management strategy' is not relevant to improve productivity in multi-storey building projects.

The use of tools tracking technology is found to be a practice which is not important to enhance productivity in multi-storey building projects. The interviewees described that due to the limited number of tools owned by a particular contractor, on-site tracking technologies such as the use of tags or barcodes is not significant. Other interviewees added that because of the shortage of on-site storage spaces, most tools are not stored on sites, and the use of tools tracking technologies is not required. The respondents suggested that it is preferable to include the cost of tools in the labour cost than purchasing and managing the tools. The respondents explained that a tradesperson who executes a particular task can bring the required tools and the tools' cost can be included in the hourly labour cost. The participants of the interviews explained that the implementation of the practice 'tools maintenance' has less relevance in improving productivity in multi-storey building projects. They described that maintenance of machinery such as forklifts is more relevant for enhancing productivity than the maintenance of tools.

5.5 Identification of Management Practices Related to Construction Methods

The summary of the interview results (Table 5-3) shows ten management practices that have the potential to enhance productivity in multi-storey building construction projects, and the practices are related to construction methods. These include integrated schedule, work schedule strategies, schedule control, dynamic site layout plan, traffic control plan, site security plan, machinery positioning strategy, project start-up plan, project completion plan, and innovations and new technologies.

A scheduling system that integrates work, materials procurement and delivery, machinery, budget, and other resources has a positive impact on the productivity of multi-storey building projects. For example, if work schedule is integrated with materials and machinery schedules then the project teams are aware of when a particular activity is executed, what type of machinery should be hired, how much material and manpower should be deployed, and track the delivery of the materials. The research participants described that the best performing contractors link all the schedules together and update the schedules on a weekly or biweekly basis.

Table 5-3 Summary of the Interview Results of Management Practices Related to Construction Methods

Management Practices Related to Construction Methods	*Summary of the Interview Responses*	*Conclusion*
Integrated Schedule	"Linking various programs is essential. For instance, most contractors try to link materials procurement, lead time, work status, main work program and other issues such as the schedule for FFE (Fittings, Fixture, and Equipment) together."	suitable
Work Schedule Strategies	"There is an agreement which dictates the normal working hours per week. However, depending on the type of work (critical or near critical activities) the principal contractor negotiates with subcontractors to schedule flexible working hours. For instance, for the sake of safety, jumping of crane might not be made during normal working hours. Thus, there should be a negotiation between contractors on the date and time when the activity is done."	suitable
Schedule Control	"Principal contractors prepare target program which is usually shorter than the contract program and monitors the progress of the works executed by subcontractors accordingly. Some supervisors work in close collaboration with subcontractors, control the schedules and report to the principal contractor's project manager. Regular weekly or biweekly meetings are conducted to resolve issues which hamper the progress."	suitable
Dynamic Site Layout Plan	"The site plan is constantly changing for the sake of productivity. The gates in and out, for instance, might be altered throughout the construction period. They could be changed after completion of excavation or during superstructure and landscaping works. The site layout plan should also consider the location of temporary facilities at various stages of the project."	suitable
Traffic Control Plan	"Traffic control plan is done at different stages of construction. For example, there are traffic control plans during excavation, pouring concrete and site works. The traffic control plan is usually done by a certified traffic management company. The principal contractor employs trained traffic controllers or subcontractors are responsible for controlling the traffic during the execution of the subcontracted works."	suitable
Site Security Plan	"Site security depends on the type and the stage of the building construction projects. If long lead materials which are imported from overseas are stolen or lost towards the end of a project, there could be a project delay."	suitable
Machinery Positioning Strategy	"The location of the critical machine such as tower cranes is planned by considering the weight to be loaded, distance from the street and the nearby buildings or other property. Thus, developing a strategy for positioning cranes is critical for productivity."	suitable
Project Start-up Plan	"Prior to the start of a building construction project, the project team conducts start-up meeting that helps them to go through the list of items that trigger their memory."	suitable
Project Completion Plan	"Good project completion plan should start on day one. This could be done by reviewing the project plans and listing out all the things that need to be completed to hand over the project in time. For example, the dates when to obtain certificates of the completed tasks and other issues should be listed on spreadsheets."	suitable
Innovations and New Technologies	"There is no specific department responsible for investigating new technologies and innovations in most construction companies. However, in some situations, a project manager has the authority to implement suitable technology for a particular project."	suitable

Developing suitable working hours strategies is found to be another important management practice that has the potential to improve productivity in multi-storey building projects. There are working hour restrictions imposed by city councils, and contractors are required to develop a strategy to reduce project delays. Most principal contractors in Victoria, use the calendar prepared by Construction, Forestry, Mining and Energy Union (CFMEU) which is typically 36 working hours per week. They schedule to work either four, five or six days a week and sign contracts with their subcontractors accordingly. Some respondents described that they schedule to work only six days per week and consider Sundays and Rostered Days Off (RDOs) as non-working days. Other respondents explained that on Saturdays, they reduce the working hours by half (50%). Some interviewees described that they prefer to work five days per week because they believe that people are not productive on Saturday, Sunday and RDOs. The participants added that it is expensive to work on Sundays and after hours as the rates provided in the Enterprise Bargaining Agreement (EBA) or in the Fair Work Commission’s awards is high. Other interviewees described that the working hours are influenced by Construction, Forestry, Mining and Energy Union (CFMEU) and contractors are not flexible to develop different strategies such as working after hours, on Saturdays and shifts. However, for critical works that cannot be executed during the normal working hours, for example, for crane jumping, Saturdays or after hours can be scheduled.

The practice ‘schedule control’ is found to be one of the management practices that are related to construction methods and positively influencing productivity in multi-storey building projects. The interviewees explained that the principal contractors prepare a target program which is shorter in duration than the main contract program, and the subcontractors sign the agreement based on the target program. The respondents described that based on the target program, the subcontractors plan the number and the types of workers and machinery to be deployed to meet the target program. After the commencement of the construction works, the principal contractor’s project management team monitor the progress of the works executed by subcontractors; and prepare a report which comprises of the percentage completed, the remaining duration and the forecasted completion dates. The project manager also conducts a weekly or bi-weekly meeting to discuss issues related to the project status and other matters which influence the productivity of a multi-storey building project.

Dynamic site layout plan is found to be an essential practice that could improve productivity in multi-storey building projects. Some interviewees described that the site plan is constantly changing for the sake of productivity, and it is prepared by considering different phases of a building construction. They suggested that the gates should be planned to allow easy movement of trucks and workers, and the location of the gates could be changed to suit different activities in the project. For instance, the location of the gates during excavation, superstructure, and landscaping or site works could be different. The respondents proposed two gates (gate-in and gate-out) during the excavation works. If there is only one gate, it is not suitable for trucks to get into and out of the site and productivity can be reduced. Some interview participants described that although the practice of adopting dynamic site layout is important, it should be planned ahead to be effective. They explained that experienced contractors include their site logistics plan in a tender document. The changes in a plan that is based on the stages of construction are clearly shown in the tender document so that subcontractors are aware of the future changes in the site layout. Moreover, the respondents described that integration of the traffic control and the site layout plans has a paramount importance to reduce the loss of productivity.

Traffic control plan is found to be one of the management practices that could enhance productivity in multi-storey building projects. The interviewees explained that traffic control plans that are suitable for different stages of the building construction are prepared. The respondents suggested that traffic control plans should be prepared during excavation, pouring of concrete, delivering precast panels, and completion of the project (execution of the site works). The interviewees explained that the traffic control plan is usually done by a certified traffic management company and approved by the relevant city councils. Some of the interview participants described that the principal contractor can employ qualified traffic controllers or subcontractors are responsible for assigning their traffic controllers.

Site security plan is found to be an important practice that could influence the productivity of multi-storey building construction projects. The respondents described that the level of the site security depends on the phases of the project and the value of the properties installed or stored inside the building under construction. They explained that as the project gets towards completion, there might be an impact on the facility or some items could be stolen, and the project completion date will be delayed. As a result, the level of security is higher towards the end of the project. Some interviewees explained that certain contractors have developed procedures to build the hoardings, install the lights on the hoardings, assign after hour security guards, and place security cameras and localised- standard lamps on a site. Other respondents explained that if the site is not safe and secure, the productivity of employees decreases as they are not motivated to work in such environment. Moreover, if some of the items are stolen from the site, the contractor has to purchase and replace that item. Consequently, there can be the loss of productivity due to waiting for the replacement of the stolen or damaged materials.

The construction machinery positioning strategy is found to be an essential practice that influences productivity in multi-storey building projects. According to the interviewees, the critical machine for these projects is a tower crane, and its location on a construction site is planned by considering the weight to be loaded, the distance from the street from which the materials are lifted, the area of a building, and the distance from the existing buildings. The respondents explained that the crane needs to reach the street; it should have the capacity to lift the heaviest materials; it should cover the entire area; and it should not hit nearby buildings or other properties. In some circumstances, more than one crane can be used on a particular project if the above conditions are not satisfied by a single crane. Other respondents described that before the commencement of a building construction, the project manager and crane experts compute the footprint of the building; identify the number of cranes required for the given building area; and determine the appropriate location of the equipment or cranes. The respondents suggested that careful analysis of the position of the construction equipment using either 2D drawings or 3D model is an important practice to conduct the construction works smoothly. Besides improving productivity, the construction equipment location analysis saves cost. For instance, the number of cranes can be reduced from two to one after conducting the analysis. The interviewees described that project delays could occur due to the improper positioning of the construction equipment. They explained that, in some sites, the precast panels were too heavy to be lifted by a crane and the design of the panels was changed to suit the capacity of the existing crane. This resulted in the loss of productivity of the project due to design changes.

The preparation of the project start-up plan is essential for the smooth commencement of the construction of multi-storey building projects. The respondents explained that if the project start-up plan is done early, then a contractor can commence the construction of a building on time, and the chance of occurrence of initial project delay can be reduced. Prior to starting the project, the contractor's project team needs to conduct start-up meeting that helps them to go through the list of items that should be completed before the commencement date. The start-up plan assists the project team in identifying which tasks are completed and what activities are not executed yet. The interviewees explained that some contractors prepare a checklist which consists of many questions such as Are permits obtained? Are materials procured? Is earthwork machinery hired? Thus, the project start-up plan helps the project team to fine-tune what they are going to execute.

The practice 'project completion plan' influences the productivity of multi-storey building projects. According to the interviewees, the implementation of an effective project completion plan needs to start immediately after the commencement of the construction works. Respondents suggested that items which need certificates during the project handover phase should be sorted out early, and a project manager needs to track them starting from the project commencement date. For example, the concrete test certificates should be collected and documented immediately after the completion of the task. The respondents explained that if the relevant certificates are not obtained, the project handover process can be delayed. The project completion plan also states how temporary works and equipment such as crane are going to be dismantled. Some respondents described that, in some projects, the project meetings are conducted every six months or on scheduled dates to review the project completion plans. According to the interviewees, the completed building project might not be used unless the building surveyor or the relevant authority provides a certificate of occupancy. The project completion plan needs to address what should be fulfilled to obtain the certificate.

The use of new technologies and innovations in managing construction projects has a positive impact on the productivity of multi-storey building projects. The interviewees described that in some building construction projects, supervisors have their own tablet computers and use them for receiving and sending site information. These supervisors rarely use pen and papers to communicate with the project manager. Training is provided to the supervisors regarding the utilisation of new technologies. Some participants explained that projectors, whiteboard, automatic photocopy, dual monitors, wireless internet, and other facilities are provided to the project sites. The respondents described that most project managers of the principal contractors use commercially available software as a communication tool with subcontractors and/or supervisors. For instance, the project manager can send the pictures of the defects of the executed works including the defects' specific locations as well as the rectification order to the concerned subcontractors. Some interviewees described that contractors use a drawing review system in which drawings are reviewed electronically rather than manually.

Finally, based on the findings of the interviews, ten management practices related to construction methods are identified, and the validated conceptual framework is presented in Figure 5-5.

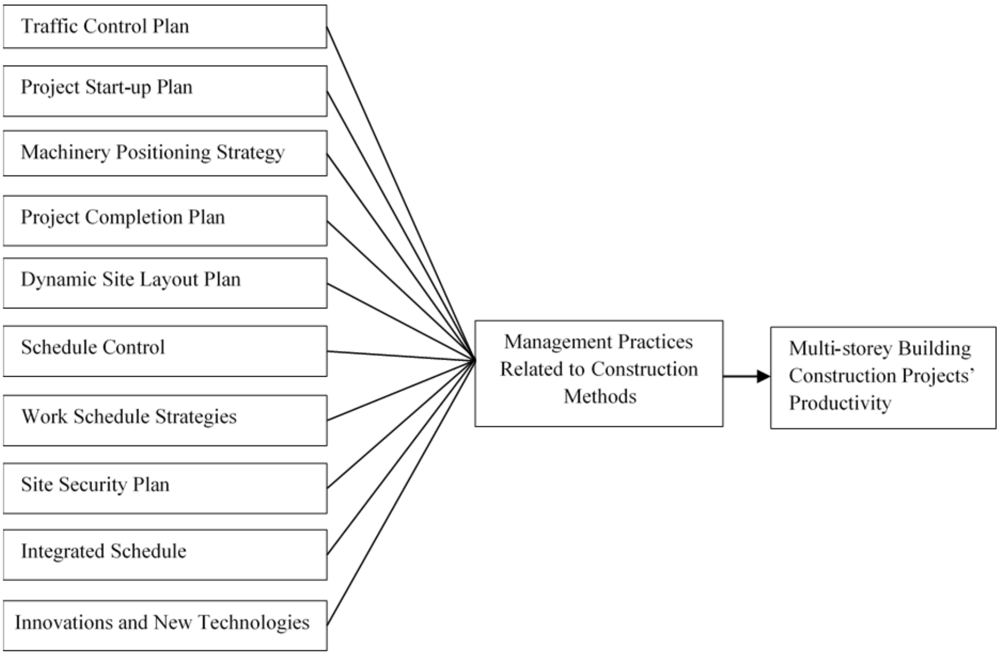


Figure 5-5 Validated Conceptual Framework of Management Practices Related to Construction Methods

5.6 Identification of Preconstruction Phase Management Practices Influencing Productivity in Multi-Storey Building Projects

The interview results revealed ten preconstruction management practices that have positive impacts on the productivity of multi-storey building construction projects in the context of Victoria State, Australia. These include Well-Defined Scope of Works, Short Interval Plan, Buildability Review, Construction Work Packages, Regulatory Requirement, Contract Types, Use of Software in Planning Work Packages, Utilities

Alignment, Dedicated Planner, and Model Development. In Table 5-4, the summary of the interview responses is presented.

Table 5-4 Summary of the Interview Results of Preconstruction Phase Management Practices

Preconstruction Phase Management Practices	*Summary of the Interview Responses*	*Conclusion*
Well-Defined Scope of Works	"The scope of works is prepared before tendering phase, and there is a section called scope of works in the tender document; for instance, façade work package has its scope of works, the structure work has its scope of works, and finishing and fitting work packages also have their scope of works. A well-defined scope of works is linked with drawings and specification, and it can be prepared based on the previous scope of works developed for similar projects. A model scope of works which can be used to prepare project specific scope of works should be prepared by contractors."	suitable
Short Interval Plan	"The short interval plan is commonly prepared on a bi-weekly basis. In the plan, the daily tasks and the required resources are indicated. The short interval plan is usually prepared after conducting project team meeting. The Project manager, contract administrator, project engineer and Foremen or supervisors are involved in the meeting. Based on the size of the project, the construction manager, sometimes, involves in the preparation of the plan."	suitable
Buildability Review	"In some projects, there is a logistic planner or a person who reviews the design before its implementation. Depending on the scope of a project, besides the design manager, other professionals are also involved in the buildability review. Design reviews need to be regularly conducted. Getting inputs from subcontractors is also essential."	suitable
Construction Work Packages	"A building project can be broken down into approximately 20 to 25 work packages. Tile, façade, structure, lift and landscape are some of the examples of the work packages. The construction work packages are prepared to suit the capacity of local subcontractors. Each work package has work program, drawings, specifications, budget, the scope of works, and site logistics."	suitable
Regulatory Requirement	"Various permits should be obtained from local authorities. These include traffic management plan, construction management plan, connection to services permit, planning permit, building permit, demolitions permit, asset protection permit, and occupancy permit among others."	suitable
Contract Types	"Predominantly, lump sum or one figure contract is used. Sometimes when the scope of work is not clearly defined or small, the principal contractors employ daily labourers to execute the activity. Generally, work packages having costs exceeding AUD 50,000 are classified as major works and more detailed contract documents are required."	suitable
Use of Software in Planning Work Packages	"Various software is used in planning the work packages. This includes Microsoft Excel, MS Project, Primavera, Job Pack and other proprietary software."	suitable
Utilities Alignment	"Before commencing the construction works, the 'Dial Before You Dig' referral system is used to identify the location of the existing services. Contractors should get approval from water, gas and electric power authorities before connecting to these utilities. The project owners should also contact the respective authorities."	suitable
Dedicated Planner	"Assigning the dedicated planner at a company and/or a project level is essential. The planner has relevant experience and records such as productivity data and activity durations which help him/her prepare good project programs."	suitable
Model Development	"3D-model development is essential as it facilitates communication of the project information. The model is vital for the construction of complex structural steel works. It is also significant to identify the clashes among different services such as mechanical, electrical and plumbing."	suitable

The practice well-defined scope of works is found to be one of the practices that have the potential to enhance productivity in multi-storey building projects. Some of the interview participants described that if uncertainties in the scope of works are reduced, or if the scope is defined well, the productivity of a building project can increase since contractors are certain on what they do and when they do. They explained that defining the scope of works involves clarifying in words what a contractor needs to do to deliver a work package or a project. For instance, the scope of works for a subcontractor involved in façade works could state the responsibilities of the subcontractor such as the provision of all necessary allowances for coping and flashing, the use of the subcontractor’s own means of access, the safety requirements, and the completion of the works in accordance with the program provided in the appendix to the contract. The respondents described that a well-defined scope of works is linked with drawings and specification, and it can be prepared based on the previous scope of works which was developed for similar projects.

The preparation of a short interval plan is also found to be one of the practices that have the potential to improve productivity in multi-storey building projects. The interviewees described that the plan shows the daily activities together with the resource requirements. Some respondents explained that the short period look-ahead programs (one week or two weeks’ programs) help to focus on specific tasks. They described that short interval planning is beneficial as it indicates what contractors should do at a certain point in time. For instance, if the current tasks are excavation and pouring of foundations’ concrete, then the project team can focus on planning and deploying of the resources which are required for the execution of these tasks. Some respondents explained that contractors usually prepare the master program and detailed short interval plans. They described that if the main program, for instance, provides nine days for excavation and earthworks, then the short interval plan provides details such as three days for bulk excavation, two days for cart away of waste soil, two days to compact the soil and two days as buffer time. Other interviewees stated that some contractors prepare the main works program that is shorter than the contract program or a project completion program which is agreed between the client and the contractor. According to the interviewees, a weekly or bi-weekly look ahead programs are prepared based on the milestones dates provided in the main works program. The interview participants suggested that the short interval plan should not be prepared using the top-down approach in which a project manager or planner dictates the durations and completion dates. They recommended that the plan should be done by involving other project team members such as site manager, supervisors or forepersons, project coordinator/project engineer and contract administrator.

Buildability review is found to be the essential practice to enhance productivity in multi-storey building projects. Some interviewees suggested procedures that could facilitate the review of the drawings before being issued to the site. They described that when a consultant issues drawings, the document controller receives and hangs the drawings on red sticks; and the project coordinators, design manager, project manager, and services managers review the drawings on the sticks and send back to the consultant for revision. The respondents recommended that drawing should be reviewed by the project team for compliance with the design brief, for any scope changes which have a major impact on cost, and for the purpose of constructability. Some interviewees explained that it could be difficult to get a design manager who knows the detailed construction processes of the building projects. They explained that most local design managers are architects who understand the details on paper, but they might not necessarily understand the construction process. According to the interviewees, in some projects or activities, how much time it will take to install can be as important as the actual cost of the material, and conducting design review can save cost and improve productivity. The respondents explained that the involvement of contractor in the design process is essential. Accordingly, awarding a contract when about 80% of the design is completed and involving the contractor to complete the remaining 20% of the design is a good practice for productivity. The participants described that this practice provides an opportunity for the contractor to provide comments regarding the constructability issues. The interviewees suggested that for the sake of productivity and smooth workflow, it is preferable to novate the original designer than to engage a new designer.

The practice of preparing manageable ‘construction work packages’ is found to be one of the factors which positively influence the productivity of multi-storey building projects. The interviewees explained that the building project’s work packages are prepared by considering the skill and the financial capacity of the local subcontractors. Some respondents described that the principal contractors do not want to break the project into very small work packages that do not worth the subcontractors to tender. Other participants suggested that, during the subcontractor selection, besides the document review, an interview should also be conducted to ensure that the subcontractor has the required capacity and experience. The respondents described that certain contractors have the policy of ‘gauging before engaging,’ and every subcontractor is interviewed before awarding a contract. The interview participants also explained that in high-rise building construction projects, there are approximately between 20 and 30 work packages, and structural concrete work is one of the major work packages. The interviewees described that for the sake of productivity, it is preferable not to break down the structure package into smaller work packages. Some interviewees stated that it is not recommended to subcontract the formwork, the reinforcement bar work, and concreting activities separately. Accordingly, it is desirable to choose one subcontractor that is responsible for placing reinforcement bars and formworks, for supplying and pumping concrete, and for providing all the necessary machinery. The interviewees explained that, for a principal contractor, it is preferable to manage one subcontractor than managing three or four subcontractors that are involved in the concrete construction. Some interviewees described that the practice of awarding a concrete work package to a single subcontractor is essential not only for enhancing productivity but also for getting workers with multi-skills. For instance, workers doing formwork can also pour concrete, and those pouring concrete can do the reinforcement work.

Identification of the permitting requirements is found to be one of the preconstruction phase management practices that could increase productivity in multi-storey building projects. The interviewees described that various permits should be approved before commencing the construction of a building project. They described that some permits have predetermined lead times. For instance, it could take between 6 to 12 weeks to get the construction management plan (CMP) approved by the city councils. This lead time should be considered during the preparation of the work program. According to the respondents, unless the CMP is approved, the construction activities cannot be commenced. In the CMP, contractors are required to address how they plan to manage issues such as public safety, amenity and site security, operating hours, noise and vibration controls, air and dust, storm water and sediment, waste and materials re-use, and traffic. The interviewees also explained that the approvals of other permits such as working on Saturdays and Sundays, working after hours, connection to the existing services, demolition, building permit, occupancy permit, traffic management plan and asset protection permits are required during the construction of multi-storey buildings in Victoria. The respondents described that some permits could take a longer time, and the productivity of a project can be influenced if the approval time is not considered while preparing the construction work program. Some interviewees described that a building permit can be approved in a shorter time than CMP and traffic management plan.

The contracting strategy is another preconstruction phase management practice that influences productivity in multi-storey building projects. The interviewees suggested that the use of back-to-back subcontracting approach is important to increase productivity. In this approach, if the head contract, for instance, is lump sum type, then the subcontract should also be lump sum type. The conditions in the head contract or the contract between the client and principal contractor are stated in the subcontract too. Thus, the subcontractors can get the chance to involve in the design, and the variations during the construction phase can be reduced. The respondents suggested that adopting lump sum contract type and involving contractors in the design of a multi-storey building can minimise the project risks and enhance productivity. Moreover, the interviewees recommended the use of appropriate contract forms; for instance, the work packages which cost over Australian Dollar (AUD) 50,000 are usually classified as the major works, and they need more detailed contract documents. However, work packages with a value less than AUD 50,000 can be considered as minor works.

The use of software in planning is found to be an essential practice that could enhance productivity in multi-storey building projects. The participants of the interviews described that preparation of the construction work schedules and the work packages using software can improve the productivity. Different software can be used to break down a project into manageable tasks. By using the software, work schedules which show materials and manpower resources, budget, milestone dates, and the durations can be prepared easily. According to the interviewees, most contractors use Microsoft Project as a planning tool, and some contractors use Primavera. Excel spreadsheet is also used for short interval planning. Some respondents explained that certain contractors have their own proprietary software that is used for planning purpose.

The practice 'utility alignment' is considered to be an important preconstruction phase management practice that has the potential to improve productivity in multi-storey building construction projects. Some interview participants described that in the construction of multi-storey buildings in Victoria, utility alignment is becoming a significant issue because of the presence of restrictions to connect the new utility lines to the existing networks. The interviewees explained that the infrastructure might not be available at the required location and some of the existing sewers do not have the capacity to provide services to the new buildings. Some respondents explained that although it is the responsibility of the client to settle the issue of external utilities, the contractor has to understand where the existing utility lines are and identify the best route to connect the new line to existing one. Other respondents explained that on most building projects, the 'Dial Before You Dig' referral system is used to identify the location of the services before commencing earthworks.

The assignment of a dedicated planner has a positive influence on the productivity of multi-storey building projects. The respondents explained that the complexity of a building project determines whether to assign the dedicated planner or not. Some respondents explained that when the project is small (less than three storeys), there is no need to have the dedicated planner as the project manager can do the work of the planner. Other respondents suggested that for multi-storey building projects, the assignment of the dedicated planner at either project or company level is considered as a good practice for enhancing productivity. The respondents explained that the dedicated planners could have rich experience and productivity data, and they can prepare better project programs.

The practice 'model development' is found to be one of the preconstruction phase management practices that have the potential to improve productivity in multi-storey building projects. The interview participants described that in building construction, the use of 3D models is essential to detect the clashes among building services such as mechanical, electrical and plumbing. The models can also be used in structural steel works. A structural steel subcontractor can use the 3D models to manufacture and install the structural elements. Some interviewees explained that the models are essential to facilitate communication. The 3D models help to visualise the design of an item. Some participants suggested that clients or project owners should make decisions to invest in the use of 3D models. They explained that the investment could worth because it can reduce risks, particularly, in complex building projects. The use of the models has paramount significance in the installation of mechanical, electrical, and plumbing services. Thus, the contractors can easily see every service lines and avoid overlapping of the services; consequently, claims for additional time and cost due to the complexity of the design is reduced.

Finally, ten preconstruction phase management practices are identified using the interviews, and the validated conceptual framework of the pre-construction phased management practices is shown in Figure 5-6.

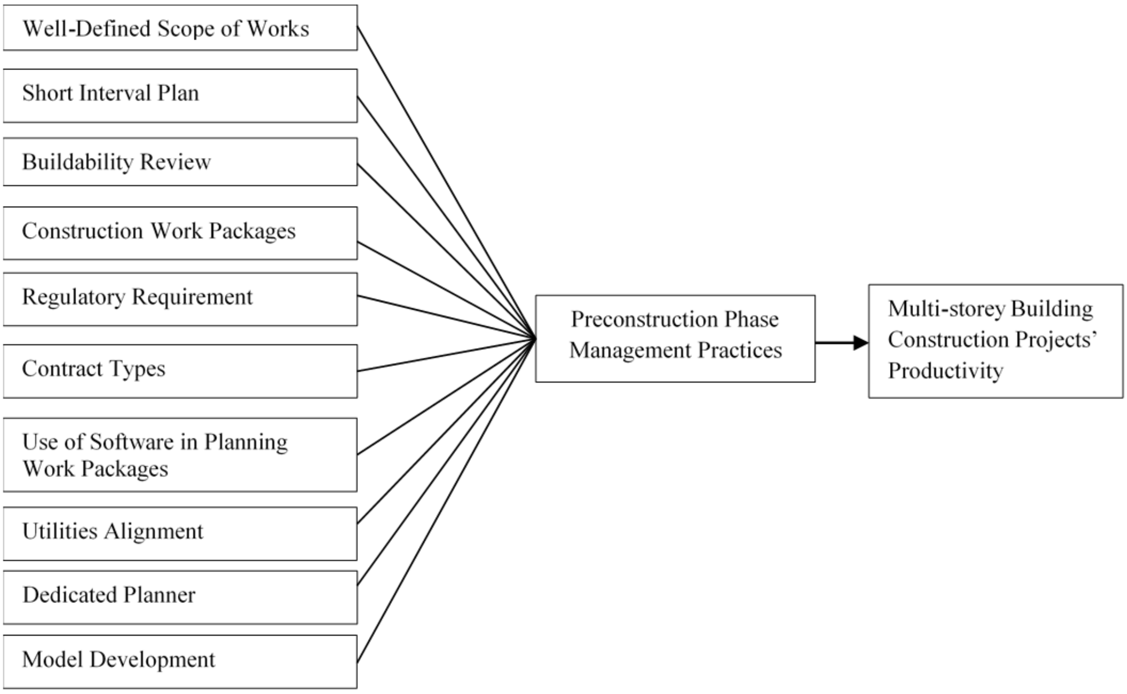


Figure 5-6 Validated Conceptual Framework of Preconstruction Phase Management Practices and Productivity

5.7 Identification of Human Resource Management Practices Influencing Productivity in Multi-Storey Building Projects

Eleven human resource management practices that have the potential to enhance productivity in multi-storey building projects have been identified. These comprise of Clear Delegation of Responsibility, Stability of Organisational Structure, Crew Composition, Retention Plan for Experienced Personnel, Employees Training, Skill Assessment and Evaluation, Career Development, Financial Incentive Programs, Social Activities, Non-Financial Incentive Programs, and Exit Interviews. In Table 5-5, the summary of the findings is presented.

Table 5-5 Summary of the Interview Results of Human Resource Management Practices

Human Resource Management Practices	*Summary of the Interview Results*	*Conclusion*
Clear Delegation of Responsibility	"The roles and responsibilities of the staff are included in the employment contract. The line manager and project manager prepare the job descriptions, and meetings are conducted so that the staff can ask questions regarding their duties and responsibilities."	suitable
Stability of Organisational Structure	"Depending on the phases of the construction project, the organisational structure could change; however, the key personnel should not leave the site. Towards the end of the project, the number of the workforce on the site is reduced. The project manager or contract administrator could be sufficient to manage the project."	suitable
Crew Composition	"The principal contractors recruit qualified professionals to form management crew, and subcontractors are responsible for forming their crews depending on the types of the work packages. Project manager, contract administrator, site manager, project coordinators and supervisors are among the crew members of most principal contractors operating in Victoria."	suitable
Retention Plan for Experienced Personnel	"Employees can be retained by promoting them. Most companies promote their personnel and increase the salaries of the employees. The majority of contractors prefer to promote the employees internally rather than recruiting externally."	suitable
Employees Training	"The construction companies provide various training to their workers. These include first aid, health and safety, the operation of cranes, working on scaffolding, techniques of using new machinery, erecting precast concrete panels, supervision, negotiation, and mental resilience."	suitable
Skill Assessment and Evaluation	"Most principal contractors assess the competency of their subcontractors or employees. The subcontractors should have the proper training to do a specific task. For example, workers doing the scaffolding should be licensed; workers involved in dogging and rigging should also have licenses; and all construction workers need to have general construction induction cards."	suitable
Career Development	"Companies have their own culture for the career paths. Some contractors conduct an annual review to discuss issues regarding the career development of their employees. Others held meetings every six or three months to address the issues of employee development."	suitable
Financial Incentive Programs	"Financial incentives are provided to motivate employees. Pay for performance scheme is practised in some construction companies. In some projects, the bonus is given to the workers if the projects are completed less than the targeted budgets."	suitable
Social Activities	"Social activities are organised every month or two months, and sometimes on public holidays. Some of the activities include involving in marathon running, dinner, Christmas party, and team exercises such as soccer game. Most contractors allocate budget for these activities."	suitable
Non-Financial Incentive Programs	"For instance, allowing the worker to do a variety of works can be considered as a non-financial incentive. Some contractors post the names of the employees who perform well. There are also incentives systems which are not directly paid for the employees. These could be providing health care to the workers."	suitable
Exit Interviews	"When an employee is quitting, the project manager or other responsible personnel conduct an interview to understand why the employee leaves the project and to know what employment conditions to improve."	suitable

Clear delegation of responsibility is found to be one of the human resource management practices that could enhance productivity in multi-storey building projects. The interviewees described that the responsibility of an employee should be clarified before commencing the construction works. However, as a project progresses, employee's role could change, and the changes can be notified through project team meeting. Some participants explained that the roles and responsibilities of each employee are emailed to all members of the project team. Other respondents suggested that besides sending the written roles and responsibilities to the respective employees, conducting a meeting to clarify any issue related to employment is also vital. During the meeting, employees get the chance to ask questions regarding the job descriptions before the start of the construction works. The interviewees described that, in some situations, it might be difficult to describe the roles and responsibilities of the employees in written form; as a result, there could be a gap in delegating the duties. However, they suggested that the gap can be minimised by forming a team that comprises of employees who worked together on previous similar projects.

Maintaining the stability of the organisational structure of a project is one of the factors that positively influence the productivity of multi-storey building projects. The interviewees suggested that an employee who is a member of the project team should not leave the job if the stability of the organisational structure is to be maintained. The employees who are working on the project from its starting date have knowledge about the status of the job, the assumptions made to estimate the project cost, and other project specific information. Some respondents recommended that as experienced employees' knowledge is gold for construction projects, these workers should not leave the project. The interviewees explained that in most building projects, the project team is formed by a dedicated person at the head office who assesses employees' experience and choose the new project's team members. Some respondents explained that towards the end of a building project, the number of employees decreases. When the project is substantially completed, the company may decide to have a project manager or contract administrator and a few labourers.

The practice 'crew composition' is found to be an important human resource management practice that has the potential to improve productivity in multi-storey building projects. According to the interviews, the principal contractor's project team, in most projects, comprises of project manager, contract administrator, project coordinators, site manager and supervisors. Some principal contractors organise the project team that consists of project manager, site engineer, general Forman and Forman. The respondents described that construction manager and design managers can also be the members of the project team, but their offices might not necessarily be on the building construction sites. The interviewees explained that subcontractors are responsible for forming crews for the trades of works they have subcontracted, and the principal contractor has no direct control over their crew compositions. However, in some circumstances, the principal contractors can request subcontractors to have a Lead Foreman within their crews and to employ experienced tradesperson and labourers. Some respondents described that, in some circumstances, the principal contractors mention the names of key personnel in the subcontract agreements to oblige subcontractors to include skilled employees in their crews.

Retention plan for experienced personnel is found to be an essential human resource management practice that can be implemented to improve productivity in multi-storey building projects. The interviewees described that the experienced personnel in construction are highly valued as they have knowledge about the construction methods, building Acts, regulations, codes and standards, and they should be retained in the company. The respondents explained that there are many regulatory changes in the building industry which could affect productivity, and knowledge about these issues is crucial. Some interviewees explained that when experienced employees who have been working on construction sites are retired, contractors assign them in the head office to retain the knowledge. The other strategy which is used by contractors to retain the key personnel is through promotion. They try to promote internally rather than recruiting externally so that they can lower the cost of recruitment and retain the knowledge which helps them to be competitive.

Providing training to the construction workers is considered to be an essential practice to improve productivity in multi-storey building projects. The interview participants suggested that employees should be trained since the local building regulations could regularly be amended, and workers need to be aware of the changes. Some respondents stated that training such as first aid, crane operation, working on scaffolding, and Occupational Health and Safety (OH&S) are commonly provided to the construction workers. Other respondents described that some contractors offer training to improve negotiation, leadership and communication skills of their employees. According to the interviewees, the training requirement varies depending on the type of the trades of works. For example, there is a regulatory requirement which obliges tradesperson such as electricians and plumbers to complete their apprenticeship before being fully certified. The absence of regulatory requirement could result in a bad workmanship; the plumbing system might not work properly; and the users of the completed project could be electrocuted because of improper installation of electric systems. For other trades such as plastering, workers can be trained on the job.

Skill assessment and evaluation is found to be an important practice that could enhance productivity in multi-storey building projects. Some interviewees suggested that before the commencement of any construction activity, a project manager or staff who is in charge of organising the site crews should evaluate the skills of the employees and understand where their experiences fit and what their strengths and weaknesses are. Moreover, the mechanisms to improve the workers' skill should also be investigated. The respondents explained that when the works are subcontracted, the project manager has the responsibility to ensure that each subcontractor has the required competency to do a specific task. This can be done by requesting the recommendation letters from the previous employer and by investigating the evidence such as pictures of the previously executed works. The interviewees suggested that employees doing a particular task should take proper training, and they should have certificates. For instance, project managers need to check if the workers have a certificate for dogging and rigging before starting the jobs related to crane or lifting works. Some respondents explained that to understand the skill level of the subcontractors' tradesperson, the supervisors of the principal contractors monitor the works of each worker and identify any defects. If there are defects, the site supervisors report to the project manager, and the manager of the subcontracting firm is notified to make corrective action.

Career development plan is another human resource management practice which influences productivity in multi-storey building projects. Some respondents described that career development is about having a vision for the workers and discussing the career paths which the employees would prefer. They explained that in most building projects, a formal meeting is held every six months or a year to discuss the issues related to career development. Some interviewees suggested that it is preferable to promote an existing employee to a new position than employing a new worker because the new employee might take a longer time to adapt to the company culture. Thus, there could be a loss of productivity until the new employee learns the company procedures and develops effective communication with the existing project team members. Besides enhancing productivity, career development plan can also save costs associated with the recruitment of new employees.

The practice ‘financial incentive programs’ is found to be one of the essential human resource management practices that could improve productivity in multi-storey building projects. The interview participants described that financial incentives are provided to motivate employees, and the incentives vary based on the employees’ roles. Some interviewees explained that certain contractors promote their employees and increase payment depending on the level of responsibility of an employee. In some circumstances, the bonus is given to workers if the actual cost of a project is less than the targeted budget. Moreover, an increase in payment based on the performance of the employee or ‘pay for performance scheme’ is practised by some construction companies. Other interviewees suggested that financial incentives are more important for subcontractors than principal contractors. They explained that if subcontractors offer good incentives, the chance of getting skilled labourer increases, and the more skilled the employees, the better chance of winning the tender is.

Organising social activities as means of motivating project team is found to be one of the factors which positively influence productivity in multi-storey building construction projects. Some respondents described that in order to keep the project team fresh and excited, social activities every month or two months or on public holidays are organised by contractors. Some of the activities include involving in marathon running, bowling, dinner, Christmas party, and soccer games. The respondents explained that some contractors allocate budget for every project and plan the event dates.

Non-financial incentive programs are among the human resource management practices that could enhance productivity in multi-storey building projects. Some interviewees explained that non-financial benefits are very important for principal contractors in particular, and allowing employees to do a variety of works or enrichment of the job is one of the effective non-financial incentive systems. Other respondents described that contractors post names and photos of the well-performing employees on the notice board at head office and project sites. They also announce their names on a team meeting and media functions. The interviewees stated that there are other non-financial incentive schemes such as health care services which the employees do not pay for.

The practice ‘exit interviews’ is found to be an essential practice that positively influences productivity in multi-storey building construction projects. The interviewees described that conducting an exit interview helps a contractor to understand why an employee leaves and what the firm should do to change the employee’s mind. Other issues which the contractor needs to improve could also be identified via exit interviews. Some respondents suggested that the interview should be conducted at both project site and head office levels. Other interviewees explained that exit interviews and written feedbacks to a contractor are vital provided that the contractor takes corrective actions. According to the respondents, in some circumstances, some contractors disregard all the comments given by the employee during the exit interview. They consider that the employee was not good and the comments are not relevant.

Finally, eleven human resource management practices are identified, and the validated conceptual framework of human resource management practices is shown in Figure 5-7.

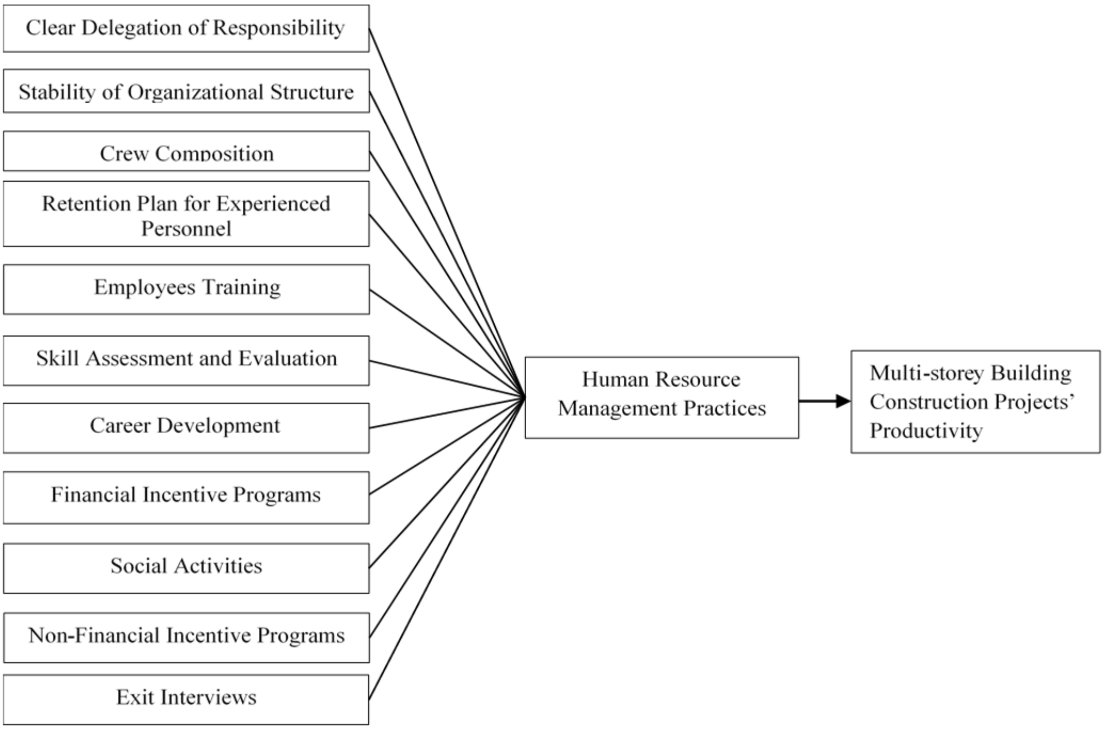


Figure 5-7 Validated Conceptual Framework of Human Resource Management Practices and Productivity

5.8 Identification of Safety and Health Practices Influencing Productivity in Multi-Storey Building Projects

‘Safety and health policy,’ ‘safety and health plan,’ ‘hazard analysis,’ ‘safe work method statement,’ ‘toolbox safety meetings,’ ‘housekeeping,’ and ‘safety and health training’ are found to be the seven important safety and health practices that have the potential to enhance productivity in multi-storey building projects. However, the practice ‘drugs and alcohol testing program’ is considered to be not vital to improve productivity in multi-storey building projects in the context of Victoria State, Australia. Summary of the interview results of safety and health practices is presented in Table 5-6.

The preparation of the safety and health policy for a certain multi-storey building project is found to be an essential practice that could improve productivity. According to the interviewees, most contractors have safety and health policy at company and project levels. The respondents explained that some construction companies have established the minimum requirements that help them to manage the risks at their projects and use the term Global Minimum Requirements (GMRs) for the minimum safety standards. Other participants explained that some contractors have an accredited safety and health management systems. The interviewees explained that the project specific safety policies are usually displayed at places where most employees can see. Moreover, the construction workers are informed during site induction phase, and the copies of the safety and health policies are provided to subcontractors.

Safety and health plan is found to be one of the safety and health practices that have the potential to improve productivity in multi-storey building projects. Some interviewees explained that contractors plan to reduce the number of accidents on building construction sites as it is difficult to avoid accidents completely. The respondents explained that certain contractors have developed their own methodology to reduce the accidents rates by focusing on engineering controlling techniques than on the administrative controlling techniques. They explained that the administrative controlling technique lists the items that should be checked prior to executing the work. In the engineering controlling technique, loads are calculated, and appropriate materials are recommended to ensure the safety of workers. According to the interviews, in some building projects, there are rewards for employees who achieve the zero accident plan.

Other respondents described that, in some projects, contractors plan not to exceed a specified value of the lost-time injury frequency rate (LTIFR). The lost-time injury frequency rate (LTIFR) of the previous projects is computed and used as a benchmark to prepare the target LTIFR for new projects.

Table 5-6 Summary of the Interview Results of Safety and Health Practices

Safety and Health Practices	*Summary of the Interview Responses*	*Conclusion*
Safety and Health Policy	"Most contractors have safety and health policy at company and project levels. Some contractors have accredited safety policy. The project specific policies are clearly displayed on sites, and workers are informed during the induction process. Some principal contractors also provide copies of their safety policies to their subcontractors."	suitable
Safety and Health Plan	"The maximum number of lost-time injuries are planned for new building project based on the number of accidents occurred in the past projects. The lost-time injury frequency rate (LTIFR) is computed for the previous projects and used as a benchmark to prepare the target LTIFR for new projects."	suitable
Hazards Analysis	"Workers give answers to the safety-related questions which are distributed every month or two months to identify the potential hazards. There are also workshops to identify hazards which are not considered during task safety analysis."	suitable
Safe Work Method Statement	"In some projects, subcontractors prepare a Safe Work Method Statement (SWMS) for each task, and the principal contractors review and approve the SWMS. Safety manager monitors the progress of subcontractors on a daily basis and checks if the works are executed as per the approved SWMS. Safety audits are also conducted regularly, for instance, every six months."	suitable
Toolbox Safety Meetings	" The practice of conducting safety meetings varies from project to project. On some sites, there is a regular weekly or fortnightly toolbox safety meeting. On other projects, the meeting is conducted when high-risk works are executed."	suitable
Housekeeping	"The construction sites need to be clean; otherwise, accidents could occur and productivity will be lost. In most projects, two big bins are provided by a principal contractor and subcontractors place the waste materials in the bins.The subcontractors are required to have the green bins or medium size bins. The principal contractor needs to make sure that the statement 'a subcontractor should clean its working area' is included in the scope of works of each subcontractor."	suitable
Safety and Health Training	"Every worker has to take a minimum of general construction induction training and has to have a white card or red card or other certificates. Graduates and cadets should take about six months training regarding safety issues while working on different sites. Training on the use of new equipment and removal of asbestos is also conducted."	suitable
Drugs and Alcohol Testing Program	"Drugs and alcohol testing programs are not common in the building industry. The issue of alcohol and drugs are discussed during the induction phase, but there is no formal testing program. Generally, on most building construction jobs, drugs and alcohol testing is not conducted since it is not included in the employment agreement."	not suitable

Hazard analysis is another safety and health practice that positively influences productivity in multi-storey building construction projects. The interview participants suggested that the potential hazards that are not identified during the preparation of the safe work method statement (SWMS) should be analysed separately. The interviewees described that conducting hazard analysis is also essential for 'works of minor nature' or works which the safety regulations do not oblige contractors to prepare SWMS. The respondents explained that to identify the potential hazards, the construction workers give answers to the safety-related questions which are distributed every month or two months. Workshops are also organised to identify hazards.

The practice 'Safe Work Method Statement (SWMS)' is also found to be one of the safety and health practices that could enhance productivity in multi-storey building projects. The interviewees explained that SWMS is prepared by conducting safety analysis for each task classified under high-risk construction works. To prepare the SWMS, the activities involved and the procedures for execution of the task are identified, potential hazards are listed, and mechanisms for minimising or eliminating the risks are proposed. Finally, the person who monitors the compliance with the SWMS is assigned. Some interviewees described that, in some projects, SWMS is prepared by subcontractors and approved by the principal contractor. Other respondents explained that there are safety representatives at project sites and head office who oversee the Occupational Health and Safety. The safety audit is conducted every six months or year in the presence of a safety representative from the head office.

Toolbox safety meeting is found to be one of the safety and health practices that positively influence productivity in multi-storey building construction projects. Some interview participants recommended that there should be regular on-site meetings to discuss various issues related to safety. The meetings help the project team to share safety information and to solve problems jointly. Some interviewees explained that in building construction projects in Victoria, toolbox safety meetings are usually conducted every week or two weeks. Other respondents described that on some building projects, tool box meeting is not regularly scheduled. It is conducted when executing risky tasks that require workers to discuss the installation methods of the tasks. For example, lifting of heavy precast panels requires safety meeting. The participants suggested that besides regular toolbox meetings, the daily brief or pre-start induction is also essential. The daily orientation helps the workers to know what is happening on that particular date.

The practice 'housekeeping' is found to be one of the important safety and health practices that have the potential to improve productivity in multi-storey building projects. The interviewees explained that the lack of cleanliness of project sites can result in accidents and loss of productivity. The respondents described that, in most building projects in Victoria, two large bins are provided by principal contractors, and subcontractors put the waste materials in the bins. In other projects, subcontractors are entirely responsible for managing their wastes. However, the responsibilities of the subcontractors need to be specified in the scope of works or in the subcontract agreement. Some interviewees described that the principal contractor's supervisor can stop the subcontractor's personnel from working on a particular site if the housekeeping is not good. Other respondents explained that to keep the site clean and safe, most construction materials are not stored on a building site.

The practice 'safety and health training' is considered to be one of the safety and health practices that positively influence productivity in multi-storey building projects. The interviewees described that safety training and inductions need to be conducted. Since regulations might change, the latest information must be provided to the construction workers. Some interview participants explained that every worker should have a minimum of white card or red card or other evidence which shows the completion of the general construction induction training. Moreover, the construction workers should be given project specific information prior to commencing the construction activities. The interviewees described that some principal contractors require their employees to have Certificate 3 in Work Health and Safety. First aid, asbestos removal, and new equipment operation are some of the training provided to the building construction workers. Some respondents suggested that graduates and cadets should be trained for about six months regarding the safety and health issues.

Finally, seven safety and health practices are found to have the potential to improve productivity in multi-storey building projects, and the validated frame of safety and health practices shown in Figure 5-8.

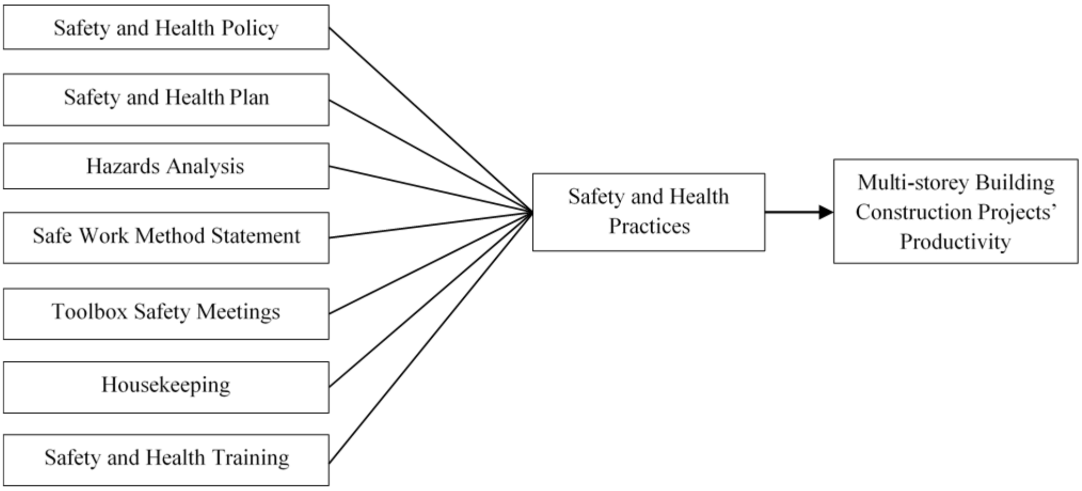


Figure 5-8 Validated Conceptual Framework of Safety and Health Practices and Productivity

The practice 'drugs and alcohol testing program' is found to be not suitable to improve productivity in multi-storey building projects in the context of Victoria State, Australia. Some interview participants explained that drug and alcohol testing is not conducted in most building construction projects in Victoria, but the issue is getting attention since workers come to a building site after drinking alcohol, particularly on Saturdays. Other respondents described that the use of alcohol and drugs is addressed during the induction phase, but there is no formal testing program. According to the interview, the safety representatives can figure out the drunken workers and prohibit them from commencing the construction works. Other interviewees described that drugs and alcohol testing is not conducted in most building construction projects since it is not included in the employment agreement.

5.9 Summary

After analysing the qualitative data, part of Objective 1 or "to identify construction management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia" is achieved. Moreover, part of Objective 2 or "to refine the scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects" is met. Forty-seven context specific construction management practices have been identified, and the validated conceptual frameworks of the practices have been developed. The construction management practices comprise of six construction materials management practices, three construction equipment management practices, ten management practices related to construction methods, ten preconstruction phase management practices, eleven human resource management practices, and seven safety and health practices. Finally, the 47 independent variables (the construction management practices) indicated in the validated conceptual frameworks (Figure 5-3, Figure 5-4, Figure 5-5, Figure 5-6, Figure 5-7, and Figure 5-8) are used as input to the second phase of the research which comprises of quantitative data collection and analysis (please refer Part I of the Questionnaire in Appendix-1 for the list of the practices). Furthermore, the levels of implementation of the 47 practices were refined from the existing tools based on the findings of the interviews, and the unweighted scoring tools for the practices in the context of multi-storey building projects were prepared. The unweighted scoring tools were validated during Phase I of the research and used as an instrument to collect quantitative data (please refer Part II-C of the Questionnaire in Appendix-1 for the validated instruments or unweighted scoring tools). The preliminary quantitative data analysis is presented in the next chapter.

CHAPTER SIX

6 PRELIMINARY QUANTITATIVE DATA ANALYSIS

6.1 Introduction

This chapter presents the preliminary analysis of the quantitative data. The background of the respondents involved in Phase II of the research and the profiles of the companies are described in Section 6.2. The productivity factors of the projects are computed, and the results are shown in Section 6.3. In Section 6.4, the descriptive analyses of the construction management practices' data are conducted. Thus, the descriptive statistics of the construction materials management practices, the construction equipment management practices, the management practices related to construction methods, the preconstruction phase management practices, the human resource management practices, and the safety and health practices are presented in Section 6.4. Finally, the summary of the chapter is provided in Section 6.5.

6.2 Profiles of the Companies and the Respondents

The profiles of the questionnaire survey participants are indicated in Figure 6-1. Accordingly, the majority of the participants (46%) are project managers with an average of 13 years of experience in building construction.

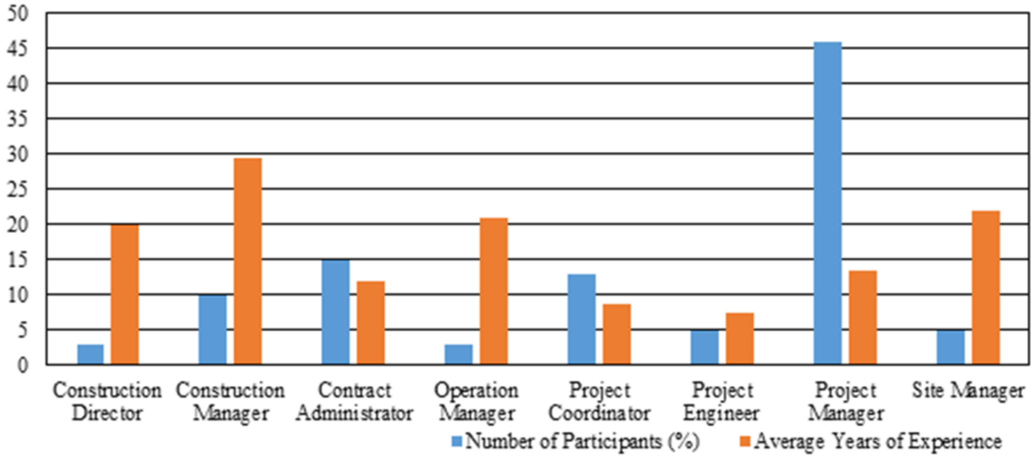


Figure 6-1 Profiles of the Questionnaire Survey Participants

About 15% of the respondents are contract administrators having an average of 12 years of work experience;13% of the survey participants are project coordinators with an average of nine years of experience; 10% of the participants are construction managers having an average of 29 years of experience; projects engineers with an average of eight years of experience comprises 5% of the total respondents; site managers having an average of 22 years of experience also comprises 5% of the total respondents; 3% of the participants are operation managers having 21 years of experience; and 3% of the total respondents consist of construction directors with 20 years of experience (Figure 6-1).

Figure 6-2 presents the distributions of the contractors by the company sizes. Accordingly, 59% of them have employees greater than 200, and 41% of them have between 20 and 199 employees. This research will explore if larger companies have better management practices than smaller companies.

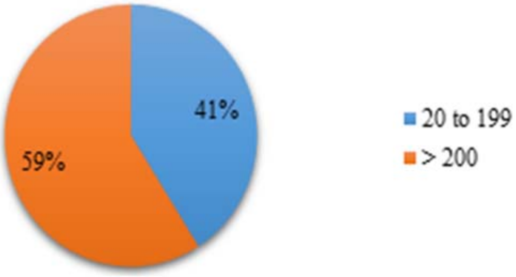


Figure 6-2 Distributions of Contractors by Company Sizes

The annual turnover of the contractors in the year 2014/15 is indicated in Figure 6-3. Accordingly, 38% of the contractors have the annual turnover between 100 and 500 million Australian Dollars (AUD), 29% of them have the annual turnover between 501 and 1000 million AUD, 13% of the contractors have between 1001 and 2000 million AUD, and 21% of them have the annual turnover exceeding 2000 million AUD. This study will investigate whether companies with high annual turnover also implement higher levels of the construction management practices.

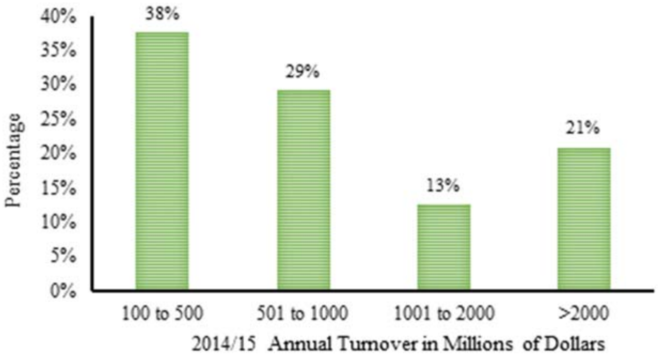


Figure 6-3 Distributions of Contractors by Annual Turnover

The experience of the contractors in the construction industry is presented in Figure 6-4. Accordingly, 29% of the contractors have experience between 10 to 20 years; 21% of them have between 21 and 40 years; 32% of the construction companies have between

41 and 60 years; about 13% of them have between 61 and 80 years; and 5% of them have greater than 80 years of experience. This research will explore if the implementation level of the management practices is associated with the experience of the contractors.

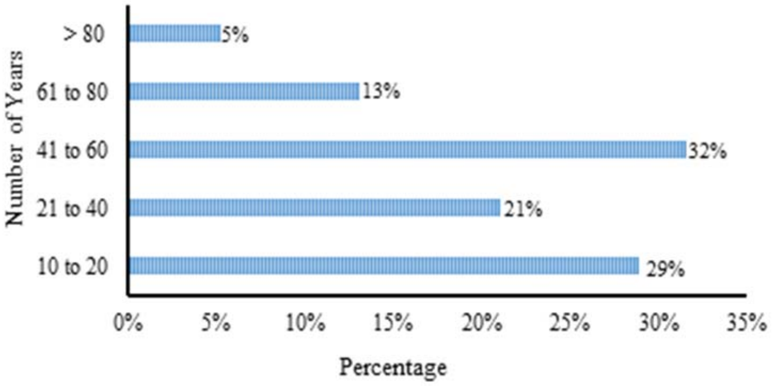


Figure 6-4 Distributions of the Contractors by Years of Experience

6.3 Characteristics of the Projects and Computation of Productivity Factors

Before calculating the projects' productivity factors, the percentage distributions of their costs are computed, and the results are presented in Figure 6-5. Accordingly, 36% of the projects have project costs between 8 and 19 million Australian Dollar (AUD), 21% of them have project costs between 20 to 39 million AUD, 18% of them have project costs between 40 and 100 million AUD,13% of them have project costs ranging from 101 to 150 million AUD, 8% of them have project costs between 151 and 200 million AUD and 5% of them have project costs greater than 200 million AUD.

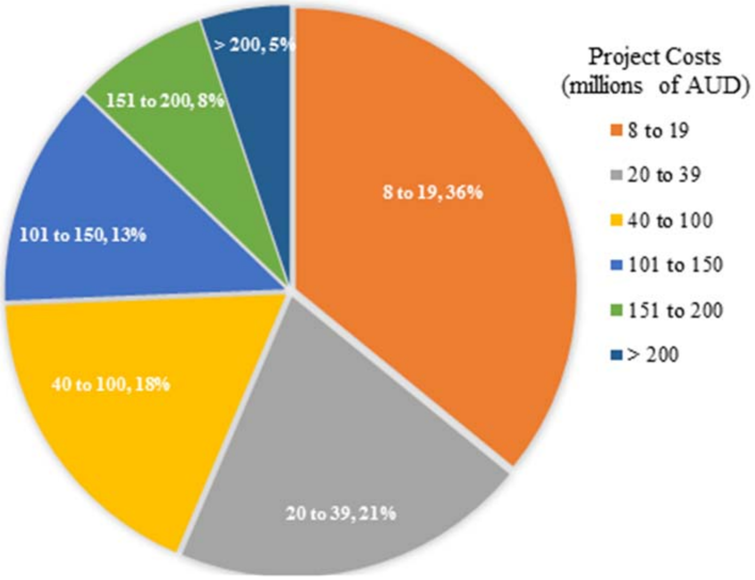


Figure 6-5 Percentage Distributions of the Costs of the Building Projects

In Figure 6-6, the proportions of the building projects which incurred project delays are shown. Accordingly, about 54% of the projects are completed on and before the planned completion date; 21% of them incurred project delays ranging from 1day to 50 days; 10% of them have project delays between 51 and 100 days; about 5% of them incurred project delays ranging from 101 to 149 days; and 10% of them have project delays exceeding 150 days.

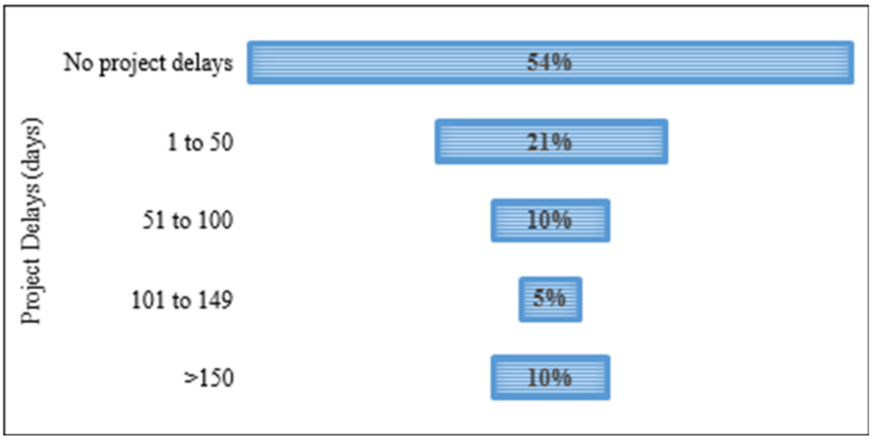


Figure 6-6 Percentage Distributions of the Project Delays

The productivity factors (PFs) of the projects are computed using the project durations, and project costs and the results are shown in Table 6.1. The minimum PF value is 0.59, the maximum PF value is 1.14, and the average PF value is found to be 0.95. Based on their PFs, the projects are grouped and analysed. The proportions of projects with PFs ranging from 0.5 to 0.70, 0.71 to 0.90, 0.91 to 1.10, and exceeding 1.10 are presented in Figure 6-7. Accordingly, 8% of the projects have PFs ranging from 0.50 to 0.70, 28% of the projects have PFs between 0.71 and 0.90, 54% of the projects have productivity factors ranging from 0.91 to 1.10, and 10% of the projects have PFs exceeding 1.10.

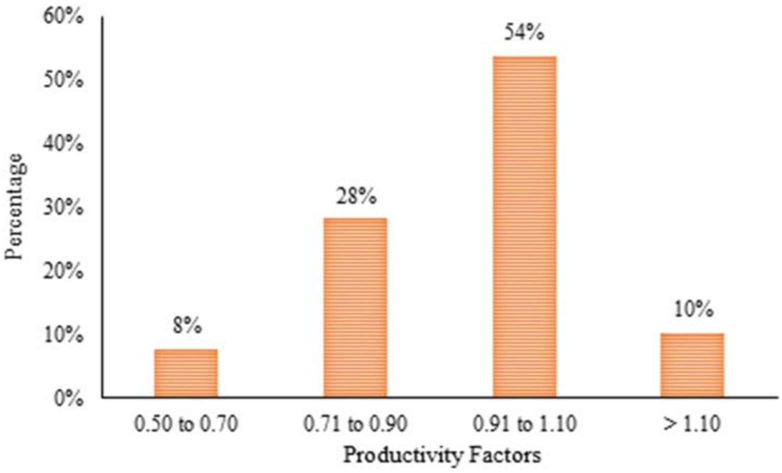


Figure 6-7 Percentage Distributions of the Productivity Factors of the Projects

Table 6-1 Productivity Factors of the Projects

Project Code	*Project Start Date* (a)	*Planned completion date* (b)	*Actual completion date* (d)	*Project Cost ($AUD Million)* (f)	*planned input* g=(b-a)	*actual input* h=(d-a)	*Actual productivity* i = (f)/(h)	*Planned Productivity* j =(f)/(g)	*Productivity Factor (PF)* (i)/(j)
R1	1-Mar-13	1-Jun-14	1-Jun-14	30	457	457	0.0656	0.0656	1.00
R2	1-Jun-11	1-Mar-14	1-Aug-14	100	1004	1157	0.0864	0.0996	0.87
R3	29-Jan-15	16-Oct-15	12-Oct-15	106	260	256	0.4141	0.4077	1.02
R4	1-Aug-14	10-Feb-16	1-Feb-16	42.5	558	549	0.0774	0.0762	1.02
R5	13-Jan-14	4-Dec-14	2-Dec-14	28	325	323	0.0867	0.0862	1.01
R6	1-Feb-12	1-Jun-15	1-Mar-16	110	1216	1490	0.0738	0.0905	0.82
R7	1-Oct-14	1-Dec-15	1-Apr-16	50	426	548	0.0912	0.1174	0.78
R8	1-May-14	1-Nov-15	1-Oct-15	160	549	518	0.3089	0.2914	1.06
R9	29-May-12	30-Aug-14	30-Aug-14	150	823	823	0.1823	0.1823	1.00
R10	1-May-14	1-Oct-15	1-Aug-15	32	518	457	0.0700	0.0618	1.13
R11	1-Jan-10	29-Oct-10	23-May-11	17	301	507	0.0335	0.0565	0.59
R12	1-Sep-14	31-Dec-14	1-Feb-15	20	121	153	0.1307	0.1653	0.79
R13	1-Jun-14	1-Sep-15	1-Aug-15	240	457	426	0.5634	0.5252	1.07
R14	13-Jan-14	2-Dec-14	12-Feb-15	25	323	395	0.0633	0.0774	0.82
R15	19-Oct-12	17-Dec-13	14-Feb-14	17	424	483	0.0352	0.0401	0.88
R16	1-Jan-12	1-Oct-13	1-Oct-13	15	639	639	0.0235	0.0235	1.00
R17	1-Oct-13	1-Apr-15	1-Jan-16	175	547	822	0.2129	0.3199	0.67
R18	1-Apr-12	1-Sep-13	1-Sep-13	14	518	518	0.0270	0.0270	1.00
R19	1-Apr-15	1-May-16	31-Mar-16	15	396	365	0.0411	0.0379	1.08
R20	27-May-14	27-Nov-14	22-Dec-14	13.6	184	209	0.0651	0.0739	0.88
R21	28-Apr-15	3-Jan-16	13-Jan-16	10.6	250	260	0.0408	0.0424	0.96
R22	1-Jun-13	1-May-15	1-May-15	20	699	699	0.0286	0.0286	1.00
R23	1-Jul-09	1-Feb-12	1-Jun-12	200	945	1066	0.1876	0.2116	0.89
R24	1-May-13	1-May-14	1-Jun-14	14.5	365	396	0.0366	0.0397	0.92
R25	1-Aug-12	1-Jun-14	1-Jul-14	18.5	669	699	0.0265	0.0277	0.96
R26	28-May-15	23-Dec-15	26-Feb-16	10.8	209	274	0.0394	0.0517	0.76
R27	1-Mar-14	1-May-16	1-Mar-16	105	792	731	0.1436	0.1326	1.08
R28	1-Jan-15	15-Aug-15	11-Jan-16	12	226	375	0.0320	0.0531	0.60
R29	1-Apr-13	1-Apr-14	1-May-14	30	365	395	0.0759	0.0822	0.92
R30	1-Jan-14	1-Aug-15	1-Jun-15	70	577	516	0.1357	0.1213	1.12
R31	7-Mar-11	24-Feb-12	30-Mar-12	8.2	354	389	0.0211	0.0232	0.91
R32	1-Feb-12	1-Jun-13	1-Apr-13	80	486	425	0.1882	0.1646	1.14
R33	30-May-15	24-Mar-16	27-Apr-16	13.3	299	333	0.0399	0.0445	0.90
R34	6-Sep-14	16-May-16	1-Apr-16	197	618	573	0.3438	0.3188	1.08
R35	1-Jul-12	1-Jan-14	1-Dec-13	15	549	518	0.0290	0.0273	1.06
R36	1-Jun-14	25-Dec-14	25-Dec-14	28	207	207	0.1353	0.1353	1.00
R37	1-Oct-13	1-Dec-14	1-Nov-14	59	426	396	0.1490	0.1385	1.08
R38	1-Apr-14	1-Mar-16	1-Mar-16	115	700	700	0.1643	0.1643	1.00
R39	4-Dec-12	30-Oct-14	28-Aug-14	40	695	632	0.0633	0.0576	1.10

6.4 Descriptive Analysis of the Construction Management Practices

The descriptive data analysis of the 47 construction management practices revealed that the practice well-defined scope of works has the highest mean value of 4.79, and the practice model development has the lowest mean value of 2.69 (Table 6-2). The descriptive statistics of all the management practices are shown in Table 6-2, and the raw data used in the computation is presented in Appendix-2.

Table 6-2 Descriptive Statistics of the Construction Management Practices

Construction Management Practices	*N*	*Range*	*Min*	*Max*	*Mean*		*Std. Dev*	*Var.*
					Statistic	Std. Error		
Construction Materials Management Practices								
(1) Procurement Plans for Materials	39	4	1	5	4.23	0.13	0.84	0.71
(2) Long-Lead Materials Identification	39	3	2	5	**4.59**	0.11	**0.68**	0.45
(3) Materials Status Database	39	4	1	5	3.31	0.16	0.98	0.96
(4) Materials Delivery Schedule	39	3	2	5	3.74	0.15	0.94	0.88
(5) Material Inspection Process	39	4	1	5	3.49	0.15	0.94	0.89
(6) Materials Inspection Team	39	3	1	4	**2.85**	0.15	**0.96**	0.92
Construction Equipment Management Practices								
(1) Procurement Plan for Construction Equipment	39	4	1	5	3.46	0.16	0.97	0.94
(2) Construction Equipment Productivity Analysis	39	4	1	5	3.03	0.16	0.99	0.97
(3) Construction Equipment Maintenance	39	4	1	5	**3.95**	0.18	1.12	1.26
Management Practices Related to Construction Methods								
(1) Integrated Schedules	39	4	1	5	3.28	0.14	0.89	0.79
(2) Work Schedule Strategies	39	3	2	5	3.67	0.10	**0.66**	0.44
(3) Schedule Control	39	3	2	5	3.87	0.12	0.77	0.59
(4) Dynamic Site Layout Plan	39	2	3	5	4.08	0.11	0.70	0.49
(5) Traffic Control Plan	39	2	3	5	**4.26**	0.11	0.72	0.51
(6) Site Security Plan	39	3	2	5	3.67	0.13	0.81	0.65
(7) Machinery Positioning Strategy	39	3	2	5	4.08	0.14	0.93	0.86
(8) Project Start -up Plan	39	3	2	5	**4.26**	0.12	0.75	0.56
(9) Project Completion Plan	39	4	1	5	4.13	0.15	**0.95**	0.9
(10) Innovations and New Technologies	39	4	1	5	3.18	0.14	0.89	0.78
Preconstruction Phase Management Practices								
(1) Short Interval Plan	39	3	2	5	4.38	0.11	0.71	0.51
(2) Well-Defined Scope of Work	39	3	2	5	**4.79**	0.09	**0.57**	0.33
(3) Use of Software in Planning Work Packages	39	3	2	5	3.82	0.15	0.94	0.89
(4) Dedicated Planner	39	4	1	5	3.05	0.18	**1.10**	1.21
(5) Construction Work Packages	39	2	3	5	4.28	0.11	0.69	0.47
(6) Buildability Review	39	2	3	5	4.38	0.09	0.59	0.35
(7) Utilities Alignment	39	3	2	5	3.79	0.12	0.77	0.59
(8) Contract Types	39	3	2	5	3.87	0.13	0.80	0.64
(9) Model Development	39	4	1	5	**2.69**	0.17	1.03	1.06
(10) Regulatory Requirement	39	3	2	5	4.26	0.14	0.85	0.72
Human Resource Management Practices								
(1) Crew Composition	39	4	1	5	3.85	0.16	0.99	0.98
(2) Skill Assessment and Evaluation	39	4	1	5	3.69	0.16	1.00	1.01
(3) Employees Training	39	4	1	5	3.74	0.16	0.99	0.99
(4) Career Development	39	4	1	5	3.54	0.15	0.91	0.83
(5) Non-Financial Incentive Programs	39	4	1	5	3.26	0.16	1.02	1.04
(6) Financial Incentive Programs	39	4	1	5	3.36	0.17	**1.06**	1.13
(7) Social Activities	39	3	2	5	3.36	0.14	0.87	0.76
(8) Stability of Organizational Structure	39	3	2	5	4.08	0.12	**0.74**	0.55
(9) Clear Delegation of Responsibility	39	3	2	5	**4.18**	0.13	0.79	0.63
(10) Retention Plan for Experienced Personnel	39	3	2	5	3.82	0.13	0.82	0.68
(11) Exit Interviews	39	4	1	5	**2.87**	0.17	1.03	1.06
Safety and Health Practices								
(1) House Keeping	39	2	3	5	4.44	0.09	0.60	0.358
(2) Safety and Health Policy	39	2	3	5	**4.74**	0.08	0.50	0.248
(3) Safety and Health Plan	39	2	3	5	4.62	0.10	0.63	0.401
(4) Safe Work Method Statement	39	2	3	5	4.56	0.11	0.68	0.463
(5) Hazards Analysis	39	2	3	5	4.62	0.11	0.67	0.453
(6) Safety and Health Training	39	2	3	5	4.44	0.13	**0.79**	0.621
(7) Toolbox Safety Meetings	39	2	3	5	4.54	0.11	0.68	0.466

The median values of the 47 construction management practices are computed, and the distributions of the data are indicated in Figure 6-8. Box plots are used to display the results since they are suitable to compare the medians of the practices. The practices long-lead materials identification, well-defined scope of works, safety and health policy, safety and health plan, safe work method statement, hazards analysis, safety and health training, and toolbox safety meetings have the highest median values of 5.

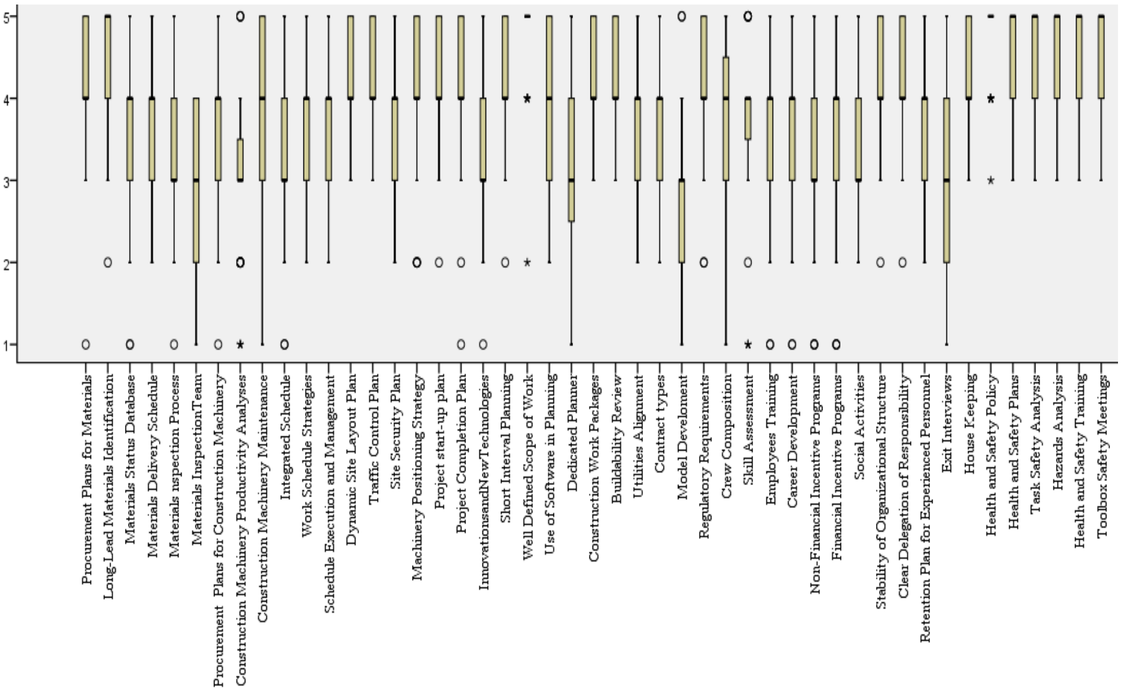


Figure 6-8 Box-plots of the Construction Management Practices

The percentage distributions of the respondents who selected 1 for not important, 2 for slightly important, 3 for somewhat important, 4 for very important, and 5 for extremely important practice are shown in Table 6-3. Accordingly, most respondents (85%) perceived the implementation of the practice well-defined scope of works as ‘extremely important’ (a response scale of 5) to improve productivity in multi-storey building construction projects. Overall, the majority of the respondents (36%) rated that the 47 construction management practices are very important (a response scale of 4) to improve productivity in multi-storey building projects (Table 6-3). This finding verifies the finding obtained in Phase I of this research. The qualitative data analyses in Phase I revealed that the 47 construction management practices have the potential to improve productivity in multi-storey building projects in the context of Victoria State, Australia.

Table 6-3 Distribution of the Responses of the Construction Management Practices on a Scale of 1 to 5

Construction Management Practices	*Not Important (1)*	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
Construction Materials Management Practices (CMMP)					
Procurement Plans for Materials	3%	0%	10%	46%	41%
Long-Lead Materials Identification	0%	3%	3%	28%	67%
Materials Status Database	5%	15%	28%	46%	5%
Materials Delivery Schedule	0%	10%	28%	38%	23%
Material Inspection Process	3%	8%	44%	31%	15%
Materials Inspection Team	10%	23%	38%	28%	0%
Average of CMMP	*4%*	*10%*	*25%*	***36%***	*25%*
Construction Equipment Management Practices (CEMP)					
Procurement Plan for Construction Equipment	3%	13%	33%	38%	13%
Construction Equipment Productivity Analysis	8%	15%	51%	18%	8%
Construction Equipment Maintenance	3%	10%	18%	28%	41%
Average of CEMP	*5%*	*13%*	***34%***	*28%*	*21%*
Management Practices Related to Construction Methods (MPRCM)					
Integrated Schedules	5%	10%	38%	44%	3%
Work Schedule Strategies	0%	3%	36%	54%	8%
Schedule Control	0%	3%	28%	51%	18%
Dynamic Site Layout Plan	0%	0%	21%	51%	28%
Traffic Control Plan	0%	0%	15%	44%	41%
Site Security Plan	0%	5%	38%	41%	15%
Machinery Positioning Strategy	0%	10%	8%	44%	38%
Project Start -up Plan	0%	3%	10%	46%	41%
Project Completion Plan	3%	3%	15%	38%	41%
Innovations and New Technologies	3%	18%	44%	31%	5%
Average of MPRCM	*1%*	*6%*	*25%*	***44%***	*24%*
Pre-Construction Phase Management Practices (PCPMP)					
Short Interval Plan	0%	3%	5%	44%	49%
Well-Defined Scope of Work	0%	3%	0%	13%	**85%**
Use of Software in Planning Work Packages	0%	8%	31%	33%	28%
Dedicated Planner	10%	15%	44%	21%	10%
Construction Work Packages	0%	0%	13%	46%	41%
Buildability Review	0%	0%	5%	51%	44%
Utilities Alignment	0%	3%	33%	46%	18%
Contract Types	0%	5%	23%	51%	21%
Model Development	13%	28%	41%	13%	5%
Regulatory Requirement	0%	5%	10%	38%	46%
Average of PCPMP	*2%*	*7%*	*21%*	***36%***	*35%*
Human Resource Management Practices (HRMP)					
Crew Composition	3%	8%	18%	46%	26%
Skill Assessment and Evaluation	8%	3%	15%	62%	13%
Employees Training	5%	5%	18%	54%	18%
Career Development	5%	5%	28%	54%	8%
Non-Financial Incentive Programs	8%	10%	38%	36%	8%
Financial Incentive Programs	8%	10%	31%	41%	10%
Social Activities	0%	15%	44%	31%	10%
Stability of Organizational Structure	0%	3%	15%	54%	28%
Clear Delegation of Responsibility	0%	3%	15%	44%	38%
Retention Plan for Experienced Personnel	0%	5%	28%	46%	21%
Exit Interviews	8%	31%	33%	23%	5%
Average of HRMP	*4%*	*9%*	*26%*	***45%***	*17%*
Safety and Health Practices (SHP)					
Housekeeping	0%	0%	5%	46%	49%
Safety and Health Policy	0%	0%	3%	21%	77%
Safety and Health Plan	0%	0%	8%	23%	69%
Safe Work Method Statement	0%	0%	10%	23%	67%
Hazards Analysis	0%	0%	10%	18%	72%
Safety and Health Training	0%	0%	18%	21%	62%
Toolbox Safety Meetings	0%	0%	10%	26%	64%
Average of SHP	*0%*	*0%*	*9%*	*25%*	***66%***
Average of the Construction Management Practices (CMP)	*3%*	*7%*	*23%*	***36%***	*31%*

Descriptive Statistics of the Construction Materials Management Practices

As shown in Table 6-2 above, under the construction materials management category, the practice long-lead materials identification has a mean of 4.59 which is the maximum value, and the practice materials inspection team has the mean of 2.85 which is the minimum value. Moreover, ‘long-lead materials identification’ has the smallest standard deviation (SD=0.68) and smallest standard error (0.11) which indicates that there is low variability among the responses to this practice. The practice ‘materials status database’ has the highest standard deviation of 0.98 which shows that the perception of the respondents regarding the importance of this practice to enhance productivity in multi-storey building projects is different.

The median values of the six construction materials management practices are computed, and the distributions of the data are indicated in Figure 6-8 above. Accordingly, long-lead materials identification has the highest median value of 5; materials status database and materials delivery schedule have both median values of 4, and materials inspection process and materials inspection team have both the lowest median values of 3.

The percentage distributions of the respondents regarding the importance of the six construction materials management practices are shown in Table 6-3 above. Accordingly, in this category, most respondents (67%) rated the long-lead materials identification as ‘extremely important’ practice for enhancing productivity in multi-storey building projects, and none of them responded the practice as ‘not important.’ About 46% of the participants responded that ‘materials status database’ and ‘procurement plans for materials’ are very important (response scale of 4) practices to improve productivity in multi-storey building projects. Forty-four percent of the respondents rated the practice materials inspection process as somewhat important (response scale of 3). None of the participants responded materials inspection team as extremely important. Overall, most of the participants (36%) rated the six construction materials management practices as very important (Table 6-3). This finding confirms the finding of the first phase of the study which also revealed that the six construction materials management practices are important to improve productivity in multi-storey building projects.

Descriptive Statistics of the Construction Equipment Management Practices

In the construction equipment management practices category, the practice construction equipment maintenance has the highest mean value of 3.95 and construction equipment productivity analysis has the lowest mean value of 3.03 (Table 6-2). Procurement plan for construction equipment has a mean value of 3.46. The practice construction equipment maintenance has the highest standard deviation (1.12) which indicates the high variabilities among the responses to this practice. The practice procurement plan for construction equipment has the lowest variance (0.94) which shows low variability among the data.

The distribution of the construction equipment management practices data is shown using the box plots indicated in Figure 6-8 above. Accordingly, the practice construction equipment productivity analysis has the lowest median value of 3, and the practices ‘procurement plan for construction equipment’ and ‘construction equipment maintenance’ have both median values of 4.

The percentage distributions of responses (on a scale of 1 to 5) of the construction equipment management practices are presented in Table 6-3 above. Accordingly, in the construction equipment management practices category, the majority of the respondents (41%) rated construction equipment maintenance is ‘extremely important’ (response scale of 5) to improve productivity in multi-storey building construction projects. Thirty-eight percent of the participants rated the practice procurement plan for construction equipment as ‘very important’ (response scale of 4). About 51% of the participants responded that construction equipment productivity analysis is ‘somewhat important’ (response scale of 3) for improving productivity. As shown in Table 6-3, the overall average percentage distribution for ‘not important,’ ‘slightly important,’ ‘somewhat important,’ ‘very important’ and ‘extremely important’ are 4%, 13%, 34%, 28%, and 21% respectively. Accordingly, the majority of the respondents (34%) rated the three construction equipment management practices as ‘somewhat important’ (response scale of 3) to improve productivity in building projects.

Descriptive Statistics of the Management Practices Related to Construction Methods

The highest mean value of 4.26 is obtained for practices ‘traffic control plan’ and ‘project start-up plan’ in the category of management practices related to construction methods (Table 6-2). The practice ‘innovations and new technologies’ has the lowest mean value of 3.18. The practice ‘project completion plan’ has the highest variance of 0.90 which indicates the high variability of the data, and the practice ‘work schedule strategies’ has the lowest variance of 0.44 which implies the variability among the perception of the respondents regarding the importance of this practice is low.

The median values of the ten management practices related to construction methods are computed, and the results are shown in Figure 6-8. Accordingly, the median values of Work Schedule Strategies, Schedule Control, Dynamic Site Layout Plan, Traffic Control Plan, Site Security Plan, Machinery Positioning Strategy, Project Start-up Plan and Project Completion Plan are equal to 4. ‘Integrated Schedules’ and ‘Innovations and New Technologies’ have both minimum median values of 3.

The percentage distribution of the responses (on a scale of 1 to 5) of the ten management practices related to construction methods is presented in Table 6-3 above. Accordingly, about 44% of the respondents rated the practice integrated schedule as ‘very important,’ and 3% of them responded as ‘extremely important.’ For the practice work schedule strategies, 54% of the participants responded that the practice is very important, and none of them rated the practice as ‘not important’ (response scale of 1). All respondents did not rate schedule control, dynamic site layout plan, traffic control plan, site security plan, machinery positioning strategy, and project start-up plan as ‘not important’ to improve the productivity of building projects. Overall, most respondents (44%) rated that the management practices related to construction methods are very important to improve productivity in multi-storey building projects. This result confirms the findings of Phase I of the study regarding the suitability of the management practices to enhance productivity in multi-storey building construction projects. The qualitative data analysis in the previous chapter revealed that the ten practices related to construction methods are important for improving productivity in building projects.

Descriptive Statistics of the Pre-Construction Phase Management Practices

The practice well-defined scope of works has the highest mean value of 4.79, and the practice model development has the lowest mean value of 2.69 in the pre-construction phase management practices category (Table 6-2). The practice dedicated planner has a highest standard deviation of 1.10 which indicates that respondents have different views about the importance of this practice. ‘Well-defined scope of works’ has the lowest standard deviation of 0.57 which shows that the participants have similar views on the importance of adequately defining the scope of works to improve productivity.

The median values and the distribution of the ten preconstruction phase management practices' data are plotted using box and whisker diagram (Figure 6-8 above). Accordingly, the practice well-defined scope of works has the highest median value of 5. Dedicated planner and model development have the lowest median values of 3. As shown in the figure, the practice dedicated planner has the longest box plot indicating that the range of the responses to this practice is high. Short Interval Plan, Use of Software in Planning Work Packages, Construction Work Packages, Buildability Review, Utilities Alignment, Contract Types, and Regulatory Requirement have equal median values of 4.

The percentage distribution of the responses for each preconstruction phase management practice is shown in Table 6-3 above. Accordingly, the survey participants rated well-defined scope of work (85%), short-interval plan (49%), regulatory requirement (46%), and buildability review (44%) as extremely important practice to improve productivity in multi-storey building construction projects. The practice model development has been rated as 'extremely important' by a few respondents (5%). The practices 'dedicated planner' and 'model development' are perceived as not important practices for improving productivity in building projects by 10% and 13% of the respondents respectively (Table 6-3). Overall, the majority of the respondents (36%) perceive the preconstruction phase management practices as very important (response scale of 4). This finding verifies the finding of Phase I of the research in which the ten preconstruction phase management practices are found to be essential to improve productivity in multi-storey building projects.

Descriptive Statistics of the Human Resource Management Practices

In the human resource management category, the practice clear delegation of responsibility has the highest mean value of 4.17 with a standard error of 0.13 (Table 6-2 above). Exit interview has the lowest mean value of 2.87 with a standard error of 0.17. The practice 'financial incentive programs' has the highest standard deviation of 1.06 which indicates that respondents have different perception regarding the importance of this practice in improving productivity in building projects. On the other hand, the practice stability of organisational structure has the lowest standard deviation of 0.55 which implies that there is less dispersion of the data from the mean value.

The distribution of the eleven human resource management practices' data is presented using boxplots indicated in Figure 6-8 above. Accordingly, the practices non-financial incentive programs, social activities, and exit interviews have the lowest median values of 3. Crew Composition, Skill Assessment and Evaluation, Employees Training, Career Development, Financial Incentive Programs, Stability of Organisational Structure, Clear Delegation of Responsibility, and Retention Plan for Experienced Personnel have equal median values of 4.

The percentage distributions of the responses (on a scale of 1 to 5) of the human resource management practices concerning their importance in improving the productivity of multi-storey building projects are provided in Table 6-3 above. Accordingly, 46% of the respondents rated the practice crew composition as very important (response scale of 4). Similarly, the participants perceive skill assessment (62%), employees training (54%), career development (54%), stability of organizational structure (54%), clear delegation of responsibility (44%), and retention plan for experienced personnel (46%) as 'very important' (response scale of 4). Overall, most respondents (45%) rated that human resource management practices are very important to improve productivity in building projects (Table 6-3). This finding confirms the finding of Phase I of this research which revealed that the eleven human resource management practices have the potential to improve productivity in multi-storey building construction projects.

Descriptive Statistics of the Safety and Health Practices

As shown in Table 6-2 above, all the seven safety and health practices have the minimum values of 3, the maximum values of 5 and range of 2. The practice 'safety and health policy' has the highest mean value of 4.74 with a minimum standard error of 0.08. 'Safety and health training' and 'housekeeping' have both mean values of 4.44 which is the minimum value. Safety and health training has the highest standard deviation of 0.79 which implies that the data is more dispersed. The practice 'safety and health policy' has the lowest standard deviation of 0.60 which indicates that the level of dispersion of the data is low.

The medians of the seven safety and health practices are shown in Figure 6-8 above. Accordingly, the practice housekeeping has the lowest median value of 4. Safety and Health Policy, Safety and Health Plan, Safe Work Method Statement, Hazards Analysis, Safety and Health Training, and Toolbox Safety Meetings have equal median values of 5.

In Table 6-3 above, the percentage distributions of the relative importance of the seven safety and health practice on a scale of 1 to 5 are provided. Accordingly, none of the respondents rated the safety and health practices as 'not important' (response scale of 0) and 'slightly important' (response scale of 1). The proportions of respondents who rated the practices housekeeping, safety and health policy, safety and health plan, safe work method statement, hazard analysis, safety and health training, and toolbox safety meetings as 'extremely important' are 49%, 77%, 69%, 67%,72%, 62%, and 64% respectively. Overall, the majority of the respondents (66%) rated that safety and health practices are 'extremely important' (response scale of 5) to improve productivity in multi-storey building construction projects. This finding verifies the finding of Phase I of the research in which the seven safety and health practices have been identified as essential practices that have the potential to improve productivity in multi-storey building projects.

6.5 Summary

This chapter described the background of the questionnaire survey participants. Moreover, the profiles of the contractors that have nominated the 39 multi-storey building projects are explained. Based on the characteristics of the construction companies, various propositions which will be confirmed in the next chapter were made. In Chapter 7, the detailed quantitative data analysis will be carried out to answer the following questions related to the profiles of the companies: Do contractors with higher turnover implement higher levels of the construction management practices? Do contractors having higher experience implement higher levels of management practices? and Do larger companies implement higher levels of the construction management practices?

The productivity factors (PFs) of the building projects which are used as inputs to the analysis conducted in next chapter were computed, and the projects were analysed based on their PFs. The findings of the preliminary quantitative data analysis confirmed that the management practices identified in Phase I of the research are essential for improving productivity in multi-storey building projects. The construction materials management practices, the management practices related to construction methods, the preconstruction phase management practices and the human resource management practices were perceived by the majority of the respondents as ‘very important’ (response scale of 4). The safety and health practices were rated as extremely important (response scale of 5) practices to improve productivity in multi-storey building construction projects. The equipment management practices have been considered as somewhat important (response scale of 3). The next chapter presents the detailed quantitative data analysis and findings.

CHAPTER SEVEN

7 QUANTITATIVE DATA ANALYSIS AND FINDINGS

7.1 Introduction

In this chapter, the quantitative data is analysed to achieve part of Objective 1 or ‘to prioritize the construction management practices’ and part of Objective 2 of the study which is ‘to validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects.’ In Section 7.2, the relative importance indexes of the management practices are computed, and the practices are ranked accordingly. In Section 7.3, the scoring tools for the management practices are weighted and validated. The reliability tests for the tools are also carried out in Section 7.3. The correlation analyses between productivity and the management practices are conducted, and the findings are presented in Section 7.4. Moreover, the associations among the company profiles, project characteristics, and the management practices are investigated in Section 7.4. Finally, the chapter is summarised in Section 7.5.

7.2 Relative Importance of the Construction Management Practices

To address part of Objective 1 or ‘to prioritise the management practices,’ the relative importance indexes (RII) of the practices are computed using Equation 7-1.

$$\mathrm{RII}=\frac{5(n_5)+4(n_4)+3(n_3)+2(n_2)+n_1}{5(n_5+n_4+n_3+n_2+n_1)} \qquad \text{Equation 7-1}$$

In the equation, n_5 represents the number of respondents who rated 5 (extremely important); n_4 stands for the number of respondents who rated 4 (very important); n_3 denotes the number of respondents who rated 3 (somewhat important); n_2 represents the number of respondents who rated 2 (slightly important); and n_1 stands for the number of respondents who rated 1(not important). For instance, the RII of the practice Short Interval Plan is computed to be 0.88 (refer the computation below). Using similar technique, the weights for other 46 management practices are calculated, and the results are shown in Table 7-1. Based on their weights, the practices are then ranked.

$$\text{Relative Importance Index (RII) of 'Short Interval Plan'}=\frac{5\times19+4\times17+3\times2+2\times1+1\times0}{5\times(19+17+2+1+0)}=\mathbf{0.88}$$

The practice well-defined scope of works with RII of 0.96 is found to be the most important practice. Safety and health policy (RII=0.95) is ranked second, safety and health plan (RII=0.92) and hazard analysis (RII=0.92) are both ranked third. All the safety and health practices are ranked within the top ten which implies that, in the context of Victoria, the safety and health practices are more important in improving productivity in multi-storey building construction projects than other practices.

Table 7-1 Relative Importance Indexes of the Construction Management Practices

Construction Management Practices	*RII*	*Overall Rank*
Well-Defined Scope of Work	0.96	1
Safety and Health Policy	0.95	2
Safety and Health Plan	0.92	3
Hazards Analysis	0.92	3
Long-Lead Materials Identification	0.92	5
Safe Work Method Statement	0.91	6
Toolbox Safety Meetings	0.91	7
Housekeeping	0.89	8
Safety and Health Training	0.89	8
Short Interval Plan	0.88	10
Buildability Review	0.88	10
Construction Work Packages	0.86	12
Traffic Control Plan	0.85	13
Project Start -up Plan	0.85	13
Regulatory Requirement	0.85	13
Procurement Plans for Materials	0.85	16
Clear Delegation of Responsibility	0.84	17
Project Completion Plan	0.83	18
Machinery Positioning Strategy	0.82	19
Dynamic Site Layout Plan	0.82	20
Stability of Organizational Structure	0.82	20
Construction Equipment Maintenance	0.79	22
Contract Types	0.77	23
Schedule Control	0.77	24
Crew Composition	0.77	24
Use of Software in Planning Work Packages	0.76	26
Retention Plan for Experienced Personnel	0.76	26
Utilities Alignment	0.76	28
Materials Delivery Schedule	0.75	29
Employees Training	0.75	29
Skill Assessment and Evaluation	0.74	31
Work Schedule Strategies	0.73	32
Site Security Plan	0.73	32
Career Development	0.71	34
Material Inspection Process	0.7	35
Procurement Plan for Construction Equipment	0.69	36
Financial Incentive Programs	0.67	37
Social Activities	0.67	37
Materials Status Database	0.66	39
Integrated Schedules	0.66	40
Non-Financial Incentive Programs	0.65	41
Innovations and New Technologies	0.64	42
Dedicated Planner	0.61	43
Construction Equipment Productivity Analysis	0.61	44
Exit Interviews	0.57	45
Materials Inspection Team	0.57	46
Model Development	0.54	47

Construction Management Practices	*RII*	*Rank within Category*
Construction Materials Management Practices (CMMP)		
Long-Lead Materials Identification	0.92	1
Procurement Plans for Materials	0.85	2
Materials Delivery Schedule	0.75	3
Material Inspection Process	0.70	4
Materials Status Database	0.66	5
Materials Inspection Team	0.57	6
Average weight of CMMP	***0.74***	
Construction Equipment Management Practices (CEMP)		
Construction Equipment Maintenance	0.79	1
Procurement Plan for Construction Equipment	0.61	2
Construction Equipment Productivity Analysis	0.79	3
Average weight of CEMP	***0.73***	
Management Practices Related to Construction Methods (MPRCM)		
Traffic Control Plan	0.851	1
Project start-up plan	0.851	1
Machinery Positioning Strategy	0.826	3
Project Completion Plan	0.821	4
Dynamic Site Layout Plan	0.815	5
Schedule Control	0.769	6
Work Schedule Strategies	0.733	7
Site Security Plan	0.733	7
Integrated Schedule	0.656	9
Innovations and New Technologies	0.636	10
Average weight of MPRCM	***0.77***	
Pre-Construction Phase Management Practices (PCPMP)		
Well-Defined Scope of Work	0.959	1
Short Interval Plan	0.877	2
Buildability Review	0.877	2
Construction Work Packages	0.856	4
Regulatory Requirement	0.851	5
Contract Types	0.774	6
Use of Software in Planning Work Packages	0.764	7
Utilities Alignment	0.759	8
Dedicated Planner	0.61	9
Model Development	0.538	10
Average weight of PCPMP	***0.79***	
Human Resource Management Practices (HRMP)		
Clear Delegation of Responsibility	0.836	1
Stability of Organizational Structure	0.815	2
Crew Composition	0.769	3
Retention Plan for Experienced Personnel	0.764	4
Employees Training	0.749	5
Skill Assessment and Evaluation	0.738	6
Career Development	0.708	7
Financial Incentive Programs	0.672	8
Social Activities	0.672	8
Non-Financial Incentive Programs	0.651	10
Exit Interviews	0.574	11
Average weight of HRMP	***0.72***	
Safety and Health Practices (SHP)		
Safety and Health Policy	0.949	1
Safety and Health Plan	0.923	2
Hazards Analysis	0.923	2
Safe Work Method Statement	0.913	4
Toolbox Safety Meetings	0.908	5
Housekeeping	0.887	6
Safety and Health Training	0.887	6
Average weight of SHP	***0.91***	

The average weights of the practices categorised under safety and health practices, pre-construction phase management practices, management practices related to construction methods, construction materials management practices, human resource management practices, and construction equipment management practices are 0.91, 0.79, 0.77, 0.74, 0.72, and 0.70 respectively (Table 7-1). Accordingly, the Safety and Health practices are ranked first, pre-construction phase management practices are ranked second, management practices related to construction methods are ranked third, construction materials management practices are ranked fourth, human resource management practices are ranked fifth, and construction equipment management practices are ranked sixth. The finding indicates that the implementation of Safety and Health practices is more important than the implementation of construction equipment management practices in enhancing productivity in multi-storey building projects.

Normality test is conducted to decide whether to use parametric or non-parametric tests in making statistical commentary regarding the significance of the differences among the weights of the 47 construction management practices. If assumptions of the parametric test (for instance, normality) are fulfilled, ‘repeated measures ANOVA’ will be used, or else the Friedman test which is non-parametric will be adopted. In the normality test, the null hypotheses of the Shapiro-Wilk test which states ‘the data is normally distributed’ will be rejected if p-values are less than 5%. Accordingly, the normality test is conducted using SPSS 24, and all the *p-values* of the Shapiro-Wilk test are less than 0.05 indicating that the data is not normally distributed (Table 7-2). Thus, the non-parametric test or Friedman test is used to analyse the differences among the weights of the practices.

The Friedman test for the 47 management practices is conducted and a *p-value* less than 0.001 is obtained (Table 7-3). The finding implies that there are significant differences among the weights of the practices. Iterative Friedman Test is carried out to identify the practices with similar weights, and a *p-value* of 0.16 is obtained for the top seven management practices (Table 7-3). This indicates that well-defined scope of work, safety and health policy, safety and health plan, hazard analysis, long-lead materials identification, safe work method statement and toolbox safety meetings are equally important to improve productivity in multi-storey building projects.

Table 7-2 Normality Test Results of the Construction Management Practices

Construction Management Practices	*Shapiro-Wilk*		
	Statistic	*df*	*Sig.*
Construction Materials Management Practices			
Procurement Plans for Materials	0.754	39	<0.001
Long-Lead Materials Identification	0.632	39	<0.001
Materials Status Database	0.863	39	<0.001
Materials Delivery Schedule	0.875	39	<0.001
Material Inspection Process	0.886	39	0.001
Materials Inspection Team	0.864	39	<0.001
Construction Equipment Management Practices			
Construction Equipment Maintenance	0.834	39	0.002
Procurement Plan for Construction Equipment	0.900	39	<0.001
Construction Equipment Productivity Analysis	0.887	39	0.001
Management Practices Related to Construction Methods			
Integrated Schedule	0.840	39	<0.001
Work Schedule Strategies	0.811	39	<0.001
Schedule Control	0.849	39	<0.001
Dynamic Site Layout Plan	0.805	39	<0.001
Traffic Control Plan	0.788	39	<0.001
Site Security Plan	0.861	39	<0.001
Machinery and Equipment Positioning Strategy	0.792	39	<0.001
Project start-up plan	0.793	39	<0.001
Project Completion Plan	0.803	39	<0.001
Innovations and New Technologies	0.895	39	0.002
Pre-construction Phase Management Practices			
Short Interval Plan	0.743	39	<0.001
Well-Defined Scope of Work	0.409	39	<0.001
Use of Software in Planning Work Packages	0.866	39	<0.001
Dedicated Planner	0.907	39	0.003
Construction Work Packages	0.782	39	<0.001
Buildability Review	0.738	39	<0.001
Utilities Alignment	0.848	39	<0.001
Contract Types	0.851	39	<0.001
Model Development	0.906	39	0.003
Regulatory Requirement	0.781	39	<0.001
Human Resource Management Practices			
Crew Composition	0.854	39	<0.001
Skill Assessment and Evaluation	0.748	39	<0.001
Employees Training	0.818	39	<0.001
Career Development	0.814	39	<0.001
Non-Financial Incentive Programs	0.886	39	0.001
Financial Incentive Programs	0.882	39	0.001
Social Activities	0.874	39	<0.001
Stability of Organizational Structure	0.822	39	<0.001
Clear Delegation of Responsibility	0.818	39	<0.001
Retention Plan for Experienced Personnel	0.863	39	<0.001
Exit Interviews	0.913	39	0.005
Safety and Health Practices			
Housekeeping	0.733	39	<0.001
Safety and Health Policy	0.553	39	<0.001
Safety and Health Plan	0.633	39	<0.001
Safe Work Method Statement	0.654	39	<0.001
Hazards Analysis	0.606	39	<0.001
Safety and Health Training	0.687	39	<0.001
Toolbox Safety Meetings	0.675	39	<0.001

Table 7-3 Friedman Test Results of the Construction Management Practices

47 Construction Management Practices	*N*	*Mean Rank*	*χ2 approximation*	*df*	*p-value*
Integrated Schedule	39	15.31	648.17	46	<0.001
Work Schedule Strategies	39	19.77			
Schedule Control	39	23.06			
Dynamic Site Layout Plan	39	26.42			
Traffic Control Plan	39	28.85			
Site Security Plan	39	20.46			
Machinery Positioning Strategy	39	26.81			
Project start-up plan	39	28.97			
Project Completion Plan	39	27.73			
Innovations and New Technologies	39	13.90			
Procurement Plans for Materials	39	28.81			
Long-Lead Materials Identification	39	34.83			
Materials Status Database	39	15.54			
Materials Delivery Schedule	39	21.96			
Materials nspection Process	39	18.21			
Materials InspectionTeam	39	10.78			
Procurement Plans for Construction Machinery	39	17.65			
Construction Machinery Productivity Analyses	39	11.92			
Construction Machinery Maintenance	39	25.23			
Short Interval Planning	39	31.45			
Well Defined Scope of Work	39	37.22			
Use of Software in Planning	39	22.46			
Dedicated Planner	39	13.51			
Construction Work Packages	39	29.68			
Buildability Review	39	30.51			
Utilities Alignment	39	21.82			
Contract types	39	23.74			
Model Requirements	39	9.49			
Regulatory Requirements	39	29.79			
Crew Composition	39	23.42			
Skill Assessment	39	21.49			
Employees Training	39	22.44			
Career Development	39	18.73			
Non-Financial Incentive Programs	39	15.59			
Financial Incentive Programs	39	17.68			
Social Activities	39	16.32			
Stability of Organizational Structure	39	26.44			
Clear Delegation of Responsibility	39	27.76			
Retention Plan for Experienced Personnel	39	22.49			
Exit Interviews	39	11.32			
House Keeping	39	32.08			
Health and Safety Policy	39	36.56			
Health and Safety Plans	39	34.73			
Task Safety Analysis	39	34.01			
Hazards Analysis	39	35.00			
Health and Safety Training	39	32.18			
Toolbox Safety Meetings	39	33.87			

Top 7 Construction Management Practices	*N*	*Mean Rank*	*χ2 approximation*	*df*	*p-value*
Long-Lead Materials Identification	39	3.97	9.27	6	0.16
Well Defined Scope of Work	39	4.45			
Health and Safety Policy	39	4.29			
Health and Safety Plans	39	3.91			
Task Safety Analysis	39	3.74			
Hazards Analysis	39	3.96			
Toolbox Safety Meetings	39	3.67			

The Friedman and Wilcoxon Test results as well as the relative importance of the practices within their respective categories are described in the following subsections.

Relative Importance of the Construction Materials Management Practices

Long-materials identification is found to be the most critical materials management practice that could increase productivity in multi-storey building construction projects (Table 7-1). Procurement plans for materials, materials delivery schedule, materials inspection process, and materials status database are ranked second, third, fourth and fifth respectively. Materials inspection team is ranked last in the construction materials management category.

The outputs of the Friedman test for the construction materials management practices are shown in Table 7-4, and the p-value is found to be statistically significant at 5% level of significance (p<0.001<0.05). Thus, the null hypothesis which states 'the weights of the six construction materials management practices are equal' is rejected. Therefore, there is a significant difference between the weights assigned to the six practices. However, as the Friedman test is not suitable to identify where the difference lies, posthoc analysis or Wilcoxon test is conducted. Wilcoxon test is chosen since it is the most suitable test after analysing the data using the Friedman test (Pereira et al., 2015).

Table 7-4 Outputs of Friedman and Wilcoxon Tests - Construction Materials Management Practices

Friedman Test

Construction Materials Management Practices	*N*	*Mean Rank*	*$\chi2$ approximation*	*df*	*p-value*
Procurement Plans for Materials	39	4.5	99.886	5	<0.001
Long-Lead Materials Identification	39	5.19			
Materials Status Database	39	2.67			
Materials Delivery Schedule	39	3.63			
Material Inspection Process	39	3.06			
Materials Inspection Team	39	1.95			

Wilcoxon Test

Construction Materials Management Practices	*P-values*					
	PPM	*LLM*	*MSD*	*MDS*	*MIP*	*MIT*
Procurement Plans for Materials	_	**0.004**	**<0.001**	**0.001**	**<0.001**	**<0.001**
Long-Lead Materials Identification	_	_	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Materials Status Database	_	_	_	**0.001**	0.235	**0.014**
Materials Delivery Schedule	_	_	_	_	0.059	**<0.001**
Material Inspection Process	_	_	_	_	_	**0.001**
Materials Inspection Team	_	_	_	_	_	_

Note: PPM=Procurement Plans for Materials, LLM= Long-Lead Materials Identification, MSD= Materials Status Database, MDS= Materials Delivery Schedule, MIP= Material Inspection Process, MIT= Materials Inspection Team.

The results of the Wilcoxon test indicate that the null hypothesis which states 'the weights of materials inspection process and materials status database' is the same is accepted as the p-value exceeds 0.05 (p=0.235>0.05). Similarly, the null hypothesis for materials inspection process and materials delivery schedule is not rejected since

p=0.059>0.05. This implies that there are no significant differences between the weights of materials inspection process and materials status database. However, there are significant differences among the thirteen combinations that are indicated in bold in Table 7-4. For instance, there is a significant difference between the top three materials management practices (long-lead materials identification, procurement plans for materials and materials delivery schedule).

Relative Importance of the Construction Equipment Management Practices

As shown in Table 7-1, in the construction equipment management practices category, construction equipment maintenance is ranked first, procurement plan for construction equipment is ranked second, and construction equipment productivity analysis is ranked third. The result of Friedman test for the construction equipment management practices shows p<0.001, df = 2, and Chi-square=15.57. The mean ranks for procurement plan for construction equipment, construction equipment productivity analysis, and construction equipment maintenance are 2, 1.63 and 2.37 respectively. Based on the p-value, the null hypothesis for the test which states ‘there are no differences among the weights of the three construction equipment management practices’ is rejected and the alternative hypothesis which states ‘there are significant differences among the weights’ is accepted. However, since Friedman test does not indicate which variable is significantly different from another, Wilcoxon test is carried out. Pair-wise comparisons using Wilcoxon’s test indicate p=0.007<0.05 for construction equipment procurement plan and construction equipment productivity analysis; p=0.031<0.05 for construction equipment procurement plan and construction equipment maintenance; and p=0.001<0.05 for construction equipment productivity analysis and construction equipment maintenance. All the three possible combinations are statistically significant which shows that the weights of the practices are different from each other.

Relative Importance of the Management Practices Related to Construction Methods

The practice traffic control plan and project start-up plan have both equal weight of 0.851 and ranked first in the category of management practices related to construction methods (Table 7-1). Machinery positioning strategy, project completion plan, and dynamic site layout plan are ranked from third to fifth. The practice ‘innovations and new technologies’ is assigned a weight of 0.636 and ranked last. To check if there are statistically significant differences among the weights of the ten management practices related to construction methods, Friedman test is conducted, and the results are presented in Table 7-5. For instance, to investigate if there is a significant difference between the weights 0.851 and 0.826 (project start-up plan and machinery positioning strategy), the Friedman test is carried out and a *p-value* less than 0.0001 is obtained. Since the p-value is much less than the cut-off *p-value* of 0.05, the null hypothesis which states ‘the weights of all the ten management practices related to construction methods are equal’ is rejected. Thus, there are statistically significant differences among the weights assigned to the practices.

Table 7-5 Outputs of Friedman and Wilcoxon Tests - Management Practices Related to Construction Methods

Friedman Test

Management Practices Related to Construction Methods	*N*	*Mean Rank*	*$\chi 2$ approximation*	*df*	*p-value*
Integrated Schedule	39	3.72			
Work Schedule Strategies	39	4.76			
Schedule Control	39	5.49			
Dynamic Site Layout Plan	39	6.24			
Traffic Control Plan	39	6.76			
Site Security Plan	39	4.86	74.73	9	<0.0001
Machinery and Equipment Positioning Strategy	39	6.29			
Project start-up plan	39	6.82			
Project Completion Plan	39	6.59			
Innovations and New Technologies	39	3.47			

Wilcoxon Test

Management Practices Related to Construction Methods	*P-values*									
	IS	*WSS*	*SC*	*DSLP*	*TCP*	*SSP*	*MPS*	*PSP*	*PCP*	*INT*
Integrated Schedule	_	0.013	0.001	<0.001	<0.001	0.04	<0.001	<0.001	<0.001	0.557
Work Schedule Strategies	_	_	0.046	0.014	<0.001	1	0.028	0.002	0.013	0.003
Schedule Control	_	_	_	0.242	0.023	0.158	0.252	0.036	0.14	<0.001
Dynamic Site Layout Plan	_	_	_	_	**0.159**	0.009	**0.95**	**0.162**	**0.947**	<0.001
Traffic Control Plan	_	_	_	_	_	0.001	**0.233**	**0.917**	**0.414**	<0.001
Site Security Plan	_	_	_	_	_	_	0.023	0.002	0.025	0.004
Machinery and Equipment Positioning Strategy	_	_	_	_	_	_	_	**0.339**	**0.836**	<0.001
Project start-up plan	_	_	_	_	_	_	_	_	**0.446**	<0.001
Project Completion Plan	_	_	_	_	_	_	_	_	_	<0.001
Innovations and New Technologies	_	_	_	_	_	_	_	_	_	_

Note: IS=Integrated Schedule, WSS= Work Schedule Strategies, SC=Schedule Control, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies.

By using Wilcoxon test, pair-wise analyses between the ten management practices related to construction methods are conducted, and the results are shown in Table 7-5. Accordingly, 45 possible combinations are analysed, and twenty-nine of them are found to be statistically significant. For instance, the p-value between work schedule strategies and dynamic site layout plan is 0.01 indicating that the difference between them is significant. On the other hand, 15 combinations of the practices are found to statistically insignificant at the 5% level of significance. From the 15 combinations, 10 of them represent the combinations of the top 5 practices (refer *p-values* indicated in bold in Table 7-5). The *p-value* between traffic control plan and project start-up plan is 0.92 >

0.05 which shows that there is no significant difference between the weights of these two practices. Similarly, the *p-value* between project completion plan and dynamic site layout plan is 0.95 > 0.05 indicating that there is no major difference between the weights of these practices (0.826 and 0.815). After analysing the ten combinations, it is found that there are no significant differences among the weights of the top five management practices related to construction methods. Therefore, traffic control plan, project start-up plan, machinery positioning strategy, project completion plan and dynamic site layout plan are equally important to improve productivity in multi-storey building projects.

Relative Importance of the Pre-Construction Phase Management Practices

In the pre-construction phase category, the practice well-defined scope of work with RII of 0.96 is ranked first. Short interval planning and buildability review with RII of 0.88 are both ranked second (Table 7-1). Dedicated planner and model development with the relative importance indexes of 0.61 and 0.54 are ranked ninth and tenth respectively.

In Table 7-6, the results of Friedman and Wilcoxon Tests for the pre-construction phase management practices are presented. The Friedman's *p-value* (<0.001) indicates that there are differences among the weights of the pre-construction phase management practices. Out of 45 possible combinations in the Wilcoxon Test (Table 7-6), nine of them have *p-values* greater than 0.05 (statistically insignificant), and 36 of them have *p-values* less than 0.05 (statistically significant).

Short interval plan and buildability review have a *p-value* of 1 which indicates that there is no difference between their weights. There is also no significant difference between the weights of short interval plan and construction work packages as the p=0.49>0.05. Short interval plan and regulatory requirement have a *p-value* of 0.34>0.05, and the difference between their weights is insignificant. No significant difference between the weights of buildability review and construction work packages is found (p=0.4>0.05). Similarly, the weights of buildability review and regulatory requirement are similar as p=0.43>0.05. Construction work packages and regulatory requirement also have a *p-value* of 0.84>0.05. Based on these findings, it is concluded that there is no significant difference between the practices ranked from 2 to 5 in preconstruction phase category. Thus, short interval plan, buildability review, construction work packages, and regulatory requirement are equally important to improve productivity in multi-storey building projects.

Table 7-6 Outputs of Friedman Test - Pre-Construction Phase Management Practices

Friedman Test

Pre-Construction Phase Management Practices	*N*	*Mean Rank*	*χ2 approximation*	*df*	*p-value*
Short Interval Plan	39	6.83			
Well-Defined Scope of Work	39	8.13			
Use of Software in Planning Work Packages	39	4.94			
Dedicated Planner	39	3.13			
Construction Work Packages	39	6.51			
Buildability Review	39	6.67	151.324	9	<0.0001
Utilities Alignment	39	4.74			
Contract Types	39	5.21			
Model Development	39	2.37			
Regulatory Requirement	39	6.47			

Wilcoxon Test

Pre-Construction Phase Management Practices	*P-values*									
	SIP	*WSW*	*US*	*DP*	*CWP*	*BR*	*UA*	*CT*	*MD*	*RR*
Short Interval Plan	_	0.008	0.008	<0.001	**0.488**	**1**	0.001	0.003	<0.001	**0.343**
Well-Defined Scope of Work	_	_	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	0.003
Use of Software in Planning Work Packages	_	_	_	0.003	0.014	0.002	**0.954**	**0.824**	<0.001	0.023
Dedicated Planner	_	_	_	_	<0.001	<0.001	<0.001	<0.001	0.022	<0.001
Construction Work Packages	_	_	_	_	_	**0.403**	0.007	0.006	<0.001	**0.837**
Buildability Review	_	_	_	_	_	_	<0.001	0.003	<0.001	**0.433**
Utilities Alignment	_	_	_	_	_	_	_	**0.628**	<0.001	0.002
Contract Types	_	_	_	_	_	_	_	_	<0.001	0.027
Model Development	_	_	_	_	_	_	_	_	_	<0.001
Regulatory Requirement	_	_	_	_	_	_	_	_	_	_

Note: SIP= Short Interval Plan, WSW=Well-defined Scope of Work, US= Use of Software in Planning Work Packages, DP= Dedicated Planner, CWP= Construction Work Package, BR= Buildability Review, UA= Utilities Alignment, CT= Contract Types, MD= Model Development, RR=Regulatory Requirement

As shown in Table 7-6, there are no significant differences among contract types and use of software in planning work packages (*p*=0.82>0.05); contract types and utilities alignment (*p*=0.63>0.05); and use of software in planning work packages and utilities alignment (*p*=0.95>0.05). Thus, contract types, use of software in work packaging and utilities alignment have equal importance in improving productivity in multi-storey building construction projects. In other words, the practices ranked from 6 to 8 have similar weights.

Relative Importance of the Human Resource Management Practices

Clear delegation of responsibility with RII of 0.84 is ranked first in the human resource management (HRM) practices category. Stability of organisational structure having RII of 0.82 is ranked second (Table 7-1). Financial incentive programs and social activities have equal weights (0.67), and both are ranked eighth. Non-financial incentive programs (0.65) and exit interviews (0.57) are ranked tenth and eleventh respectively. The result of Friedman test for HRM practices is indicated in Table 7-7 and a *p-value* less than 0.001 is found. The finding shows that there are significant differences among the 11 human resource management practices.

Table 7-7 Outputs of Friedman and Wilcoxon Tests - Human Resource Management Practices

Friedman Test

Human Resource Management Practices	*Mean Rank*	*N*	*χ2 approximation*	*df*	*p-value*
Crew Composition	6.85	39	71.163	10	<0.0001
Skill Assessment and Evaluation	6.38				
Employees Training	6.69				
Career Development	5.71				
Non-Financial Incentive Programs	4.87				
Financial Incentive Programs	5.26				
Social Activities	4.94				
Stability of Organizational Structure	7.54				
Clear Delegation of Responsibility	7.74				
Retention Plan for Experienced Personnel	6.45				
Exit Interviews	3.58				

Wilcoxon Test

Human Resource Management Practices	*P-values*										
	CC	*SA*	*ET*	*CD*	*NFIP*	*FIP*	*SoA*	*SOS*	*CDR*	*RPEP*	*EI*
Crew Composition	_	**0.299**	**0.388**	**0.117**	0.003	0.046	0.018	**0.318**	**0.066**	**0.846**	0
Skill Assessment and Evaluation	_	_	**0.593**	**0.291**	0.018	**0.116**	**0.101**	**0.076**	0.025	**0.51**	0
Employees Training	_	_	_	**0.106**	0.038	**0.1**	0.037	**0.073**	**0.054**	**0.689**	0
Career Development	_	_	_	_	**0.106**	**0.375**	**0.246**	0.005	0.003	**0.095**	0.001
Non-Financial Incentive Programs	_	_	_	_	_	**0.627**	**0.567**	0.001	0	0.017	**0.067**
Financial Incentive Programs	_	_	_	_	_	_	**0.975**	0.001	0.001	0.047	0.041
Social Activities	_	_	_	_	_	_	_	0	0	0.011	0.016
Stability of Organizational Structure	_	_	_	_	_	_	_	_	**0.457**	**0.103**	0
Clear Delegation of Responsibility	_	_	_	_	_	_	_	_	_	0.028	0
Retention Plan for Experienced Personnel	_	_	_	_	_	_	_	_	_	_	0
Exit Interviews	_	_	_	_	_	_	_	_	_	_	_

Notes: CC= Crew Composition, SA=Skill Assessment, ET= Employee Training, CD = Career Development, NFIP= Non-Financial Incentive Programs, FIP= Financial Incentive Programs, SoA= Social Activities, SOS= Stability of Organizational Structure, CDR= Clear Delegation of Responsibility, RPEP=Retention Plan for Experienced Personnel, EI= Exit Interviews.

The results of the Wilcoxon test are shown in Table 7-7. Fifty-five possible pair-wise comparisons are analysed, and 28 combinations have a p-value less than 0.05 and 27 pairs have p-values greater than 0.05 (p-values shown in bold in Table 7-7). If the p-value is less than 0.05, the null hypothesis of the Wilcoxon test which states ‘the weights of the HRM practices are equal’ is rejected. For instance, there is no significant difference between the weights of clear delegation of responsibility and stability of organisational structure (p=0.457>0.05). Clear delegation of responsibility and crew composition have a *p-value* of 0.066>0.05 which indicates that there is no significant difference between the two practices’ weights. The p-value for the stability of the organisational structure and crew composition is 0.318 which shows that there is no significant difference between their weights. Similarly, there are 27 combinations which have no statistically significant differences (Table 7-7). On the other hand, a significant difference between the weights of ‘clear delegation of responsibility’ and ‘retention plan for experienced personnel’ (p=0.028<0.05) is found, and there are 28 combinations which have significant differences (p-values indicated in bold in Table 7-7).

Based on the findings of the Wilcoxon Test, it is concluded that there are no significant differences among the weights of the top three human resource management practices. Thus, clear delegation of responsibility, the stability of the organisational structure and crew composition are equally important to improve productivity in multi-storey building construction projects.

Relative Importance of Safety and Health Practices

The practice safety and health policy has the maximum weight of 0.95 and ranked first in the safety and health category. Safety and health plan and hazard analysis have equal weights of 0.92, and both ranked second. Safe work method statement and toolbox safety meetings with weights of 0.913 and 0.908 are ranked fourth and fifth respectively. Housekeeping and safety and health training have both equal weights of 0.887 and ranked sixth.

The results of Friedman test shows are presented in Table 7-8, and a *p-value* (0.08) which is greater than 0.05 is obtained. This implies that the null hypothesis of the test or 'there are no significant differences among the weights of the safety and health practices' is accepted. Thus, all the safety and health practices are equally important to improve productivity in multi-storey building construction projects.

Table 7-8 Outputs of Friedman Test - Safety and Health Practices

Safety and Health Practices	*Mean Rank*	*N*	*χ2 approximation*	*df*	*p-value*
Housekeeping	3.67	39	11.468	10	0.075
Safety and Health Policy	4.51				
Safety and Health Plan	4.15				
Safe Work Method Statement	3.95				
Hazards Analysis	4.19				
Safety and Health Training	3.65				
Toolbox Safety Meetings	3.87				

7.3 Preparing and Validating the Weighted Scoring Tools of the Construction Management Practices

7.3.1 Preparing the Weighted Scoring Tools

To prepare the weighted scoring tools, the weight of each practice computed in Section 7.2 is proportionally distributed among the five levels of implementation a particular practice. For instance, the weight proportions for construction equipment management practices are computed as follows. Procurement plan for construction equipment's weight is 0.69, and the weight proportions are Level A= 0, Level B = 1/5 × (0.69) = 0.14, Level C = 2/5 × (0.69) = 0.28, Level D = 3/5 × (0.69) = 0.41, Level E=4/5 × (0.69) = 0.55, and Level F = 0.69. The weight of the practice construction equipment productivity analysis is 0.61, and the weight proportions are Level A= 0, Level B = 1/5× (0.61) = 0.12, Level C = 2/5 × (0.61) = 0.24, Level D = 3/5× (0.61) = 0.37, Level E = 4/5× (0.61) = 0.49, and Level F= 0.61. For the practice construction equipment maintenance, its weight is 0.79 and the weight proportions are Level A=0, Level B = 1/5 × (0.79) = 0.16, Level C = 2/5 × (0.79) = 0.32, Level D = 3/5× (0.79) = 0.47; Level E= 4/5 × (0.79) = 0.63, and Level F= 0.79. Using similar techniques, the weight proportions of all the 47 construction management practices are computed and the results are presented in Table 7-9.

By using the weight proportions indicated in Table 7-9, the weighted scoring tools (the ‘scoring tools’) for the construction management practices in the context of multi-storey building projects are prepared. For illustration purpose, the scoring tools for the three management practices categorised under construction equipment management practices are presented in this section (Table 7-10). The scoring tools for all management practices are provided in the Summary and Conclusion Chapter (Chapter 10).

Table 7-9 Distribution of the Weights of the Construction Management Practices

Construction Management Practices	*Weight*	*Weight proportions*					
		Level A	*Level B*	*Level C*	*Level D*	*Level E*	*Level F*
Construction Materials Management Practices							
Procurement Plans for Materials	**0.85**	0	0.17	0.34	0.51	0.68	0.85
Long-Lead Materials Identification	**0.92**	0	0.18	0.37	0.55	0.73	0.92
Materials Status Database	**0.66**	0	0.13	0.26	0.4	0.53	0.66
Materials Delivery Schedule	**0.75**	0	0.15	0.3	0.45	0.6	0.75
Material Inspection Process	**0.7**	0	0.14	0.28	0.42	0.56	0.7
Materials Inspection Team	**0.57**	0	0.11	0.23	0.34	0.46	0.57
Construction Equipment Management Practices							
Procurement Plan for Construction Equipment	**0.69**	0.00	0.14	0.28	0.41	0.55	0.69
Construction Equipment Productivity Analysis	**0.61**	0.00	0.12	0.24	0.37	0.49	0.61
Construction Equipment Maintenance	**0.79**	0.00	0.16	0.32	0.47	0.63	0.79
Management Practices Related to Construction Methods							
Integrated Schedule	**0.66**	0	0.13	0.26	0.4	0.53	0.66
Work Schedule Strategies	**0.73**	0	0.15	0.29	0.44	0.58	0.73
Schedule Control	**0.77**	0	0.15	0.31	0.46	0.62	0.77
Dynamic Site Lay Out Plan	**0.83**	0	0.16	0.33	0.49	0.66	0.82
Traffic Control Plan	**0.85**	0	0.17	0.34	0.51	0.68	0.85
Site Security Plan	**0.73**	0	0.15	0.29	0.44	0.58	0.73
Machinery Positioning Strategy	**0.82**	0	0.16	0.33	0.49	0.66	0.82
Project Start-Up Plan	**0.85**	0	0.17	0.34	0.51	0.68	0.85
Project Completion Plan	**0.83**	0	0.17	0.33	0.5	0.66	0.83
Innovations and New Technologies	**0.64**	0	0.13	0.26	0.38	0.51	0.61
Pre-Construction Phase Management Practices							
Well-defined Scope of Work	**0.96**	0	0.19	0.38	0.58	0.77	0.96
Short Interval Plan	**0.88**	0	0.18	0.35	0.53	0.7	0.88
Buildability Review	**0.88**	0	0.18	0.35	0.53	0.7	0.88
Construction Work Packages	**0.86**	0	0.17	0.34	0.52	0.69	0.86
Regulatory Requirement	**0.85**	0	0.17	0.34	0.51	0.68	0.85
Contract Types	**0.77**	0	0.15	0.31	0.46	0.62	0.77
Use of Software in planning Work Packages	**0.76**	0	0.15	0.3	0.46	0.61	0.76
Utilities Alignment	**0.76**	0	0.15	0.3	0.46	0.61	0.76
Dedicated Planner	**0.61**	0	0.12	0.24	0.37	0.49	0.61
Model Development	**0.54**	0	0.11	0.22	0.32	0.43	0.54
Human Resource Management Practices							
Crew Composition	**0.77**	0	0.15	0.31	0.46	0.62	0.77
Skill Assessment and Evaluation	**0.74**	0	0.15	0.3	0.44	0.59	0.74
Employees Training	**0.75**	0	0.15	0.3	0.45	0.6	0.75
Career Development	**0.71**	0	0.14	0.28	0.43	0.57	0.71
Non-Financial Incentive Programs	**0.65**	0	0.13	0.26	0.39	0.52	0.65
Financial Incentive Programs	**0.67**	0	0.13	0.27	0.4	0.54	0.67
Social Activities	**0.67**	0	0.13	0.27	0.4	0.54	0.67
Stability of Organizational Structure	**0.82**	0	0.16	0.33	0.49	0.66	0.82
Clear Delegation of Responsibility	**0.84**	0	0.17	0.34	0.5	0.67	0.84
Retention Plan for Experienced Personnel	**0.76**	0	0.15	0.3	0.46	0.61	0.76
Exit Interviews	**0.57**	0	0.11	0.23	0.34	0.46	0.57
Safety and Health Practices							
Housekeeping	**0.89**	0	0.18	0.36	0.53	0.71	0.89
Safety and Health Policy	**0.95**	0	0.19	0.38	0.57	0.76	0.95
Safety and Health Plan	**0.92**	0	0.18	0.37	0.55	0.74	0.92
Safe Work Method Statement	**0.91**	0	0.18	0.36	0.55	0.73	0.91
Hazards Analysis	**0.92**	0	0.18	0.37	0.55	0.74	0.92
Safety and Health Training	**0.89**	0	0.18	0.36	0.53	0.71	0.89
Toolbox Safety Meetings	**0.91**	0	0.18	0.36	0.54	0.73	0.91

Table 7-10 Scoring Tools for Construction Equipment Management Practices

1. Procurement Plan for Construction Equipment		**Weights**
Level A	A procurement plan for construction equipment is not applicable for this building project.	0
Level B	Construction equipment procurement plan is not prepared for this building project.	0.14
Level C	Construction equipment procurement strategies such as hiring or leasing are prepared for this building project.	0.28
Level D	Continuation of Level C and there is a procedure for identifying reputation of potential equipment suppliers	0.41
Level E	Continuation of Level D, plus the plan identifies necessary equipment and onsite resources to support delivery.	0.55
Level F	Continuation of Level E and construction equipment schedule is integrated with other project schedules.	0.69
2. Construction Equipment Productivity Analysis		
Level A	Construction equipment is not used on this building project.	0
Level B	Construction equipment is utilized but requirements and usage are not planned and tracked.	0.12
Level C	Construction equipment requirements are planned and tracked but they are not tied to a schedule. The usage is tracked against budget only.	0.24
Level D	Continuations of Level C, and regular meeting is conducted to assess the requirement of construction equipment.	0.37
Level E	Continuation of Level D, and construction equipment resource curves are drawn and resources are leveled.	0.49
Level F	Continuation of Level E and equipment schedule is adjusted based on the audit report that shows equipment downtime and other information.	0.61
3. Construction Equipment Maintenance		
Level A	Construction equipment maintenance is not applicable to this building project.	0
Level B	Construction equipment maintenance is not planned for this building project.	0.16
Level C	Construction equipment is logged in simplified spreadsheet and maintenance is carried out by operator request.	0.32
Level D	Continuation of Level C, and equipment maintenance record is linked to individual construction equipment, and maintenance is centrally scheduled and administered.	0.47
Level E	Continuation of Level D, and a computer program is used to record and administer equipment maintenance information such as required and accomplished maintenance logs and usage logs.	0.63
Level F	Continuation of Level E and maintenance schedule is electronically updated and maintenance due notices are automatically issued to concerned parties.	0.79

To validate the scoring tools and to conduct inferential statistical analyses, the scores of the management practices of the projects are computed based on the respondents' selected level of implementation of each practice on the nominated 39 projects. For instance, for a project coded R1, the respondent ticked Level B for construction equipment procurement plan, Level B for construction productivity analysis, and Level C for construction equipment maintenance, and the equivalent total score of construction equipment management practice for that particular project is 0.14 + 0.12 + 0.32 = **0.58** (Table 7-11). Similarly, based on the respondent's chosen levels of implementations, the project's materials management practices score =1.88 (sum of the scores of 6 practices), management practices related to construction methods' score = 3.09 (sum of 10 practices), preconstruction phase management practices' score = 4.18 (sum of 10 practices), HRM practices' score = 3.30 (sum of 11 practices), and safety and health practices' score = 4.94 (sum of 7 practices). Thus, the project's total construction management practices score = 0.58 + 1.88 + 3.09 + 4.18 + 3.30 + 4.94 =

17.97 (Table 7-11). By using similar procedures, the 39 projects' management practices scores are computed, and the results are presented in Table 7-11.

Table 7-11 Scores of the Construction Management Practices

Projects	*Construction Materials Management Practices Scores (A)*	*Construction Equipment Management Practices Scores (B)*	*Management Practices Related to Construction Methods Scores (C)*	*Pre-construction Phase Management Practices (D)*	*Human Resource Management Practices (E)*	*Safety and Health Practices (F)*	**Construction Management Practicess Scores** *G=A+B+C+D+E+F*
R1	1.88	0.58	3.09	4.18	3.30	4.94	**17.97**
R2	3.77	1.35	6.77	6.10	6.52	5.31	29.82
R3	2.91	0.83	4.89	4.90	4.47	6.03	24.03
R4	3.14	1.08	5.55	5.36	6.96	5.29	27.38
R5	2.28	0.58	5.36	4.07	4.67	4.55	21.51
R6	1.36	0.89	5.44	5.68	5.73	6.39	25.49
R7	3.49	1.67	6.14	5.69	6.57	6.39	29.95
R8	2.99	1.11	6.16	4.94	5.50	5.49	26.19
R9	2.98	1.23	5.09	5.46	5.45	6.03	26.24
R10	3.97	1.23	5.72	5.31	6.13	5.29	27.65
R11	1.53	0.58	3.86	3.65	3.52	4.01	17.15
R12	2.49	1.41	4.85	4.50	5.06	6.02	24.33
R13	1.84	0.97	4.57	4.40	5.36	6.03	23.17
R14	1.97	0.44	4.31	2.61	4.23	2.73	16.29
R15	2.17	0.71	4.81	5.03	4.50	5.66	22.88
R16	1.79	0.59	4.33	5.15	2.59	5.49	19.94
R17	2.37	0.72	2.90	3.30	2.05	5.12	16.46
R18	2.23	0.00	4.06	4.52	4.30	5.65	20.76
R19	1.45	0.56	3.31	3.00	4.49	5.68	18.49
R20	1.41	0.58	3.96	2.77	3.39	4.39	16.50
R21	2.66	0.58	5.10	3.46	5.32	6.03	23.15
R22	2.44	1.39	5.86	5.33	6.74	5.29	27.05
R23	2.66	1.37	3.61	4.61	5.27	6.21	23.73
R24	1.18	0.58	2.64	3.85	2.48	4.03	14.76
R25	1.08	0.68	1.89	2.80	2.04	4.76	13.25
R26	1.32	0.00	2.78	3.99	3.88	4.39	16.36
R27	1.92	1.55	6.17	5.85	7.19	6.03	28.71
R28	1.66	0.16	2.14	1.19	0.92	4.00	10.07
R29	2.34	1.47	5.03	5.25	5.03	6.21	25.33
R30	3.91	1.49	5.31	5.50	3.81	5.85	25.87
R31	2.77	0.96	3.69	4.39	3.97	5.86	21.64
R32	3.81	1.69	5.58	7.11	5.14	6.03	29.36
R33	1.57	0.42	1.95	1.79	2.64	5.48	13.85
R34	2.97	1.08	5.24	6.01	4.54	5.85	25.69
R35	1.68	0.59	4.48	2.05	4.14	5.29	18.23
R36	2.74	1.39	5.95	4.09	5.59	6.21	25.97
R37	3.92	2.09	6.97	6.72	6.27	6.21	32.18
R38	1.53	0.70	5.58	5.27	4.89	5.12	23.09
R39	3.61	1.15	5.86	6.53	5.74	6.39	29.28

Note: **A** = PPM+ LLM+MSD+MDS+MIP+MIT ; **B** = PPCE + CEPA+ CEM; **C** = IS+WSS +SC+DSLP+TCP+SSP+MPS+PSP+PCP+INT; **D** = SIP+ WSW+ US+ DP+ CWP+ BR+ UA+ CT+ MD+ RR ; **E** = CC+SA+ET+CD+NFIP+FIP+SoA+SOS+CDR+RPEP+EI; **F**= HK+SHPo+SHP+SWMS+HA+SHT+TSM

PPM=Procurement Plan for Materials, LLM= Long-lead Materials Identification, MSD=Materials Status Database, MDS= Materials Delivery Schedule, MIP=Materials Inspection Process MIT =Materials Inspection Team; PPCE=Procurement Plans for Construction Equipment, CEPA=Construction Equipment Productivity Analysis, CEM=Construction Equipment Maintenance; IS=Integrated Schedule, WSS= Work Schedule Strategies, SC=Schedule Control, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies;SIP= Short Interval Plan, WSW=Well-defined Scope of Work, US= Use of Software in Planning Work Packages, DP= Dedicated Planner, CWP= Construction Work Package, BR= Buildability Review, UA= Utilities Alignment, CT= Contract Types, MD= Model Development, RR=Regulatory Requirement; CC= Crew Composition, SA=Skill Assessment and Evaluation, ET= Employee Training, CD = Career Development, NFIP= Non-Financial Incentive Programs, FIP= Financial Incentive Programs, SoA= Social Activities, SOS= Stability of Organizational Structure, CDR= Clear Delegation of Responsibility, RPEP=Retention Plan for Experienced Personnel, EI= Exit Interviews; HK= Housekeeping, SHPo = Safety and Health Policy, SHP= Safety and Health Plan, SWMS = Safe Work Method Statement, HA= Hazard Analysis, SHT= Safety and Health Training, and TSM= Toolbox Safety Meeting.

7.3.2 Validation of the Weighted Scoring Tools

To address part of Objective 2 of the study which is 'to validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects,' the mean, mode, and median scores were computed to choose a baseline score for grouping the projects into high and low scores. The total construction management practices' median score = 23.09, mean score = 22.75, skewness = -0.386, standard error (*SE*) of skewness = 0.378 and Z=-0.386/0.378 =-1.02 are obtained. If data is not highly skewed, mean is the best measure of central tendency (Lurd and Lurd, 2013). According to Kim (2013), if *Z-score* for skewness is less than 1.96, the distribution could be considered as normal or not highly skewed. Thus, the mean score of 22.75 is used as a baseline for classification since the absolute value of Z (1.02) is less than 1.96. Projects with total construction management practices scores less than mean value (22.75) are classified under Group-1(low-score), and those having scores greater than the baseline (22.75) are classified under Group-2 (high-score).

To decide the type of test to be used for analysing the difference between the groups, normality test is conducted, and the results are shown in Table 7-12. The Shapiro-Wilk test result for Group 1 indicates $p = 0.37 > 0.05$ which implies the data is normally distributed. For group 2, $p = 0.31 > 0.05$ is found indicating that the data in group 2 is also normally distributed. Levene's test is also conducted to check the homogeneity of variance, and $p = 0.382 > 0.05$ is found. This shows that the variances are homogeneous and another assumption of the parametric test is satisfied. Thus, t-test can be conducted to investigate the difference between the two groups.

Table 7-12 Outputs of the Normality and t-Tests for Projects Grouped Based on the Total Construction Management Practices Scores

Normality Test								
	Descriptive				*Test of Normality*			
					Shapiro-Wilk			
	N	*Mean PF*	*Minimum PF*	*Maximum PF*		*Statistic*	*df*	*Sig*
Group 1	21	1	0.78	1.14	Group 1	0.952	21	0.371
Group 2	21	0.9	0.59	1.08	Group 2	0.942	18	0.313

t- Test								
		t-test for Equality of Means						
		t	*df*	*Sig.(2-tailed)*	*Mean Difference*	*Std. Error Difference*	*95% Confidence Interval of the Difference*	
							Lower	*Upper*
PF	Equal variances assumed	2.221	37	0.033	0.097	0.044	0.008	0.185
	Equal variances not assumed	2.176	31.638	0.037	0.097	0.044	0.006	0.187

The results of t-test are shown in Table 7-12, and the *p-value* is found to be $0.03 < 0.05$. The finding implies that building projects with higher levels of implementation of construction management practices also have higher productivity. Therefore, the scoring tools are valid. The mean productivity factor (PF) for Group-1 and Group-2 are 0.996 and 0.899 respectively. The box-plots of the two groups are drawn to visually represent the difference between the PFs of the two groups (Figure 7-1).

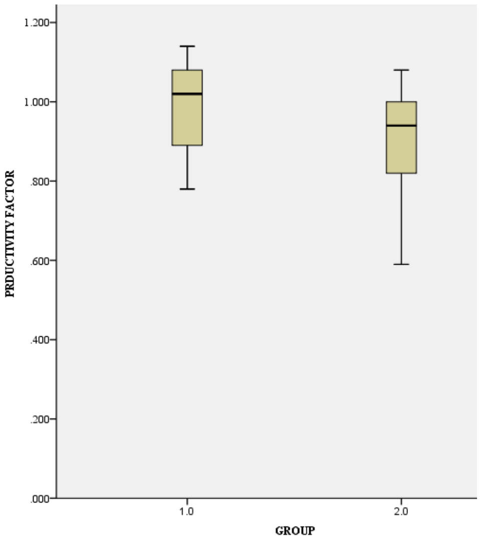


Figure 7-1 Box-Plots of the PFs of the Projects Based on Total Construction Management Practices Scores

The validity tests for the scoring tools of the six categories of the construction management practices are conducted, and the results are presented in subsequent sections.

Validity Test of the Scoring Tools of the Construction Materials Management Practices

To validate the scoring tools for the construction materials management practices, the projects are divided into high score group (Group 1) and low score group (Group 2) based on their construction materials management practices scores. To determine the baseline for classification, the mean score = 2.4, the median score = 2.34, the mode score =1.53, the skewness=0.37, the *SE* of skewness=0.38 and *Z*= (skewness)/ (*SE* of skewness) = 0.98 are obtained. As *Z*=0.98 is less than 1.96, the mean materials management practices score (2.4) is considered for classification purpose. Accordingly, 20 projects are grouped under Group 1, and 19 projects are grouped under Group 2 based on their construction materials management practices scores.

Normality tests are conducted for the two independent groups, and the results are shown in Table 7-13. The Shapiro-Wilk test's hypotheses are H_o (null): the data in the group is normally distributed, and H_a (alternative): the data is not normally distributed. Accordingly, for Group 1, the null hypothesis is not rejected since the $p = 0.096 > 0.05$

and the data is normally distributed. The *p-value* for Group 2 is 0.033 which is less than 0.05. However, Z = Skewness/SE = 0.27 < 1.96, and the data in Group 2 can be considered as normally distributed. Test of homogeneity (Levene's test) is also conducted. The hypotheses for Levene's test are H_o (null): the variances of Group1and Group 2 projects are equal, and H_a (alternative): the variances of Group 1 and Group 2 projects are different. Accordingly, a $p = 0.343 > 0.5$ is obtained. This shows that the null hypothesis is accepted, and the variances of the data are homogeneous. Therefore, the parametric test (ANOVA or t-test) could be used to check the difference between the means of two groups. Since there are only two independent samples (groups), independent sample t-test is used in the analysis (Table 7-13).

Table 7-13 Outputs of the Normality and t-Tests for Projects Grouped Based on Material Management Practices Scores

Normality Test								
Descriptive					*Test of Normality*			
					Shapiro-Wilk			
	N	*Mean PF*	*Minimum PF*	*Maximum PF*		*Statistic*	*df*	*Sig*
Group 1	20	0.996	0.941	1.051	Group 1	0.919	20	0.096
Group 2	19	0.905	0.83	0.979	Group 2	0.891	19	0.033

t- Test								
		t-test for Equality of Means						
		t	*df*	*Sig.(2-tailed)*	*Mean Difference*	*Std. Error Difference*	*95% Confidence Interval of the Difference*	
							Lower	*Upper*
PF	Equal variances assumed	0.922	0.343	2.09	37	0.044	0.091	0.044
	Equal variances not assumed			2.07	33.57	0.046	0.091	0.044

Since the variances are equal, the results in the first row of the t-test output are considered. Accordingly, the null hypothesis for this t-test or the means of the groups are equal is rejected as $p = 0.04 < 0.05$. Therefore, there is a statistically significant difference between the Group 1 and Group 2 projects, and the scoring tools for construction materials management practices are valid. The box-plots of the two groups are drawn to visually represent the difference between the PFs (Figure 7-2). The mean PF of Group-1 is approximately 1, and the mean PF of Group-2 is 0.91.

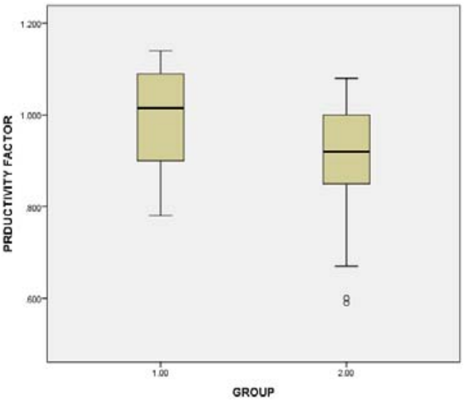


Figure 7-2 Box-Plots of the PFs of the Projects Based on the Construction Materials Management Practices Scores

Validity Test of the Scoring Tools of the Construction Equipment Management Practices

To validate the scoring tools of the construction equipment management practices, the mean construction equipment management practices score = 0.93, the mode score=0.58, the median score=0.89, the skewness=0.157, standard error= 0.378, and Z= (0.157/0.378) = 0.41< 1.96 are computed. The mean score (0.93) is chosen as the baseline for classifying projects since the data can be considered as normal (Z<1.96). The projects are then grouped into Group 1(high score), and Group 2 (low score) based on their construction equipment management practices scores, and statistical analysis is conducted to check the difference between the groups. Normality test is conducted for the two groups, and the results are presented in Table 7-14. Accordingly, both groups' p-values are found to be significant (*p-value* for Group 1= 0.043 < 0.5, *p-value* for Group 2 = 0.027 < 0.5) which implies that the data is not normally distributed. Hence, Mann-Whitney test is used instead of t-test or one-way ANOVA.

Table 7-14 Outputs of the Normality Test for Projects Grouped Based on the Scores of Construction Equipment Management Practices

	Descriptive					*Test of Normality*			
				95% CI for Mean PF		*Shapiro-Wilk*			
	N	Mean PF	Std. Error	Lower Bound	Upper Bound		Statistic	df	Sig
Group 1	19	1.009	0.027	0.953	1.066	Group 1	0.897	19	0.043
Group 2	20	0.896	0.033	0.827	0.964	Group 2	0.89	20	0.027

The test statistic for Mann-Whitney U test is 98, the asymptotic p-value is 0.01, and the exact *p-value* is 0.009. The mean rank for Group 1 and Group 2 are 24.84 and 14.40 respectively. The conclusion to be drawn from the Mann-Whitney U test is the rejection of the null hypothesis (the two groups are the same) as the *p-value* is less than 0.05.

Therefore, there is a significant difference between the productivity factors of the two groups, and the scoring tools of the construction equipment management practices are valid. Box plots are drawn to visualise the difference between Group 1 and Group 2 projects (Figure 7-3). The mean PF for Group 1 and Group 2 are 1.01 and 0.90 respectively.

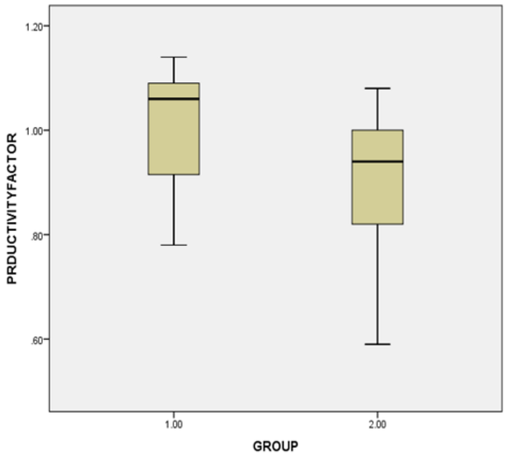


Figure 7-3 Box-plots of the PFs of Projects with Low and High Construction Equipment Management Practice Scores

Validity Test of the Scoring Tools of the Management Practices Related to Construction Methods

The mean score of the management practices related to construction methods, the median score, the skewness, and standard error for skewness are computed to determine a baseline score which is used to divide projects into high-score and low-score based on their management practices related to construction methods' scores. Accordingly, mean score =4.84, median score=4.93, skewness=-0.32, and standard error for skewness=0.38 are found. Since Z=|-0.32/0.38|=0.84<1.96, the data is considered as normal, and the mean score (4.84) is chosen as a measure of central tendency. The projects are then divided into two groups using the mean score as a baseline. The first group (Group 1 or high score) are projects that have the scores of the management practices related to construction methods greater than the mean score (4.84), and the second group (Group 2 or low score) are projects that have the scores less than the mean value.

The results of the normality test and the descriptive statistics are shown in Table 7-15. There are 21 projects in Group 1 and 18 projects in Group 2, and the mean productivity factor (PF) of Group 1 and Group 2 are 0.88 and 1.01 respectively. The following hypotheses are tested using Shapiro-Wilk analysis H_o: the PF data is normally distributed and H_a: the data is not normally distributed. Accordingly, for Group 1, the *p*-

value is 0.008 < 0.05 and the null hypothesis is rejected or the PFs data for Group 1 is not normally distributed. For group 2, the *p-value* is 0.108 > 0.05, and the null hypothesis is accepted indicating that the data is normally distributed. However, since both groups are not normally distributed non-parametric tests (Mann-Whitney test) is chosen to check if there is a statistically significant difference between the productivity factors of Group 1 and Group 2 projects and to validate the scoring tools for management practices related to construction methods.

Table 7-15 Outputs of the Normality Test of Projects Grouped Based on the Scores of Management Practices Related to Construction Methods

	Descriptive					*Test of Normality*		
			95% CI for Mean PF			*Shapiro-Wilk*		
	N	*Mean PF*	*Lower Bound*	*Upper Bound*		*Statistic*	*df*	*Sig*
Group 1	21	1.01	0.96	1.06	Group 1	0.867	21	0.008
Group 2	18	0.88	0.81	0.96	Group 2	0.916	18	0.108

The result of the Mann-Whitney test shows a *p-value* of 0.003 < 0.05 which indicates that there is a statistically significant difference between the two groups. The finding implies that projects with higher levels of implementation of the management practices related to construction methods also have higher productivity. Therefore, the scoring tools of the management practices related to construction methods are valid. Finally, as shown in Figure 7-4, the PFs of the projects are plotted to visualise the difference between the two groups.

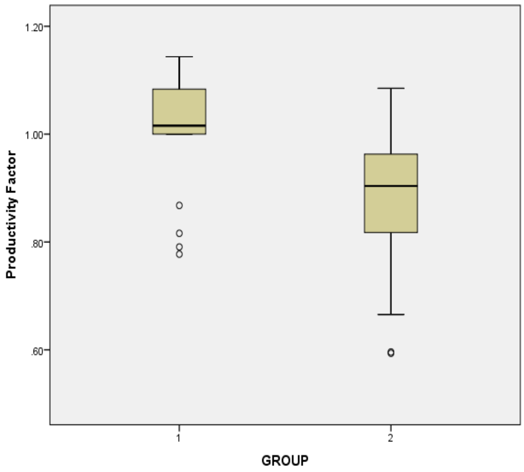


Figure 7-4 Box-Plot of Projects with Low and High Scores of the Management Practices Related to Construction Methods

Validity Test of the Scoring Tools of the Pre-Construction Phase Management Practices

To validate the scoring tools of the preconstruction phase management practices, the projects are grouped into high and low scores by using the mean preconstruction phase management practices score of 4.52 since the *Z value* of the data (1.26) is less than the reference *Z-value* (1.96). Projects with preconstruction phase management practices scores greater than or equal to 4.52 are grouped under Group 1(high score) and projects with scores less than 4.52 are grouped under Group 2 (low score). To decide the type of test to be used for analysing the difference between the projects grouped based on their preconstruction phase management practices scores, normality test is conducted, and the results are shown in Table 7-16. The Shapiro-Wilk normality test result for Group 1 indicates a $p = 0.07 > 0.05$ which implies the data is normally distributed. For group 2, a $p = 0.043 < 0.05$ which also shows the data is normally distributed. Levene's test is also conducted to check the homogeneity of variance and $p = 0.362 > 0.05$ is found. This indicates that the variances are homogeneous and another assumption of the parametric test is satisfied. Thus, the t-test can be conducted to investigate the difference between the two groups. The results of the t-test are shown in Table 7-16, and the *p-value* is found to be 0.01< 0.05. Thus, there is a significant difference between the two groups, and the scoring tools for preconstruction phase management practices are valid. Projects with higher scores of the preconstruction phase management practices have also higher productivity factors, and projects with lower scores have lower productivity factors.

Table 7-16 Outputs of the Normality and t-Tests of Projects Grouped Based on Pre-Construction Phase Management Practices Scores

Normality Test								
Descriptive					*Test of Normality*			
					Shapiro-Wilk			
	N	*Mean PF*	*Minimum PF*	*Maximum PF*		*Statistic*	*df*	*Sig*
Group 1	18	1.01	0.96	1.07	Group 1	0.903	18	0.065
Group 2	21	0.9	0.83	0.96	Group 2	0.905	21	0.043
t- Test								
		t-test for Equality of Means						
		t	*df*	*Sig.(2-tailed)*	*Mean Difference*	*Std. Error Difference*	*95% Confidence Interval of the Difference*	
							Lower	*Upper*
PF	Equal variances assumed	2.704	37	0.01	0.115	0.043	0.029	0.201
	Equal variances not assumed	2.756	36.701	0.009	0.115	0.042	0.03	0.2

To visualise the difference between the two groups, the box-plots of the productivity factors of the projects grouped based on their preconstruction phase management practices scores are shown in Figure 7-5.

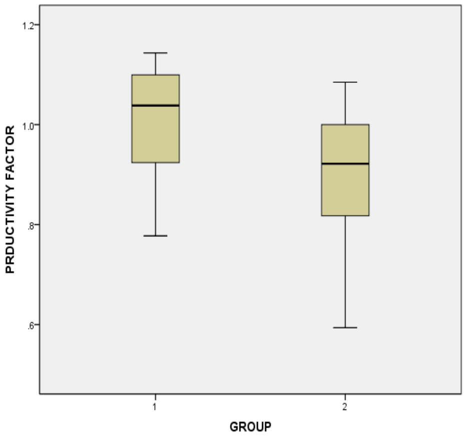


Figure 7-5 Box-plots of the PFs of the Projects with High and Low Preconstruction Phase Management Practices Scores

Validity Test of the Scoring Tools of the Human Resource Management Practices

To validate the scoring tools for the human resource management (HRM) practices, the mean and the median HRM practices scores are computed, and the central value is identified. Accordingly, median = 4.67, mean = 4.63, skewness = -0.446, *SE* of skewness = 0.378 and Z=-0.446/0.378=-1.18 are found. Since the absolute value of the *Z-value* is less than 1.96, the data can be considered as normal, and the mean value (4.63) is used as starting point to divide the data into higher and lower scores. Mean score = 4.63, mean + (5% × mean score) = 4.86, and mean score – (5% × mean score) = 4.39 are used to determine the baseline.

Mann-Whitney U test is conducted to identify if there is a significant difference between Group-1 and Group-2 projects since the data is not normally distributed. In the first trial, the mean value is used as a baseline and insignificant *p-value* ($p = 0.09 > 0.05$) is obtained. During the second trial, using mean+ (5% × mean score) as a baseline, insignificant result ($p = 0.051 > 0.05$) is found. In the third trial, using mean score – (5% × mean score) =4.39, significant result ($p = 0.016 < 0.05$) is obtained. Thus, building projects with scores greater than or equal to 4.39 are grouped under Group-1, and those with scores less than 4.39 are grouped under Group-2. The finding shows that projects with higher productivity factors (PFs) also have higher HRM practice scores, and the scoring tools for HRM practices are valid. The mean PF of Group-1 is approximately

1.0, and the mean PF of Group-2 is 0.88. To visualise the difference between the two groups, box-plots indicated in Figure 7-6 are plotted.

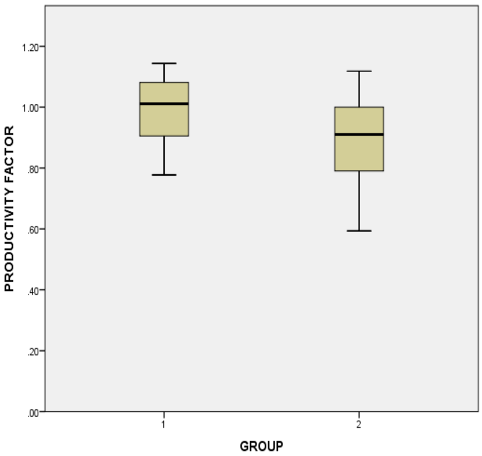


Figure 7-6 Box-plots of the PFs of the Projects with High and Low Human Resource Management Practices Scores

Validity Test of the Scoring Tool of the Safety and Health Practices

The three measures of central tendency or mean, median, mode scores of the safety and health practices are calculated, and the cut-off value for grouping them into high and low scores is determined. The mode=6.03, median=5.65, mean=5.43, Skewness=-1.26, standard error (*SE*) of Skewness = 0.38, and *Z*= (Skewness)/ (*SE*) =-3.33 are found. Since the absolute value of *Z* is greater than 1.96, the data is not considered as normally distributed, and mean is not the suitable measures of central tendency. Therefore, the median value is chosen to group projects into a high score (Group-1) and low score (Group-2). Median score = 5.65, median score + (5% × median score) = 5.93, median score – (5% × median score) = 5.37, and median score – (7.5% × median scores) = 5.23 are compared to determine a baseline.

Mann-Whitney U test is used as the data does not fulfil the requirement of the parametric test. In the first trial, the median value is used as a baseline, and insignificant p-value (p=0.053>0.05) is obtained. During the second trial, using median score + (5% × median score) as a baseline, insignificant result (p=0.258>0.05) is found. In the third trial, using median score – (5% × median score) as a baseline, insignificant *p-value* (0.05) is found. In the fourth trial, using median score – (7.5% × median score) as a baseline, and significant value (p=0.004<0.05) is obtained. Thus, building projects with scores greater than or equal to 5.23 are grouped under Group-1, and those with scores less than 5.23 are classified under Group-2. The scoring tools for safety and health practices are valid since there is a significant difference between the productivity factors of the projects with high and low safety and health practices' scores. The mean PF of Group-1 is approximately 1.0, and the mean PF of Group-2 is 0.83. The box-plots of the productivity factors of the two groups are shown in Figure 7-7.

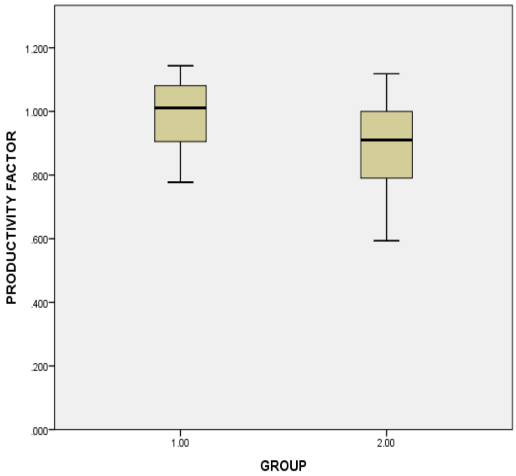


Figure 7-7 Box-plots of the PFs of the Projects with High and Low Safety and Health Practices Scores

7.3.3 Reliability Test for the Weighted Scoring Tools

Before conducting correlation and regression analyses, the internal consistency of the scoring tools of the construction management practices was checked by running the reliability test using SPSS-24. Cronbach alpha (α) is the most popular reliability statistic which determines the consistency of items in a survey instrument and the recommended acceptable minimum value of α is 0.70 (Santos, 1999). In this research, the Cronbach alpha value of 0.95 is found which indicates that the scoring tools for the 47 construction management practices are reliable.

The reliability tests for scoring tools of the six categories of the construction management practices were also conducted. Accordingly, Cronbach alpha values of 0.84, 0.74, 0.75, 0.84, 0.85, and 0.75 were obtained for construction materials management practices, construction equipment management practices, management practices related to construction methods, preconstruction phase management practices, human resource management practices, and safety and health practices respectively. The findings indicate that all the Cronbach alpha values are greater than the minimum acceptable value of 0.70. Hence the scoring tools for the six categories of the construction management practices are reliable.

7.4 Results of the Correlation Analyses

7.4.1 Relationship between Productivity and the Construction Management Practices

To investigate the relationships between productivity and the management practices, Spearman correlation analysis is conducted using SPSS-23 since the construction management practices' data (projects' scores of the construction management practices) is not normally distributed and failed to fulfil the assumptions of the parametric tests. The results are interpreted based on Cohen's effect size in which correlation coefficients of 0.1, 0.3 and 0.5 represent weak (small), moderate (medium) and strong (large) associations respectively (Cohen, 2013). Accordingly, correlation coefficient (r_s) < 0.1 implies very weak correlation; $0.1 \leq r_s < 0.3$ shows weak (low) association; $0.3 \leq r_s \leq 0.5$ implies medium (moderate) relationship; and $r_s > 0.5$ indicates strong (high) association. In Table 7-17, the results of the correlation analysis between productivity and the management practices are presented.

As shown in Table 7-17, all the construction management practices are positively correlated with productivity which confirms the findings of Phase I of this research. However, the correlation between the level of implementation of the construction management practices and productivity performance might not necessarily be a cause-effect relationship. Construction materials management practices have positive, medium strength and statistically significant (r_s=0.45, p=0.005<0.05) association with productivity. This implies that as the level of implementation of the construction materials management practices increases productivity also increases. Among the six construction materials management practices, long-lead materials identification has the highest correlation coefficient (r_s=0.41, p=0.009). The finding confirms that long-lead materials identification is the most critical materials management practice to improve productivity in multi-storey building projects (ranked as number 1 in section 7.2 in materials management category). Procurement plans for materials (r_s=0.33, p=0.04) and materials status database (r_s=0.37, p=0.02) are moderately and positively associated with productivity. The associations are significant at 5% level of significance.

'Construction equipment management practices' is positively and significantly correlated with productivity (r_s=0.366, p=0.02<0.05). This finding confirms the finding obtained in Phase I of the research (Chapter 5) in which the three construction equipment management practices are found to have a potential to enhance productivity in multi-storey building projects.

Table 7-17 Spearman Correlation Coefficients of Productivity and Construction Management Practices

Construction Materials Management Practices			*Management Practices related to Construction Methods*			*Preconstruction Phase Management Practices*			*Human Resource Management Practices*			*Safety and Health Practices*		
N=39		*PF*	*N=39*		*PF*	*N=39*		*PF*	*N=39*		*PF*	*N=39*		*PF*
MMP	Cor. Coeff. (r_s)	$.445^{**}$	MPRCM	Cor. Coeff.	$.440^{**}$	PCPBP	Coeff. (r_s)	$.455^{**}$	HRM	Coeff. (r_s)	.364*	SHP	Coeff. (r_s)	.343*
	Sig. (2-tailed)	0.005		Sig. (2-tailed)	0.004		Sig.	0.004		Sig.	0.023		Sig.	0.032
PPM	Cor. Coeff. (r_s)	$.330^{*}$	IS	Cor. Coeff.	$.466^{**}$	SIP	Coeff. (r_s)	$.355^{*}$	CC	Coeff. (r_s)	0.190	HK	Coeff. (r_s)	0.247
	Sig. (2-tailed)	0.04		Sig. (2-tailed)	0.003		Sig.	0.027		Sig.	0.246		Sig.	0.130
LLM	Cor. Coeff. (r_s)	$.414^{**}$	WSS	Cor. Coeff.	0.277	WSW	Coeff. (r_s)	$.408^{**}$	SA	Coeff. (r_s)	0.208	SHPo	Coeff. (r_s)	.335*
	Sig. (2-tailed)	0.009		Sig. (2-tailed)	0.087		Sig.	0.01		Sig.	0.205		Sig.	0.037
MSD	Cor. Coeff. (r_s)	$.367^{*}$	SEM	Cor. Coeff.	0.199	US	Coeff. (r_s)	$.368^{*}$	ET	Coeff. (r_s)	0.237	HSP	Coeff. (r_s)	.357*
	Sig. (2-tailed)	0.022		Sig. (2-tailed)	0.224		Sig.	0.021		Sig.	0.147		Sig.	0.025
MDS	Cor. Coeff. (r_s)	0.233	DSLP	Cor. Coeff.	0.260	DP	Coeff. (r_s)	0.117	CD	Coeff. (r_s)	0.218	SWMS	Coeff. (r_s)	.323*
	Sig. (2-tailed)	0.153		Sig. (2-tailed)	0.110		Sig.	0.478		Sig.	0.182		Sig.	0.045
MIP	Cor. Coeff. (r_s)	0.143	TCP	Cor. Coeff.	0.189	CWP	Coeff. (r_s)	0.225	NFIP	Coeff. (r_s)	0.056	HA	Coeff. (r_s)	.409**
	Sig. (2-tailed)	0.386		Sig. (2-tailed)	0.249		Sig.	0.169		Sig.	0.736		Sig.	0.01
MIT	Cor. Coeff. (r_s)	0.263	SSP	Cor. Coeff.	0.032	BR	Coeff. (r_s)	0.229	FIP	Coeff. (r_s)	0.243	HST	Coeff. (r_s)	0.216
	Sig. (2-tailed)	0.106		Sig. (2-tailed)	0.849		Sig.	0.162		Sig.	0.135		Sig.	0.187
Construction Equipment Management Practices			MPS	Cor. Coeff.	$.318^{*}$	UA	Coeff. (r_s)	0.299	SoA	Coeff. (r_s)	.367*	TSM	Coeff. (r_s)	0.091
CEMP	Cor. Coeff. (r_s)	0.366^{*}		Sig. (2-tailed)	0.049		Sig.	0.065		Sig.	0.022		Sig.	0.58
	Sig. (2-tailed)	0.022	PSP	Cor. Coeff.	$.527^{**}$	CT	Coeff. (r_s)	$.329^{*}$	SOS	Coeff. (r_s)	.466**			
PPCE	Cor. Coeff. (r_s)	0.435^{**}		Sig. (2-tailed)	0.001		Sig.	0.041		Sig.	0.003			
	Sig. (2-tailed)	0.006	PCP	Cor. Coeff.	$.425^{**}$	MD	Coeff. (r_s)	0.288	CDR	Coeff. (r_s)	0.277			
CEPA	Cor. Coeff. (r_s)	0.330^{*}		Sig. (2-tailed)	0.007		Sig.	0.075		Sig.	0.087			
	Sig. (2-tailed)	0.04	INT	Cor. Coeff.	0.115	RR	Coeff. (r_s)	0.168	RPEP	Coeff. (r_s)	0.199			
CEM	Cor. Coeff. (r_s)	0.162		Sig. (2-tailed)	0.485		Sig.	0.307		Sig.	0.224			
	Sig. (2-tailed)	0.324							EI	Coeff. (r_s)	0.26			
										Sig.	0.11			

Note: PF= Productivity Factor, MMP= Materials Management Practices, PPM=Procurement Plan for Materials, LLM= Long-lead Materials Identification, MSD=Materials Status Database, MDS= Materials Delivery Schedule, MIP=Materials Inspection Process, MIT =Materials Inspection Team, CEMP= Construction Equipment Management Practices, PPCE=Procurement Plans for Construction Equipment, CEPA=Construction Equipment Productivity Analysis, CEM=Construction Equipment Maintenance, MPRCM= Management Practices Related to Construction Methods, IS=Integrated Schedule, WSS= Work Schedule Strategies, SC=Schedule Control, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies, PCPMP= Pre-Construction Phase Management Practices, SIP= Short Interval Plan, WSW=Well-defined Scope of Work, US= Use of Software in Planning Work Packages, DP= Dedicated Planner, CWP= Construction Work Package, BR= Buildability Review, UA= Utilities Alignment, CT= Contract Types, MD= Model Development, RR=Regulatory Requirement, HRM= Human Resource Management Pratices, CC= Crew Composition, SA=Skill Assessment and Evaluation, ET= Employee Training, CD = Career Development, NFIP= Non-Financial Incentive Programs, FIP= Financial Incentive Programs, SoA= Social Activities, SOS= Stability of Organizational Structure, CDR= Clear Delegation of Responsibility, RPEP=Retention Plan for Experienced Personnel, EI= Exit Interviews, SHP= Safety and Health Practices, HK= Housekeeping, SHPo = Safety and Health Policy, SHP= Safety and Health Plan, SWMS = Safe Work Method Statement, HA= Hazard Analysis, SHT= Safety and Health Training, and TSM= Toolbox Safety Meeting,N= Number of Samples, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

The management practices related to construction methods are positively associated with productivity, and the relationship is statistically significant (r_s=0.44, p=0.004<0.05). The finding corroborates the previous two findings regarding the management practices related to construction methods. In Phase I of the research, it is found that the ten management practices related to construction methods have the potential to improve productivity (Chapter 5), and in Chapter 6, it was found that the management practices related to construction methods are 'very important' (response scale of 4) to enhance productivity in multi-storey building projects.

The preconstruction phase management practices are positively correlated with productivity, and the association is statistically significant (r_s=0.46, p=0.004<0.05).

Among the ten preconstruction phase management practices, the practice well-defined scope of work has the highest correlation coefficient (r_s=0.41, p=0.01). This finding confirms the finding obtained in Section 7.2 in which well-defined scope of work is ranked first.

The human resource management (HRM) practices are positively associated productivity, and the relationship is significant (r_s=0.36, p=0.02<0.05) which indicates that as the level of implementation of the HRM practices increases productivity also increases. Among the eleven HRM practices, the stability of organisational structure has the highest correlation coefficient (r_s=0.47, p=0.003<0.05). The finding confirms that maintaining the stability of the organisational structure is the second most important HRM practices (section 7.2).

Safety and health practices have a positive and statistically significant association with productivity (r_s=0.34, p=0.03<0.05). This finding confirms the findings in previous chapters. In Chapter 5, the qualitative data analysis revealed that the seven safety and health practices have the potential to improve productivity in multi-storey building projects. In Chapter 6, the preliminary quantitative data analysis showed that the safety and health practices are ‘extremely important’ (response scale of 5) to improve productivity in multi-storey building projects.

7.4.2 Relationships among the Construction Management Practices

Correlation analysis is conducted to investigate the inter-relationship among the 47 construction management practices. For the sake of brevity, the table indicating the correlation coefficients of all the practices is provided in the Appendix-4. The relationships among the six categories of the management practices and the inter-relationships among the practices within their respective categories are explained in the following subsections.

Relationships among Materials Management Practices and the Practices in other Categories

Procurement Plans for Materials is strongly associated with: Procurement Plans for Construction Equipment (r_s=0.51, p<0.01), Construction Equipment Productivity Analysis (r_s=0.59, p<0.01), and Use of Software in Planning Work Packages (r_s=0.66, p<0.01). Long -Lead Materials Identification has a strong association with Procurement

Plans for Construction Equipment (r_s=0.53, p<0.01). Materials Status Database has a strong correlation with: Procurement Plans for Construction Equipment (r_s=0.61, p<0.01), Construction Equipment Productivity Analysis (r_s=0.52, p<0.01), and Contract Types (r_s=0.55, p<0.01). Materials Delivery Schedule is strongly correlated with Procurement Plans for Construction Equipment (r_s=0.53, p<0.01). Material Inspection Process is strongly correlated with Contract Types (r_s=0.55, p<0.01).

Relationships among Equipment Management Practices and the Practices in other Categories

Procurement Plans for Construction Equipment has a strong correlation with: Short Interval Plan (r_s=0.65, p<0.01), Contract Types (r_s=0.58, p<0.01), Regulatory Requirement (r_s=0.57, p<0.01), Stability of Organizational Structure (r_s=0.57, p<0.01), Safety and Health Policy (r_s=0.67, p<0.01), and Safety and Health Training (r_s=0.63, p<0.01). Construction Equipment Productivity Analysis has a strong association with: Short Interval Plan (r_s=0.63, p<0.01), Stability of Organization Structure (r_s=0.54, p<0.01), and Safety and Health Policy (r_s=0.64, p<0.01). Construction Equipment Maintenance is strongly associated with: Safety and Health Policy (r_s=0.50, p<0.01), and Hazards Analysis (r_s=0.50, p<0.01).

Relationships among Management Practices to Construction Methods and the Practices in other Categories

Integrated Schedule has strong association with: Utilities Alignment (r_s=0.52, p<0.01), Contract Types (r_s=0.56, p<0.01), and Hazards Analysis (r_s=0.57, p<0.001). Work Schedule Strategies has strong association with: Procurement Plans for Materials (r_s=0.56, p<0.01), Contract Types (r_s=0.50, p<0.01), and Skill Assessment and evaluation (r_s=0.53, p<0.01). Schedule Control has strong association with: Buildability Review (r_s=0.67, p<0.01), and Contract Types (r_s=0.71, p<0.01). Dynamic Site Layout Plan has strong correlation with: Safe Work Method Statement (r_s=0.50, p<0.01), and Procurement Plans for Construction (r_s=0.51, p<0.01). Traffic Control Plan has strong associations with: Short Interval Plan (r_s=0.54, p<0.01), Use of Software in Planning Work Packages (r_s=0.51, p<0.01), Construction Work Packages (r_s=0.50, p<0.01), Regulatory Requirement (r_s=0.53, p<0.01), Clear Delegation of Responsibility (r_s=0.51, p<0.01), Safe Work Method Statement (r_s=0.55, p<0.01), and Hazards Analysis (r_s=0.54, p<0.01). Site Security Plan has a strong correlation with: Short Interval Plan

(r_s=0.52, p<0.01), and Construction Work Packages (r_s=0.53, p<0.01). Machinery Positioning Strategy is strongly correlated with: Utilities Alignment (r_s=0.51, p<0.01), and Financial Incentive Programs (r_s=0.57, p<0.01). Project start-up plan is strongly associated with: Construction Work Packages (r_s=0.51, p<0.01), Buildability Review (r_s=0.60, p<0.01), Contract Types (r_s=0.68, p<0.01), Social Activities (r_s=0.64, p<0.01), Exit interviews (r_s=0.50, p<0.01), and Hazards Analysis (r_s=0.52, p<0.01). Project Completion Plan is strongly related with: Long-Lead Materials Identification (r_s=0.54, p<0.01), Materials Inspection Team (r_s=0.54, p<0.01), Procurement Plans for Construction Equipment (r_s=0.53, p<0.01), Short Interval Plan (r_s=0.57, p<0.01), Construction Work Packages (r_s=0.55, p<0.01), Buildability Review (r_s=0.67, p<0.01), Contract Types (r_s=0.61, p<0.01), Regulatory Requirement (r_s=0.52, p<0.01), Crew Composition (r_s=0.51, p<0.01), Employees Training (r_s=0.53, p<0.01), Career Development (r_s=0.55, p<0.01), Exit interviews (r_s=0.51, p<0.01) and Hazards Analysis (r_s=0.57, p<0.01). Innovations and New Technologies has a strong association with: Contract Types (r_s=0.54, p<0.01) and Exit interviews (r_s=0.53, p<0.01).

Relationships among Pre-Construction Phase Management Practices and the Practices in other Categories

Short Interval Plan has a strong association with: Crew Composition (r_s=0.61, p<0.01), Skill Assessment (r_s=0.59, p<0.01), and Safety and Health Training (r_s=0.59, p<0.01). Construction Work Packages is strongly correlated with: Crew Composition (r_s=0.55, p<0.01), and Skill Assessment (r_s=0.52, p<0.01). Utilities Alignment has a strong association with: Skill Assessment (r_s=0.55, p<0.01), Career Development (r_s=0.51, p<0.01), and Financial Incentive Programs (r_s=0.53, p<0.01). Contract Types and Exit Interviews are strongly related (r_s=0.57, p<0.01). Regulatory Requirement is strongly correlated with Skill Assessment (r_s=0.51, p<0.01).

Relationships among Human Management Practices and the Practices in other Categories

Skill Assessment and Safety and Health Training have a strong relationship (r_s=0.51, p<0.01). Financial Incentive Programs has a strong correlation with Safety and Health Training (r_s=0.58, p<0.01). Social Activities and Safety and Health Plan are associated strongly (r_s=0.55, p<0.01). Stability of Organization Structure is strongly correlated with: Safety and Health Policy (r_s=0.50, p<0.01), and Safety and Health Plan (r_s=0.53,

p<0.01). The practice exit interview has a very strong association with safety and health plan (r_s=0.85, p<0.01).

Relationships among Safety and Health Practices and the Practices in other Categories

Health and Safety Policy has a strong association with Procurement Plan for Construction Equipment (r_s=0.66, p<0.01). The relationship between Safe Work Method Statement and Traffic Control Plan is strong (r_s=0.55, p<0.01). Health and Safety Training and Procurement Plans for Construction Equipment are strongly correlated (r_s=0.63, p<0.01).

Summary of the Relationships among the Six Categories of the Management Practices

The summary of the relationships among the six categories of the management practices is presented in Table 7-18. The finding indicates that all the six categories of the construction management practices are positively and strongly correlated, and the relationships are statistically significant at 1% level of significance. However, the correlation coefficient between 'management practices related to construction methods' and 'preconstruction phase management practices' is the highest (0.88); and the Spearman correlation coefficient between 'safety and health practices' and 'construction materials management practices' is the lowest (0.50).

Table 7-18 Spearman Correlation Coefficients of the Six Categories of the Construction Management Practices

		MRCM	*CMMP*	*CEMP*	*PPMP*	*HRMP*	*SHP*
MRCM	Coeff. (r_s)	1.000					
	Sig.	.					
CMMP	Coeff. (r_s)	.664**	1.000				
	Sig.	.000	.				
CEMP	Coeff. (r_s)	.643**	.704**	1.000			
	Sig.	.000	.000	.			
PPMP	Coeff. (r_s)	**.878****	.655**	.763**	1.000		
	Sig.	.000	.000	.000	.		
HRMP	Coeff. (r_s)	.701**	.584**	.682**	.701**	1.000	
	Sig.	.000	.000	.000	.000	.	
SHP	Coeff. (r_s)	.507**	**.498****	.660**	.598**	.586**	1.000
	Sig.	.001	.001	.000	.000	.000	.

Legend: MRCM=Management Practices Related to Construction Methods, CMMP= Construction Materials Management Practices, CEMP = Construction Equipment Management Practices, PPMP= Preconstruction Phase Management Practices, HRMP = Human Resource Management Practices, SHP= Safety and Health Practices, ** Correlation is significant at 0.01.

The inter-relationships among the practices within their respective categories are described in the following subsections.

Inter-relationships among Construction Materials Management Practices

In Table 7-19, the results of the correlation analysis of the materials management practices are presented. Accordingly, all the six construction materials management practices are positively correlated. Procurement plan for materials is strongly and positively associated with: long-lead material identification (r_s=0.64, p<0.001), materials status database (r_s=0.53, p=0.001), and materials inspection team (r_s=0.61, p<0.001). The relationships are statistically significant at 1% level of significance. Long-lead materials identification is strongly and significantly correlated with materials status database (r_s=0.57, p<0.001). Materials status database is strongly associated with materials inspection team (r_s=0.64, p<0.001). Materials inspection process is strongly and significantly correlated with materials inspection team (r_s=0.69, p<0.001).

Table 7-19 Spearman's Correlation Coefficients of the Construction Materials Management Practices

N=39		*PPM*	*LLM*	*MSD*	*MDS*	*MIP*	*MIT*
	Sig. (2-tailed)						
	Cor. Coeff. (r_s)	1.000					
PPM	Sig. (2-tailed)						
	Cor. Coeff. (r_s)	**.644****	1.000				
LLM	Sig. (2-tailed)	.000					
	Cor. Coeff. (r_s)	**.534****	**.565****	1.000			
MSD	Sig. (2-tailed)	.000	.000				
	Cor. Coeff. (r_s)	.336*	.423**	.345*	1.000		
MDS	Sig. (2-tailed)	.037	.007	.032			
	Cor. Coeff. (r_s)	.366*	.201	.437**	.027	1.000	
MIP	Sig. (2-tailed)	.022	.219	.005	.868		
	Cor. Coeff. (r_s)	**.605****	.496**	**.644****	.399*	.**690****	1.00
MIT	Sig. (2-tailed)	.000	.001	.000	.012	.000	-

Note: PPM=Procurement Plan for Materials, LLM= Long-lead Materials Identification, MSD=Materials Status Database, MDS= Materials Delivery Schedule, MIP=Materials Inspection Process MIT =Materials Inspection Team, N= Number of Samples, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

Inter-relationships among Construction Equipment Management Practices

The correlation analysis revealed that all the three construction equipment management practices are interrelated. Procurement plan for construction equipment is strongly correlated with construction equipment productivity analysis (r_s=0.772, p<0.001). The relationship is statistically significant at 1% level of significance. The practices procurement plan for construction equipment and construction equipment maintenance have statistically significant and medium strength association (r_s=0.424, p=0.01<0.05). Construction equipment productivity analysis is moderately correlated with construction equipment maintenance (r_s=0.419, p=0.008<0.05).

Inter-relationships among Management Practices Related to Construction Methods

All the ten management practices related to construction methods are positively correlated with each other (Table 7-20). Accordingly, integrated schedule and schedule control (r_s=0.569, p<0.001); work schedule strategy and project completion plan (r_s=0.514, p=0.001); dynamic site layout plan and machinery positioning strategy (r_s=0.604, p<0.001); and traffic control plan and site security plan (r_s=0.734, p<0.001) have strong and statistically significant relationships. The findings indicate that projects that have implemented a higher level of one management practice that is related to construction methods also implement higher levels of other practices that are related to construction methods.

Table 7-20 Spearman's Correlation Coefficients of the Management Practices Related to Construction Methods

		IS	WSS	SC	DSLP	TCP	SSP	MPS	PSP	PCP	INT
IS	Cor. Coeff.	1.00									
	Sig. (2-tailed)	-									
WSS	Cor. Coeff.	.491**	1.00								
	Sig. (2-tailed)	.001	-								
SEM	Cor. Coeff.	**.569****	.424**	1.00							
	Sig. (2-tailed)	.000	.007	-							
DSLP	Cor. Coeff.	.476**	.431**	.452**	1.00						
	Sig. (2-tailed)	.002	.006	.004	-						
TCP	Cor. Coeff.	.227	.240	.175	.381*	1.00					
	Sig. (2-tailed)	.165	.141	.288	.017	-					
SSP	Cor. Coeff.	.211	.343*	.193	.263	**.734****	1.00				
	Sig. (2-tailed)	.197	.033	.239	.106	.000	-				
MPS	Cor. Coeff.	.423**	.279	.362*	**.604****	.454**	.395*	1.00			
	Sig. (2-tailed)	.007	.086	.023	.000	.004	.013	-			
PSP	Cor. Coeff.	.468**	.243	.214	.240	.452**	.286	.264	1.00		
	Sig. (2-tailed)	.003	.137	.192	.142	.004	.077	.105	-		
PCP	Cor. Coeff.	.367*	**.514****	.258	.250	.426**	.487**	.417**	.418**	1.00	
	Sig. (2-tailed)	.022	.001	.113	.124	.007	.002	.008	.008	-	
INT	Cor. Coeff.	.201	.225	.106	.275	.256	.247	.380*	.268	.473**	1.00
	Sig. (2-tailed)	.220	.168	.521	.091	.115	.130	.017	.099	.002	-

Note: IS=Integrated Schedule, WSS= Work Schedule Strategies, SC=Schedule Control, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies. ** Correlation is significant at 0.01; * Correlation is significant at 0.05

Inter-relationships among Pre-Construction Phase Management Practices

In Table 7-21, the results of the correlation analysis of the pre-construction phase management practices are presented. Accordingly, all the ten preconstruction phase management practices are inter-related. However, the relationships between: short interval plan and construction work package (r_s=0.59, p<0.001); short interval plan and regulatory requirement (r_s=0.52, p=0.001); short interval plan and use of software in planning work packages (r_s=0.51, p=0.001); well-defined scope of work and contract types (r_s=0.51, p=0.001); construction work packages and buildability review (r_s=0.51,

p=0.001); and buildability review and contract types (r_s=0.54, p<0.001) are strong and statistically significant.

Table 7-21 Spearman's Correlation Coefficients of Pre-Construction Phase Management Practices

N=39		*SIP*	*WSW*	*US*	*DP*	*CWP*	*BR*	*UA*	*CT*	*MD*	*RR*
SIP	Coeff. (r_s)	1.000									
	Sig.										
WSW	Coeff. (r_s)	.317*	1.000								
	Sig.	.049									
US	Coeff. (r_s)	**.505****	.352*	1.000							
	Sig.	.001	.028								
DP	Coeff. (r_s)	.424**	.051	.433**	1.000						
	Sig.	.007	.756	.006							
CWP	Coeff. (r_s)	**.591****	.416**	.410**	.113	1.000					
	Sig.	.000	.009	.010	.495						
BR	Coeff. (r_s)	.468**	.381*	.415**	.091	**.501****	1.00				
	Sig.	.003	.017	.009	.580	.001	-				
UA	Coeff. (r_s)	.458**	.243	.340*	.130	.227	.401*	1.00			
	Sig.	.003	.136	.034	.431	.164	.012	-			
CT	Coeff. (r_s)	.384*	**.510****	.329*	.129	.399*	**.542****	.417**	1.00		
	Sig.	.016	.001	.041	.433	.012	.000	.008	-		
MD	Coeff. (r_s)	.106	.292	.097	.186	.124	.008	.023	.058	1.00	
	Sig.	.522	.072	.556	.257	.451	.960	.892	.728	-	
RR	Coeff. (r_s)	**.517****	.148	.448**	.388*	.359*	.372*	.483**	.364*	.102	1.00
	Sig.	.001	.368	.004	.015	.025	.020	.002	.023	.537	-

Legend: SIP= Short Interval Plan, WSW=Well-defined Scope of Work, US= Use of Software in Planning Work Packages, DP= Dedicated Planner, CWP= Construction Work Package, BR= Buildability Review, UA= Utilities Alignment, CT= Contract Types, MD= Model Development, RR=Regulatory Requirement

Inter-relationships among Human Resource Management Practices

Table 7-22 presents the results of the correlation analyses of the human resource management practices. Accordingly, all the eleven HRM practices are interrelated. The relationships between crew composition and skill assessment and evaluation (r_s=0.63, p<0.001); crew composition and employees training (r_s=0.59, p<0.001); crew composition and financial incentive programs (r_s=0.63, p=0.001); skill assessment and evaluation and financial incentive program (r_s=0.53, p=0.001); career development and financial incentive programs (r_s=0.57, p<0.001); career development and social activities (r_s=0.53, p=0.001); career development and exit interview (r_s=0.52, p=0.001); Non-financial incentive programs and financial incentive programs (r_s=0.57, p<0.001); stability of organizational structure and retention plan for experienced personnel (r_s=0.57, p<0.001) are strong and statistically significant.

Table 7-22 Spearman Correlation Coefficients of Human Resource Management Practices

		CC	*SA*	*ET*	*CD*	*NFIP*	*FIP*	*SoA*	*SOS*	*CDR*	*RPEP*	*EI*
CC	Coeff. (r_s)	1.000										
	Sig.	.										
SA	Coeff. (r_s)	**.630****	1.000									
	Sig.	.000	.									
ET	Coeff. (r_s)	**.587****	.399*	1.000								
	Sig.	.000	.012	.								
CD	Coeff. (r_s)	.433**	.487**	.273	1.000							
	Sig.	.006	.002	.093	.							
NFIP	Coeff. (r_s)	.371*	.320*	.134	.338*	1.000						
	Sig.	.020	.047	.414	.035	.						
FIP	Coeff. (r_s)	**.506****	**.525****	.307	**.566****	**.573****	1.000					
	Sig.	.001	.001	.057	.000	.000	.					
SoA	Coeff. (r_s)	.290	.276	.167	**.528****	.486**	.493**	1.000				
	Sig.	.073	.089	.310	.001	.002	.001	.				
SOS	Coeff. (r_s)	.314	.352*	.420**	.275	.140	.263	.369*	1.000			
	Sig.	.051	.028	.008	.090	.394	.106	.021	.			
CDR	Coeff. (r_s)	.459**	.347*	.214	.334*	.018	.174	.048	.491**	1.000		
	Sig.	.003	.031	.190	.038	.912	.290	.770	.001	.		
RPEP	Coeff. (r_s)	.246	.136	.242	.323*	.208	.308	.334*	**.569****	.424**	1.000	
	Sig.	.131	.410	.138	.045	.205	.056	.038	.000	.007	.	
EI	Coeff. (r_s)	.332*	.145	.301	**.522****	.384*	.376*	.430**	.476**	.431**	.452**	1.000
	Sig.	.039	.380	.063	.001	.016	.018	.006	.002	.006	.004	.

Legend: CC= Crew Composition, SA=Skill Assessment and Evaluation, ET= Employee Training, CD = Career Development, NFIP= Non-Financial Incentive Programs, FIP= Financial Incentive Programs, SoA= Social Activities, SOS= Stability of Organizational Structure, CDR= Clear Delegation of Responsibility, RPEP=Retention Plan for Experienced Personnel, EI= Exit Interviews, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

Inter-relationships among Safety and Health Practices

In Table 7-23, the results of the correlation analysis of the safety and health practices are presented. Accordingly, all the safety and health practices are positively correlated. The relationships between ‘safety and health policy’ and ‘safety and health plan’ (r_s=0.57, p<0.001); and ‘safety and health policy’ and ‘safety and health training’ (r_s=0.66, p<0.001) are strong and statistically significant at 1% level of significance.

Table 7-23 Spearman Correlation Coefficients of Safety and Health Practices

		HK	SHPo	SHP	SWMS	HA	SHT	TSM
HK	Coeff. (r_S)	1.000						
	Sig.	.						
SHPo	Coeff. (r_S)	.463**	1.000					
	Sig.	.003	.					
HSP	Coeff. (r_S)	.335*	**.571****	1.000				
	Sig.	.037	.000	.				
SWMS	Coeff. (r_S)	.362*	.250	.221	1.000			
	Sig.	.023	.124	.176	.			
HA	Coeff. (r_S)	.314	.448**	.144	.400*	1.000		
	Sig.	.052	.004	.383	.012	.		
HST	Coeff. (r_S)	.296	**.664****	.423**	.086	.398*	1.000	
	Sig.	.067	.000	.007	.603	.012	.	
TSM	Coeff. (r_S)	.004	.300	.235	.200	.016	.400*	1.000
	Sig.	.981	.064	.150	.222	.925	.012	.

Note: HK= Housekeeping, SHPo = Safety and Health Policy, SHP= Safety and Health Plan, SWMS = Safe Work Method Statement, HA= Hazard Analysis, SHT= Safety and Health Training, and TSM= Toolbox Safety Meeting, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

7.4.3 Relationship among Construction Management Practices, Company Profiles and Project Characteristics

Correlation analysis is conducted to investigate the relationships among the construction management practices, project delay, project cost, and company profiles. The results of the analysis are indicated in Table 7-24.

Table 7-24 Spearman Correlation Coefficients of Project Characteristics, Company Profiles, and Construction Management Practices

		PF	*Project Cost*	*Project Delay*	*Annual Turnover*	*Company Experience*	*Company Size*	*CMP*
Project Cost	Coeff.	.401*	1.000					
	Sig.	.011	.					
Project Delay	Coeff.	-.940**	-.281	1.000				
	Sig.	.000	.084	.				
Annual Turnover	Coeff.	.118	.356	-.041	1.000			
	Sig.	.575	.081	.847	.			
Company Experience	Coeff.	.141	.547**	-.022	.062	1.000		
	Sig.	.399	.000	.898	.769	.		
Company Size	Coeff.	.177	.593**	-.122	.565**	.536**	1.000	
	Sig.	.280	.000	.460	.003	.001	.	
CMP	Coeff.	.490**	.615**	-.422**	.122	.307	.291	1.000
	Sig.	.002	.000	.007	.562	.061	.072	.

Legend: PF= Productivity Factor, CMP=Construction Management Practices, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

As shown in Table 7-24, project cost and the construction management practices are positively and strongly correlated, and the relationship is statistically significant (r_s=0.62, p<0.001). The finding suggests that the increase in the building project costs due to the increment of the scope of works could be one of the reasons for the variations in the implementation levels of the construction management practices.

Project delay and construction management practices are negatively correlated (r_s=-0.42, p=0.01) which indicates that higher levels of implementation of the practices are associated with low project delays. Project delay and productivity have a very strong negative correlation coefficient (r_s=-0.94, p<0.001) which implies that increasing projects' productivity can reduce project delays.

Project costs and productivity have a medium and significant association (r_s=0.40, p=0.01). This finding indicates that projects with higher costs also have higher productivity. Productivity is positively but weakly associated with company experience (r_s=0.12, p=0.58), annual turnover (r_s=0.14, p=0.40), and company size (r_s=0.18, p=0.28). Moreover, the relationships are not statistically significant.

Company size and the construction management practices have medium strength association, but the relationship is not significant (r_s=0.31, p=0.06>0.05). Annual turnover and company experience have weak and statistically insignificant relationships with the construction management practices (Table 7-24).

The relationships among the six categories of the construction management practices, company profiles, and project characteristics are explained in the following subsections.

Relationships among Construction Materials Management Practices, Company Profiles, and Project Characteristics

The relationships among project delay, project cost, company experience, annual turnover, company size and the construction materials management practices are analysed, and the results are presented in Table 7-25. Accordingly, all the six construction materials management practices are negatively correlated with project delay. This indicates that as the levels of implementation of the materials management practices increase, the possibility of delaying the completion time of the building projects decreases. Long-lead materials identification has a medium and statistically significant correlation (r_s=-0.35, p=0.03) with project delay. Materials status database is moderately correlated with project delay (r_s=-0.30, p=0.06). Materials inspection team (r_s=-0.22, p=0.18) and material inspection process (r_s=-0.16, p=0.32) are weakly correlated with project delay.

Table 7-25 Spearman Correlation Coefficients of Company Profiles, Project Characteristics, and Construction Materials Management Practices

		MMP	*PPM*	*LLM*	*MSD*	*MDS*	*MIP*	*MIT*
Project Delay	Corr. Coeff.	-0.375	-0.277	-0.353	-0.303	-0.129	-0.163	-0.217
	Sig.(2-tailed)	0.019	0.088	0.027	0.061	0.434	0.322	0.184
Annual Turnover	Corr. Coeff.	0.056	-0.002	0.097	-0.028	0.019	0.099	-0.026
	Sig. (2-tailed)	0.790	0.992	0.644	0.895	0.929	0.637	0.900
Company Experience	Corr. Coeff.	0.286	**0.514****	0.413**	0.175	0.096	-0.138	0.103
	Sig. (2-tailed)	0.082	0.001	0.010	0.294	0.567	0.409	0.538
Company Size	Corr. Coeff.	0.227	0.340*	0.139	0.059	0.049	0.039	0.093
	Sig. (2-tailed)	0.165	0.034	0.399	0.721	0.767	0.812	0.574
Project Cost	Corr. Coeff.	0.474**	**0.635***	0.296	0.332*	0.149	0.147	0.355*
	Sig. (2-tailed)	0.002	<0.001	0.067	0.039	0.367	0.371	0.027

Legend: MMP=Material Management Practice (overall score), PPM=Procurement Plan for Materials, LLM=Long Lead Materials Identification, MSD=Material Status Database, MDS=Materials Delivery Schedule, MIP=Materials Inspection Process, MIT= Materials Inspection Team.

There is a very weak and insignificant correlation between annual turnover and construction materials management practices (r_s=0.06, p=0.79>0.05). Company experience is strongly associated with procurement plans for materials (r_s=0.51, p=0.001). Company size is significantly and moderately related to procurement plan for materials (r_s=0.34, p=0.03). Positive, moderate, and significant association (r_s=0.47, p=0.002) between construction materials management practices and the project cost is found. This implies that the level of implementation of the construction materials management practices increases with project cost. Among the six construction materials management practices, the practice procurement plans for materials is strongly associated with project cost (r_s=0.64, p<0.001).

Relationships among Construction Equipment Management Practices, Company Profiles, and Project Characteristics

Correlation analysis is carried out to investigate the relationship among construction equipment management practices, project delay, project cost, annual turnover, company experience and company size (Table 7-26). The project cost is positively correlated with construction equipment management practices (r_s=0.59, p<0.001) which implies that the level of implementation of the construction equipment management practices increases with project cost.

Project delay is negatively correlated with construction equipment management practices (r_s=-0.30, p=0.07) which indicates that the possibility of occurrence of the project delay decreases as the levels of implementation of the equipment management practices increase. Annual turnover (r_s=0.19, p=0.37) and company experience (r_s=0.28, p=0.09) are weakly correlated with construction equipment management practices. Company size is significantly and moderately associated with construction equipment management practices (r_s=0.40, p=0.01<0.05) which implies that larger companies implement higher levels of construction equipment management practices.

Table 7-26 Spearman Correlation Coefficients of Company Profiles, Project Characteristics, and Construction Equipment Management Practices

		CEMP	*PPCE*	*CEPA*	*CEM*
Project Cost	Corr. Coeff.	**0.585****	0.453**	0.589**	0.418**
	Sig. (2-tailed)	<0.001	0.004	<0.001	0.008
Project Delay	Corr. Coeff.	-0.298	-0.358*	-0.227	-0.151
	Sig. (2-tailed)	0.065	0.025	0.165	0.358
Annual Turnover	Corr. Coeff.	0.188	0.116	0.337	0.006
	Sig. (2-tailed)	0.368	0.580	0.100	0.977
Company Experience	Corr. Coeff.	0.276	0.284	0.274	0.266
	Sig. (2-tailed)	0.093	0.084	0.096	0.107
Company Size	Corr. Coeff.	0.400*	0.251	0.394*	0.379*
	Sig. (2-tailed)	0.012	0.123	0.013	0.017

Legend: CEMP= Construction Equipment Management Practices, PPCE=Procurement Plans for Construction Equipment, CEPA=Construction Equipment Productivity Analysis, CEM=Construction Equipment Maintenance, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

Relationships among Management Practices Related to Construction Methods, Company Profiles, and Project Characteristics

Correlation analysis is also conducted to check if the implementation levels of the management practices related to construction methods vary based on project cost, annual turnover of the companies, the experience of the companies and company sizes. The results of the analyses are shown in Table 7-27. Accordingly, all the ten management practices related to construction methods are negatively correlated with building projects' delays. This finding indicates that project with a low level of implementation of the practices or low scores is at high risk of incurring project delay. In other words, high levels of implementation of the management practices related to construction methods are associated with low project delay. Among the ten practices, project start-up plan (r_s=-0.524, p=0.001) is strongly related to project delay; and integrated schedule ($\mathrm{r_s}$=-0.470, p=0.003), project completion plan (r_s=-0.366, p=0.022), and machinery positioning strategy (r_s=-0.349, p=0.030) are moderately and significantly correlated with project delays. Work schedule strategies (r_s=-0.204, p=0.213), dynamic site layout plan (r_s=-0.262, p=0.107), schedule execution and management (r_s=-0.195, p=0.234), and traffic control plan (r_s=-0.177, p=0.280) are weakly associated with project delay. Site security plan (r_s=-0.011, p=0.949), and innovations and new technologies (r_s=-0.079, p=0.635) have a very weak association with project delay.

Table 7-27 Spearman Correlation Coefficients of Company Profiles, Project Characteristics and Management Practices Related to Construction Methods.

		IS	*WSS*	*SC*	*DSLP*	*TCP*	*SSP*	*MPS*	*PSP*	*PCP*	*INT*	*TS*
Project Delay	Corr.Coeff.	-0.470	-0.204	-0.195	-0.262	-0.177	-0.011	-0.349	-0.524	-0.366	-0.079	-0.425
	Sig.(2-tailed)	0.003	0.213	0.234	0.107	0.280	0.949	0.030	0.001	0.022	0.635	0.007
Annual Turnover	Corr.Coeff.	0.263	0.346	-0.384	0.39	0.011	-0.141	-0.064	0.087	-0.059	0.111	0.071
	Sig.(2-tailed)	0.204	0.090	0.058	0.054	0.957	0.502	0.762	0.680	0.780	0.597	0.735
Company Experience	Corr.Coeff.	0.274	0.181	0.270	0.240	0.231	0.302	-0.065	.331*	0.150	.327*	0.313
	Sig.(2-tailed)	0.096	0.277	0.101	0.147	0.162	0.065	0.700	0.042	0.370	0.045	0.056
Company Size	Corr.Coeff.	0.381*	0.284	0.289	0.250	0.001	0.053	-0.015	0.102	0.129	0.274	0.274
	Sig.(2-tailed)	0.017	0.080	0.075	0.124	0.998	0.750	0.930	0.536	0.436	0.092	0.092
Project Cost	Corr.Coeff.	0.417**	0.236	0.227	0.414**	0.361*	0.35*	0.284	0.376*	0.319*	0.368*	0.497**
	Sig.(2-tailed)	0.008	0.148	0.164	0.009	0.024	0.029	0.079	0.018	0.047	0.021	0.001

Legend: IS=Integrated Schedule, WSS= Work Schedule Strategies, SC=Schedule Control, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies, TS= Total Score of the best practices

The management practices related to construction methods are strongly and positively correlated with project cost (r_s=0.50, p=0.001). The finding suggests that one of the main reasons for variations in the levels of implementation of the management practices related to construction methods could be the change in project costs. As a project cost increases due to increment in the scope of works, the level of implementation of the management practices related to construction methods also increases.

Company's annual turnover is not associated with the management practices related to construction methods (r_s=0.071, p=0.735). Company experience is moderately correlated with management practices related construction methods (r_s=0.313, p=0.056). However, the association is not statistically significant. Company size is also moderately and insignificantly correlated (r_s=0.274, p=0.092) with the management practices related to construction methods. The finding suggests that larger and experienced companies may not implement higher levels of the practices if the scope of a project is small. Among the ten practices, integrated schedule (r_s=0.381, p=0.017) is significantly associated with company size indicating that larger companies integrate various project schedules than smaller companies.

Relationships among Preconstruction Phase Management Practices, Company Profiles, and Project Characteristics

The results of the correlation analysis among the pre-construction phase management practices, project delay, project cost, and company profiles are presented in Table 7-28. Accordingly, negative association (r_s=-0.37, p=0.02<0.05) between the preconstruction phase management practices and project delay is found which indicates that implementation of the preconstruction phase management practices could reduce project delays. Among the ten pre-construction phase management practices, the practice ‘well-defined scope of work’ has the highest correlation coefficient ($r_s=-0.43$, $p=0.007<0.05$) which is statistically significant, and dedicated planner has the lowest association ($r_s=-0.02$, $p=0.91$) with the project delay. Contract types ($r_s=-0.33$, $p=0.04$) and use of software in planning work packages ($r_s=-0.32$, $p=0.049$) have medium associations with project delay; model development ($r_s=-0.32$, $p=0.05$), short interval plan ($r_s=-0.24$, $p=0.14$), utilities alignment ($r_s=-0.22$, $p=0.18$), construction work packages ($r_s=-0.13$, $p=0.42$), and buildability review ($r_s=-0.18$, $p=0.28$) are weakly correlated with project delay.

Table 7-28 Spearman Correlation Coefficients of Company Profiles, Project Characteristics, and Pre-Construction Phase Management Practices

		PPMP	*SIP*	*WSW*	*US*	*DP*	*CWP*	*BR*	*UA*	*CT*	*MD*	*RR*
Project Delay	Coeff.	-.37*	-.24	-.43**	-.32*	-.02	-.13	-.18	-.22	-.33*	-.26	-.07
	Sig.	.02	.14	.007	.05	.91	.42	.28	.18	.04	.11	.68
Project Cost	Coeff.	.59**	.57**	.19	.48**	.54**	.36*	.28	.38*	.38*	.23	.26
	Sig.	.000	.000	.24	.002	.000	.02	.09	.02	.02	.16	.12
Annual Turnover	Coeff.	.09	.00	.27	-.22	.12	.15	-.08	.07	.43*	-.16	-.16
	Sig.	.66	.99	.19	.29	.58	.47	.70	.74	.03	.43	.44
Company Experience	Coeff.	.28	.36*	.05	.18	.48**	-.08	-.05	.25	.01	-.07	.41*
	Sig.	.09	.03	.76	.28	.003	.64	.76	.13	.95	.66	.01
Company Size	Coeff.	.19	.37*	-.02	.03	.42**	-.05	-.08	.21	.16	.11	.14
	Sig.	.24	.02	.91	.85	.01	.77	.64	.19	.33	.53	.38

Legend: PPMP= Preconstruction Phase Management Practices, SIP= Short Interval Plan, WSW=Well-defined Scope of Work, US= Use of Software in Planning Work Packages, DP= Dedicated Planner, CWP= Construction Work Package, BR= Buildability Review, UA= Utilities Alignment, CT= Contract Types, MD= Model Development, RR=Regulatory Requirement, * significant at 5%, ** significant at 1%.

Project cost is significantly and strongly correlated with preconstruction phase management practices ($r_s=0.59$, $p<0.001$) which indicates that as the project cost increases the implementation levels of the practices also increase. Short interval planning ($r_s=0.57$, $p<0.001$) and dedicated planner ($r_s=0.54$, $p<0.001$) have statistically significant and strong correlation with project costs. Use of software in planning work packages ($r_s=0.48$, $p=0.002$), construction work packages ($r_s=0.36$, $p=0.02$), utilities alignment ($r_s=0.38$, $p=0.02$), and contract types ($r_s=0.38$, $p=0.02$) have medium associations with project cost (Table 7-28). Buildability review ($r_s=0.38$, $p=0.09$), regulatory requirement ($r_s=0.26$, $p=0.12$), model development ($r_s=0.23$, $p=0.16$), and well-defined scope of work ($r_s=0.19$, $p=0.24$) have weak relationships with project cost.

Annual turnover has a very weak correlation with the pre-construction phase management practices (r_s=0.09, p=0.66) which implies the level of implementation of the preconstruction phase management practices is not related to company's turnover. The relationship between company experience and pre-construction phase management practices is weak (r_s=0.28, p=0.09). Similarly, company size is weakly correlated with pre-construction phase management practices (r_s=0.19, p=0.24).

Relationships among Human Resource Management Practices, Company Profiles, and Project Characteristics

In Table 7-29, the results of correlation analyses of project delay, project cost, company profiles and the human resource management (HRM) practices are presented. Among the eleven HRM practices, project delay is strongly associated with the stability of organisational structure (r_s= -0.47, p=0.003) and social activities (r_s=-0.41, p=0.01).

Table 7-29 Spearman Correlation Coefficients of Company Profiles, Project Characteristics, and HRM Practices

		HRM	*CC*	*SA*	*ET*	*CD*	*NFIP*	*FIP*	*SoA*	*SOS*	*CDR*	*RPEP*	*EI*
Project Delay	Coeff.	-.303	-.082	-.102	-.205	-.140	-.077	-.182	-.407*	-.470**	-.204	-.195	-.262
	Sig.	.061	.621	.535	.210	.396	.640	.267	.010	.003	.213	.234	.107
Project Cost	Coeff.	.502**	.293	.405*	.189	.314	.352*	.379*	.404*	.417**	.236	.227	.414**
	Sig.	.001	.070	.011	.248	.051	.028	.017	.011	.008	.148	.164	.009
Annual Turnover	Coeff.	0.10	-0.06	0.10	-0.14	0.33	0.02	-0.12	0.02	0.26	0.35	-0.38	0.39
	Sig.	0.65	0.79	0.65	0.51	0.11	0.92	0.56	0.93	0.20	0.09	0.06	0.05
Company Experience	Coeff.	0.32	0.14	0.28	-0.02	0.09	0.32*	0.26	0.05	0.27	0.18	0.27	0.24
	Sig.	0.05	0.40	0.09	0.90	0.60	0.05	0.11	0.77	0.10	0.28	0.10	0.15
Company Size	Coeff.	.32*	0.04	0.18	0.01	0.23	0.28	0.28	0.20	.381*	0.28	0.29	0.25
	Sig.	0.05	0.83	0.28	0.98	0.17	0.08	0.09	0.23	0.02	0.08	0.08	0.12

Legend: HRM= Best Human Resource Management Practices, CC= Crew Composition, SA=Skill Assessment and Evaluation, ET= Employee Training, CD = Career Development, NFIP= Non-Financial Incentive Programs, FIP= Financial Incentive Programs, SoA= Social Activities, SOS= Stability of Organizational Structure, CDR= Clear Delegation of Responsibility, RPEP=Retention Plan for Experienced Personnel, EI= Exit Interviews, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

Project cost and HRM practices are strongly correlated (r_s=0.51, p=0.001) which implies that projects having larger scope have higher levels of implementation of the HRM practices, and among the 11 practices the 'stability of organisational structure' has the highest correlation coefficient (r_s=0.42, p=0.008).

The annual turnover of construction companies is very weakly correlated with HRM practices (r_s=0.1, p=0.65). Company experience is moderately associated with HRM practices (r_s=0.32, p=0.05), but the relationship is not statistically significant. Among the 11 HRM practices, non-financial incentive program has the highest correlation coefficient (r_s=0.32, p=0.047), and employee training (r_s=-0.02, p=0.90) has no relationship with company experience. Company size and HRM practices have significant and moderate strength (r_s=0.32, p=0.04) relationship. This implies that the implementation of the HRM practices is more important for larger contractors than for smaller contractors. Among the eleven HRM practices, the stability of organisational structure has a stronger association with company size (Table 7-29).

Relationships among Safety and Health Practices, Company Profiles, and Project Characteristics

The Spearman correlation coefficients of project delay, project cost, and safety and health practices are presented in Table 7-30. The association between project cost and safety and health practices is positive, and the relationship is significant (r_s=0.46, p=0.003) which implies that the levels of implementation of safety and health practices increase when project costs increase.

Table 7-30 Spearman Correlation Coefficients of Company Profiles, Project Characteristics and Safety and Health Practices

		SHP	HK	SHPo	SHP	SWMS	HA	SHT	TSM
Project Cost	Coeff.	.458**	.304	.482**	.284	.149	.304	.279	.347*
	Sig.	.003	.060	.002	.080	.365	.060	.086	.030
Project Delay	Coeff.	-.243	-.212	-.219	-.286	-.273	-.342*	-.175	.134
	Sig.	.135	.196	.181	.077	.092	.033	.286	.416
Annual Turnover	Coeff.	.185	.275	.242	.341	-.005	-.090	-.136	.078
	Sig.	.376	.184	.244	.095	.982	.667	.518	.712
Company Experience	Coeff.	.329*	.206	.361*	.157	.274	.067	.154	.104
	Sig.	.043	.215	.026	.346	.096	.691	.357	.535
Company Size	Coeff.	.368*	.235	.433**	.147	.068	.198	.407*	.248
	Sig.	.021	.149	.006	.372	.681	.227	.010	.127

Note: SHP= Safety and Health Practices, HK= Housekeeping, SHPo = Safety and Health Policy, SHP= Safety and Health Plan, TSA = Safe Work Method Statement, HA= Hazard Analysis, SHT= Safety and Health Training, and TSM= Toolbox Safety Meeting, ** Correlation is significant at 0.01, * Correlation is significant at 0.05.

Project delay is negatively correlated with safety and health practices (r_s=-0.24, p=0.14). However, the degree of association is weak as well as insignificant. The result indicates that increasing the level of implementation of safety and health practices might not reduce the possibility of occurrence of project delay.

Annual turnover and safety and health practices are positively correlated, but the relationship is not significant (r_s=0.19, p=0.38). Company experience and the safety and health practices are positively associated, and the relationship is statistically significant (r_s=0.33, p=0.04). The finding shows that experienced companies have better safety and health practices. Among the seven safety and health practices, safety and health policy has the strongest association with company experience (r_s=0.36, p=0.03). This implies that the more experienced the contractors are, the better their safety policies are.

Company size is also positively associated with safety and health practices (r_s=0.37, p=0.02) which indicates that larger construction companies have higher levels of implementation of the safety and health practices. Among the seven practices, safety and health policy has the highest correlation coefficient (r_s=0.43, p=0.006). The relationship is also statistically significant at 1% level of significance. Safety and health training has a medium strength as well as statistically significant association with company size (r_s=0.41, p=0.01). The findings indicate that larger construction firms also have higher levels of implementation of 'safety and health policy' and 'safety and health training.'

7.5 Summary

After analysing the quantitative data, part of Objective 1 or 'to prioritize the construction management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia," and part of Objective 2 of the study which is 'to validate the scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects' are achieved.

In this chapter, the relative importance indexes of the 47 construction management practices were computed and the practice well-defined scope of works has been ranked first. All the safety and health practices are ranked in the top ten. The weights of the practices were used to develop the scoring tools. The validity and reliability tests for the scoring tools of the construction management practices were carried out, and acceptable results were found. Furthermore, the validity and reliability of the scoring tools for the six categories of the construction management practices were checked, and the tools were found to be valid and reliable. This implies that the six scoring tools can be separately used to measure, plan and control the practices. For instance, a project's materials management practices score can be computed in isolation, and its relationship with productivity can be investigated. The baseline score to assess a project's construction management practices is found to be 22.75. Thus, a project with overall construction management practices score exceeding 22.75 can be considered as a high-score and the associated productivity could also be high. When projects are assessed based on the scores of the six categories of the management practices, projects with scores exceeding: 2.4 for construction materials management practices, 0.93 for construction equipment management practices, 4.84 for management practices related to construction methods, 4.52 for preconstruction phase management practice, 4.39 for human resource management practices, and 5.23 for safety and health practices can be considered as high score projects and their productivity would also be high.

Correlation analyses between 47 construction management practices and productivity were conducted, and the findings revealed that all the practices are positively associated with productivity in multi-storey building projects. The correlation analyses among the construction management practices show that the practices are positively correlated. The relationships among company profiles, project characteristics and the construction management practices were also investigated, and the findings indicate that project cost is positively and strongly associated with the practices. Project delay and construction management practices are negatively correlated. The associations among the aggregated construction management practices (47 practices) and company size, annual turnover and company experience are statistically insignificant. However, company size is positively associated with ‘construction equipment management practices,’ ’human resource management practices,’ and ‘safety and health practices’, and the relationships are statistically significant. Company experience and the safety and health practices are positively correlated, and the association is statistically significant. In next chapter, the productivity prediction models based on the levels of implementations of the management practices are developed and validated.

CHAPTER EIGHT

8 REGRESSION MODELS OF CONSTRUCTION MANAGEMENT PRACTICES AND PRODUCTIVITY

8.1 Introduction

This chapter presents the analysis conducted to achieve the third objective of the thesis which is ‘to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices.’ In Section 8.2, the logistic regression models which relate the overall or the 47 construction management practices and productivity are developed. Moreover, the logistic regression models relating each of the six categories of the construction management practices and productivity are built. The linear regression models of productivity and the construction management practices are also presented in Section 8.2. In Section 8.3, the logistic and linear regression models are validated. Finally, the summary of the chapter is provided in Section 8.4.

8.2 Building the Regression Models

Two approaches have been used to develop the regression models of the construction management practices and productivity. In the first approach, logistic regression analyses are conducted to build logistic regression models which are used to predict the probability of exceeding the baseline productivity factor. In this approach, based on a project’s score of the construction management practices, the productivity factor of the particular project is estimated with respect to the baseline productivity factor. In the second approach, linear regression analysis is carried out to develop a linear regression model for predicting the productivity factor of a project based on the project’s score of the construction management practices.

8.2.1 Logistic Regression Models of the Construction Management Practices and Productivity

Before conducting the logistic regression analysis, the 39 data points are divided into two: model building datasets and validation dataset. Three-fold and 4-fold cross-validation techniques were used as they are less biased than sample splitting method (Abou-Assaleh et al., 2004). To determine the baseline productivity factor (PF) or the cut-off PF which is used to transform projects' productivity factor into binary equivalent, the 3 measures of central tendency (mean, mode and median) as well as the skewness of the PF data were computed using SPSS 24. Accordingly, the mean PF = 0.95, mode PF = 1.00, median PF = 1.00, skewness = -0.893, standard error = 0.378, and $Z = | (-0.893/0.378) | = 2.36$ were found. The mean value is the best measure of central tendency if the data is not highly skewed, and the median is the preferred value if the data is skewed (Lurd and Lurd, 2013). According to Kim (2013), if *Z-score* for skewness is greater than 1.96, the distribution of the sample is not considered as normal. Thus, the median value of 1.00 is used as a cut-off PF value since the *Z value* = 2.36 is greater than the allowable *Z value* of 1.96.

The rule of thumb for the sample size of the logistic regression analysis states that the number of Events Per Variable should be greater than 10 (Peduzzi et al., 1996). Some authors argue that the minimum of 10 events per predictor is conservative (Bowerman and Murphree, 2014). In this research, the number of positive events refers to the number of projects with productivity factors greater than the baseline PF, and there is one predictor (construction management practices). The Events Per Variables (EPV's) are computed using median PF = 1.00, median PF + (5% × median PF) =1.05, median PF - (5% × median PF) = 0.95, median PF - (10% × median PF) = 0.90, and median PF - (15% × median PF) = 0.85 as baseline productivity factors. Accordingly, using median PF as a baseline value, EPV=21>10; using (median PF) + (5% × median PF) as a cut-off value, EPV=12>10; using (median PF) – (5% × median PF) as a baseline, EPV=23>10; using (median PF) – (10% × median PF) as a cut-off value, EPV=26>10; and using (median PF) – (15% × median PF) as a baseline EPV=31>10 are obtained. Therefore, the data is suitable to run the logistic regression analysis.

As shown in Table 8-1, 15 alternative models using 3-fold cross validation and 20 alternative models using 4-fold cross validation technique were developed, and the best model of the 47 construction management practices and productivity is selected. The raw data used in the analyses are indicated in Appendix-5A7. In the 3-fold cross validation, among the 15 models, four models with better predictive accuracy and statistically significant coefficients are chosen. The first model has the predictive accuracy of 88.5% and *p-value* of 0.03, and it is coded A. The second model with predictive accuracy of 84.6% and *p-value* of 0.01 is coded B. The third model having the predictive accuracy of 84.6% and *p-value* of 0.03 is coded C. The fourth model with predictive accuracy of 73.1% and *p-value* of 0.01 is coded D.

Table 8-1 Selection of the Logistic Regression Model of the Overall Construction Management Practices and Productivity

Alternative Models Using 3-fold Cross Validation				
		Predictive Accuracy and Significance of the Models		
		Trial-1	*Trial-2*	*Trial-3*
Baseline Productivity Factors (PFs)		Validation Dataset^{11} Model Building Dataset^{21} Model Building Dataset^{31}	Model Building Dataset ^{12} Validation Dataset ^{22} Model Building Dataset ^{32}	Model Building Dataset ^{13} Model Building Dataset ^{23} Validation Dataset ^{33}
Cut-off PF$_1$=0.85	Predictive Accuracy (%)	**84.63 (B)**	80.8	76.9
	Significance of β	**0.03**	0.25	0.36
Cut-off PF$_2$=0.90	Predictive Accuracy (%)	**84.62 (C)**	69.2	61.5
	Significance of β	**0.01**	0.48	0.35
Cut-off PF$_3$=0.95	Predictive Accuracy (%)	**73.14 (D)**	65.4	69.2
	Significance of β	**0.01**	0.22	0.19
Cut-off PF$_4$=1.00	Predictive Accuracy (%)	**69.2**	65.4	65.4
	Significance of β	**0.01**	0.07	0.05
Cut-off PF$_5$=1.05	Predictive Accuracy (%)	**88.51 (A)**	76.9	73.1
	Significance of β	**0.03**	0.15	0.06

Alternative Models Using 4-fold Cross Validation					
		Predictive Accuracy and Significance of the Models			
		Trial-4	*Trial-5*	*Trial-6*	*Trial-7*
Baseline Productivity Factors (PFs)		Validation Dataset^{14} Model Building Dataset^{24} Model Building Dataset^{34} Model Building Dataset^{44}	Model Building Dataset^{15} Validation Dataset^{25} Model Building Dataset^{35} Model Building Dataset^{45}	Model Building Dataset^{16} Model Building Dataset^{26} Validation Dataset^{36} Model Building Dataset^{46}	Model Building Dataset^{17} Model Building Dataset^{27} Model Building Dataset^{37} Validation Dataset^{47}
Cut-off PF1=0.85	Predictive Accuracy (%)	**82.85 (E)**	89.7	75.9	80
	Significance of β	**0.04**	0.12	0.14	0.4
Cut-off PF2=0.90	Predictive Accuracy (%)	**75.97 (G)**	79.3	69	70
	Significance of β	**0.01**	0.21	0.12	0.4
Cut-off PF3=0.95	Predictive Accuracy (%)	69	72.4	65.5	66.7
	Significance of β	0.02	0.12	0.06	0.21
Cut-off PF4=1.00	Predictive Accuracy (%)	65.5	69	65.5	66.7
	Significance of β	0.02	0.04	0.02	0.06
Cut-off PF5=1.05	Predictive Accuracy (%)	**79.36 (F)**	65.5	82.8	66.7
	Significance of β	**0.04**	0.06	0.05	0.06

Note: A, B, C and D are codes for good models in 3-fold cross validation; 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation; E ,F, and G are codes for good models in 4-fold cross-validation; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation.

Comparison of the Selected Models										
Model's code	*Overall accuracy*	*Model AUC*	*Sig. of Model's AUC*	*Coefficient (β)*	*Sig. of β*	*Constant (β_o)*	*Sig of β_o*	*Cut-off PF*	*Validation AUC*	*Model Building dataset codes*
A	88.51%	0.95	<0.01	0.28	0.03	-7.24	0.02	1.05	0.54	21+31
C	**84.62%**	**0.8**	**0.02**	**0.41**	**0.01**	**-7.65**	**0.02**	**0.90**	**0.73**	**21+31**
B	84.63%	0.88	0.03	0.34	0.03	-4.87	0.08	0.85	0.5	21+31
E	82.85%	0.87	0.04	0.23	0.04	-3.49	0.13	0.85	0.56	24+34+44
F	79.36%	0.86	0.01	0.26	0.04	-7.01	0.03	1.05	0.64	24+34+44
G	75.97%	0.75	0.04	0.28	0.01	-5.52	0.03	0.90	0.81	24+34+44
D	73.14%	0.78	0.02	0.30	0.01	-6.02	0.02	1.00	0.73	21+31

In the 4-fold cross validation, among 20 alternative models, 3 models with better predictive accuracy and statistically significant coefficients are selected. The model having a predictive accuracy of 82.8% and *p-value* of 0.04 is coded E; the model with the predictive accuracy of 79.3% and *p-value* of 0.04 is coded F; and the model having a predictive accuracy of 75.9% and *p-value* of 0.01 is coded G. The seven models (A, B, C, D, E, F, and G) are then compared among themselves to choose the best logistic regression model (Table 8-1). The criteria for selection include predictive accuracy, Area Under the Curve (AUC) and significance of the coefficients.

Model-A has the highest predictive accuracy (88.5%) but its validation dataset's AUC (0.54) is close to the rejection value (0.50), and it is not chosen as the best model (Table 8-1). Model-B also has a low AUC (0.50) of the validation dataset, and it cannot be the best model. Model-E has insignificant constant (p=0.13>0.05). Model-F (79.36%), Model-G (75.97%), and Model-D (73.14%) have low predictive accuracy as compared to Model-C (Table 8-1). Thus, Model-C is selected as the best model since it has a better predictive accuracy (84.6%); its variable's coefficient is significant (p=0.01<0.05); the model's constant is significant (p=0.02<0.05); and its AUC is acceptable (0.80>0.5). Therefore, the data sets coded 21 and 31 were used in model building; dataset coded 11 was used as a validation dataset (refer Appendix-5A7 for the raw data); and PF=0.90 was used as a baseline PF. The results of the logistic regression analysis of the best model (Model-C) are presented in Table 8-2.

As indicated in Table 8-2, in Block-0 of the logistic regression analysis, the true negative percentage is 0.0%, the true positive percentage is 100.0%, and overall model accuracy is 69.2%. These imply that all projects with productivity factor (PF) greater than 0.90 are correctly predicted, and no project with PF less than 0.90 is correctly predicted. The variable in the equation is insignificant (p=0.06>0.05) and the variable not in the equation is significant (p<0.001) which implies that the model in Block-1 is better than the model in Block-0. In Block-1, the Chi-square (12.53) of the Omnibus test is statistically significant at 5% level of significance (p<0.001) which shows that the model in Block-1 is better than the null model (model in Block-0). The significance value of Chi-square (5.21) of Hosmer and Lemeshow test of goodness is greater than the acceptable *p-value* (p=0.63>0.05) and the null hypothesis of the test which states 'the construction management practices and productivity model is good in fitting the data' is accepted. Therefore, the model in Block-1 is good.

Table 8-2 Outputs of the Logistic Regression Analysis of the Overall Construction Management Practices

Block-0

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 0	PF	0	0	8	0
		1	0	18	100
	Overall Percentage				69.2

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	0.811	0.425	3.642	1	0.056	2.25

Variables not in the Equation

		Score	df	Sig.
Step 0	Con Mgt Practices	10.55	1	0.001
	Overall Statistics	10.55	1	0.001

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	12.525	1	0
	Block	12.525	1	0
	Model	12.525	1	0

Hosmer and Lemeshow Test

	Chi-square	df	Sig.
Step 1	5.21	7	0.634

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 1	PF	0	6	2	75
		1	2	16	88.9
	Overall Percentage				84.6

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	Con Mgt. Practices	0.407	0.158	6.601	1	0.01	1.502
	Constant	-7.654	3.218	5.657	1	0.017	0

Bootstrapping

Bootstrap

		B	Bias	SE	Sig.	95% Confidence Interval Lower	95% Confidence Interval Upper
Step 1	Con Mgt. Practices	0.407	1.535	8.302	0.005	0.225	21.136
	Constant	-7.654	-26.78	140.98	0.007	-382.19	-3.737

The overall prediction accuracy of the model in Block-1 is 84.6% which is better than the null model's predictive accuracy (69.2%).The true negative prediction accuracy of the model is 75.0%, and the true positive prediction accuracy is 88.9% (Table 8-2). Wald Chi-square (6.60) for the variable in the equation is statistically significant at 5% level of significance (p=0.01<0.05). Similarly, the Wald Chi-square (5.66) for the constant is statistically significant (p=0.02<0.05).The Exp(B) for the variable 'construction management practices' is 1.5 which indicates that for one unit increase in the score of the construction management practices (the variable), the odd of exceeding the productivity factor of 0.90 increases by a factor of 1.5.

To test the reliability of the logistic regression model of the overall or the 47 construction management practices and productivity, bootstrapping using 1000 samples are conducted using SPSS-24, and the results are shown in Table 8-2. Accordingly, the coefficient (0.41) and constant (-7.65) in the bootstrapping are found to be similar to the model's coefficient and constant. The *p-values* of both the variable (*p*=0.005) and constant (*p*=0.007) in bootstrapping are statistically significant. Therefore, the construction management practices and productivity model is reliable.

By using the coefficients indicated in Table 8-2, the model's equation is constructed as follows.

$$\mathbf{Log(Odds)=Logit(P_i)=Ln\left(\frac{P_i}{1\text{-}P_i}\right)=0.41CMP_i\text{-}7.65}$$

Where Pi=probability of exceeding PF=0.90 of an i^{th} project, and CMP_i = the overall score of the construction management practices for an i^{th} project. To compute the probabilities easily, the above equation is simplified as indicated in Equation 8-1.

$$\mathbf{P_i=\frac{e^{0.41CMP_i-7.65}}{1+e^{0.41CMP_i-7.65}}} \qquad \text{Equation 8-1}$$

The results of the logistic regression analysis of the six categories of the construction management practices are explained in the following subsections.

Logistic Regression Model of Construction Materials Management Practices and Productivity

Fifteen alternative logistic regression models of the six construction materials management practices and productivity are developed using 3-fold cross-validation technique, and the results are presented in Table 8-3. Accordingly, the model that has the highest predictive accuracy of 88.5% and statistically significant coefficient of *p*=0.03<0.05 is chosen and coded H (Table 8-3). Among the 20 alternative models developed using 4-fold cross-validation technique, two models with the highest predictive accuracy are selected. The first model (coded I) has the predictive accuracy of 89.7% and a *p-value* of 0.03 < 0.05; and the second model (coded J) has the predictive accuracy of 82.8%, and the coefficient of the independent variable (β) is statistically significant at 5% level of significance (*p*=0.02 <0.05).

Table 8-3 Selection of the Logistic Regression Model of the Construction Materials Management Practices and Productivity

Alternative Models Using 3-fold Cross Validation

Baseline Productivity Factors (PFs)		*Trial-1*	*Trial-2*	*Trial-3*
		Predictive Accuracy and Significance of the Models		
		Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
		Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
		Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
Cut-off PF_1=0.85	Predictive Accuracy (%)	80.8	80.8	76.9
	Significance of β	0.19	0.34	0.24
Cut-off PF_2=0.90	Predictive Accuracy (%)	73.1	65.4	65.4
	Significance of β	0.04	0.57	0.46
Cut-off PF_3=0.95	Predictive Accuracy (%)	57.7	69.2	57.7
	Significance of β	0.07	0.35	0.21
Cut-off PF_4=1.00	Predictive Accuracy (%)	57.7	61.5	61.5
	Significance of β	0.09	0.16	0.08
Cut-off PF_5=1.05	Predictive Accuracy (%)	**88.5 (H)**	80.8	73.1
	Significance of β	**0.03**	0.16	0.04

Alternative Models Using 4-fold Cross Validation

Baseline Productivity Factors (PFs)		*Trial-4*	*Trial-5*	*Trial-6*	*Trial-7*
		Predictive Accuracy and Significance of the Models			
		Validation Dataset^{14}	Model Building	Model Building	Model Building Dataset^{17}
		Model Building Dataset^{24}	Validation Dataset^{25}	Model Building	Model Building Dataset^{27}
		Model Building Dataset^{34}	Model Building	Validation Dataset^{36}	Model Building Dataset^{37}
		Model Building Dataset^{44}	Model Building	Model Building	Validation Dataset^{47}
Cut-off PF1=0.85	Predictive Accuracy (%)	79.3	86.2	72.4	80
	Significance of β	0.08	0.58	0.24	0.24
Cut-off PF2=0.90	Predictive Accuracy (%)	72.4	75.9	55.2	70
	Significance of β	0.03	0.62	0.27	0.48
Cut-off PF3=0.95	Predictive Accuracy (%)	62.1	65.5	65.5	63.3
	Significance of β	0.04	0.33	0.12	0.29
Cut-off PF4=1.00	Predictive Accuracy (%)	58.6	55.2	65.5	60
	Significance of β	0.06	0.15	0.06	0.12
Cut-off PF5=1.05	Predictive Accuracy (%)	**82.83 (J)**	69	**89.71 (I)**	66.7
	Significance of β	**0.02**	0.09	**0.03**	0.06

Note: H is code for a good model in 3-fold cross validation; 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation; I, and J are codes for good models in 4-fold cross-validation; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation.

Comparison of the Selected Models

Model's code	*Overall accuracy*	*Model AUC*	*Sig. of Model's AUC*	*Coefficient (β)*	*Sig. of β*	*Constant (β_o)*	*Sig of β_o*	*Cut-off PF*	*Model Building dataset codes*
I	**89.70%**	**0.84**	**0.03**	**1.81**	**0.03**	**-6.46**	**0.01**	**1.05**	**16+26+46**
H	88.50%	0.91	<0.01	1.58	0.03	-4.56	0.01	1.05	21+31
J	82.80%	0.95	0.04	1.52	0.02	-4.62	0.01	1.05	24+34+44

The 3 selected models (H, I and J) are compared based on the statistical significance of their coefficients, their AUCs, and their predictive accuracy (Table 8-3). All the 3 models have AUC > 0.5; their AUCs are statistically significant; the variables' coefficients are statistically significant at 5% level of significance; and the constants of the 3 models are also statistically significant. However, the model coded I is selected as it has the best predictive accuracy (89.7%). The data sets coded 16, 26 and 46 are used in model building, the data set coded 46 is used to validate the model, and PF=1.05 is used as a cut-off productivity factor (refer Appendix-5A1 for the raw data).

The results of the logistic regression analysis of the selected model (Model-I) are shown in Table 8-4. In Block-0, the true negative percentage of 100.0%, the true positive percentage of 0.0%, and overall model accuracy of 82.8% are found. These imply that all projects with productivity factors (PFs) less than 1.05 are correctly predicted, and no project with PF greater than1.05 is correctly predicted. The variable in the equation (-1.57) is significant (*p*=0.001<0.05) and the variable not in the equation (7.03) is also significant (*p*=0.01<0.05).

Table 8-4 Outputs of the Logistic Regression Analysis of the Construction Materials Management Practices

Block-0

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 0	PF	0	24	0	100
		1	5	0	0
	Overall Percentage				82.8

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	-1.569	0.492	10.182	1	0.001	0.208

Variables not in the Equation

		Score	df	Sig.
Step 0	Con. Mate. Management Practices	7.032	1	0.008
	Overall Statistics	7.032	1	0.008

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	7.342	1	0.007
	Block	7.342	1	0.007
	Model	7.342	1	0.007

Hosmer and Lemeshow Test

	Chi-square	df	Sig.
Step 1	7.125	7	0.416

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 1	PF	0	23	1	95.8
		1	2	3	60
	Overall Percentage				89.7

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	Con. Mat. Management Practices	1.808	0.806	5.037	1	0.025	6.099
	Constant	-6.461	2.484	6.764	1	0.009	0.002

Bootstrapping

		B	Bootstrap Bias	Bootstrap SE	Bootstrap Sig.
Step 1	Con. Mat. Management Practices	1.808	25.397	106.28	0.021
	Constant	-6.461	-91.58	390.47	0.016

In Block-1, the Chi-square (7.34) of the Omnibus test is statistically significant at 5% level of significance (*p*=0.01<0.05) which shows that the model is better than the null model (Block-0). The Hosmer and Lemeshow test shows *p*=0.42>0.05 which implies the model in Block-1 is good (Table 8-4). The overall prediction accuracy of the model is 89.7%, and the value is greater than the null model's prediction accuracy (82.8%). The true negative prediction accuracy of the model is 95.8%, and the true positive prediction accuracy is 60.0%. Wald Chi-square (5.04) for the variable in the equation is statistically significant at 5% level of significance (p=0.03<0.05). Similarly, the Wald Chi-square (6.76) for the constant is statistically significant (p=0.01<0.05). The Exp(B) for the variable (construction materials management practices) is 6.10 which indicates that for one unit increase in the score of the construction materials management practices, the odd of exceeding the productivity factor of 1.05 increases by a factor of 6.10. In Table 8-4, the results of bootstrapping of the construction materials management practices data by using 1000 samples are presented. Accordingly, the p-values of both the variable (p=0.021<0.05) and the constant (p=0.016<0.05) are found to be statistically significant. The coefficient and the constant obtained after bootstrapping is similar to the model's coefficient and constant. Therefore, the logistic regression model of the construction materials management practices and productivity is reliable.

Finally, by using the variable's coefficient and the constant indicated in Table 8-4, the equation for the construction materials management practices and productivity model is developed as shown in Equation 8-2.

$$\mathbf{Log(Odds)=Logit(P_i)=Ln\left(\frac{P_i}{1\text{-}P_i}\right)=1.81MMP_i\text{-}6.46}$$

In the equation, P_i is the probability of exceeding PF=1.05 for an i^{th} project, and MMP_i is the score of the construction materials management practices for an i^{th} project. The above equation can be simplified as follows:

$$\mathbf{P_i=\frac{e^{1.81MMP_i\text{-}6.46}}{1+e^{1.81MMP_i\text{-}6.46}}} \quad \text{Equation 8-2}$$

Logistic Regression Model of Construction Equipment Management Practices and Productivity

The results of the 35 alternative logistic regression models of the construction equipment management practices and productivity are presented in Table 8-5. Accordingly, the model developed using model building datasets coded 21 and 31 and PF=0.90 as a baseline productivity factor is chosen among the 15 alternative models built using 3-fold cross-validation technique (refer Appendix-5 A3 for the datasets). The predictive accuracy of the model is 76.9%, and coefficient of the variable (*β*) is statistically significant (p=0.04<0.05). Among the 20 models developed using 4-fold cross-validation technique, only two construction equipment management practices and productivity models are statistically significant; however, they have lower prediction accuracy (62.1% and 60%) as compared to prediction accuracy of the model chosen in 3-fold cross-validation. Therefore, the model with a predictive accuracy of 76.91% and a p-value of 0.04 is chosen as the best model, and the results of the logistic regression analysis are presented in Table 8-6.

Table 8-5 Selection of the Logistic Regression Model of the Construction Equipment Management Practices and Productivity

Alternative Models Using 3-fold Cross Validation				
		Predictive Accuracy and Significance of the Models		
		Trial-1	*Trial-2*	*Trial-3*
		Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
		Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
Baseline Productivity Factors (PFs)		Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
Cut-off	Predictive Accuracy (%)	80.8	80.8	76.9
PF$_1$=0.85	Significance of β	0.12	0.46	0.38
Cut-off	Predictive Accuracy (%)	**76.91**	65.4	65.4
PF$_2$=0.90	Significance of β	**0.04**	0.79	0.51
Cut-off	Predictive Accuracy (%)	73.1	61.5	57.7
PF$_3$=0.95	Significance of β	0.13	0.57	0.55
Cut-off	Predictive Accuracy (%)	61.5	65.4	61.5
PF$_4$=1.00	Significance of β	0.09	0.26	0.41
Cut-off	Predictive Accuracy (%)	61.5	76.9	65.4
PF$_5$=1.05	Significance of β	0.03	0.19	0.04

Alternative Models Using 4-fold Cross Validation					
		Predictive Accuracy and Significance of the Models			
		Trial-4	*Trial-5*	*Trial-6*	*Trial-7*
		Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
		Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
		Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
Baseline Productivity Factors (PFs)		Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
Cut-off	Predictive Accuracy (%)	79.3	86.2	72.4	80
PF1=0.85	Significance of β	0.12	0.3	0.38	0.45
Cut-off	Predictive Accuracy (%)	75.9	75.9	65.5	70
PF2=0.90	Significance of β	0.08	0.23	0.5	0.63
Cut-off	Predictive Accuracy (%)	69	69	62.1	60
PF3=0.95	Significance of β	0.21	0.27	0.37	0.7
Cut-off	Predictive Accuracy (%)	58.6	69	65.5	56.7
PF4=1.00	Significance of β	0.14	0.1	0.21	0.56
Cut-off	Predictive Accuracy (%)	**62.1**	58.6	82.8	**60**
PF5=1.05	Significance of β	**0.04**	0.05	0.07	**0.04**

Note: 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation.

As shown in Table 8-6, the results of Block-0 (model without independent variable) indicate the true negative percentage of 0%, the true positive proportion of 100% and overall accuracy is 69.20%. The true negative is the number of projects with observed PF less than the cut-off PF = 0.90 and predicted as 0 (less than cut-off PF), and true positive implies projects with PF greater than or equal cut-off PF and predicted as 1. No project is predicted as 0, but there are eight projects which should have been predicted as 0, and the percentage is 0/8=0% (Table 8-6). However, all projects with PF value of 1 are correctly predicted ((18/18) × 100% = 100%). The overall percentage is computed as (18/26) ×100% = 69.2%.

Table 8-6 Outputs of the Logistic Regression Analysis of the Construction Equipment Management Practices

Block-0

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 0	PF	0	0	8	0
		1	0	18	100
	Overall Percentage				69.2

Cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	0.81	0.43	3.64	1	0.06	2.25

Variables not in the Equation

		Score	df	Sig.
Step 0	Con. Eqt. Management Practices	4.82	1	0.03
	Overall Statistics	4.82	1	0.03

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	5.44	1	0.02
	Block	5.44	1	0.02
	Model	5.44	1	0.02

Hosmer and Lemeshow Test

	Chi-square	df	Sig.
Step 1	3.7	6	0.72

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 1	PF	0	3	5	37.5
		1	1	17	94.4
	Overall Percentage				76.9

Cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	Con. Eqt. Management Practices	2.29	1.15	3.98	1	0.04	9.9
	Constant	-0.98	0.93	1.12	1	0.03	0.38

Bootstrapping

		B	Bootstrap Bias	Bootstrap S.E	Bootstrap Sig.	Bootstrap 95% Lower	Bootstrap 95% Upper
Step 1	Con. Eqt. Management Practices	2.29	3.83	42.4	0.03	0.26	13.62
	Constant	-0.98	-2.1	23.91	0.03	-7.14	-1.08

In Block-1 or the analysis which considers an independent variable, the Chi-square (5.44) of the Omnibus test is statistically significant at 5% level of significance

(p=0.02<0.05) indicating that the model in Block-1 is better than the null model (model in Block-0). The *p-value* (0.72) of the Chi-square (3.7) in Hosmer and Lemeshow test of goodness is greater than 0.05 which indicates that the construction equipment management practices and productivity model is acceptable.

The overall prediction accuracy of the model is 76.9%, and it is better than the null model's predictive accuracy. The true negative prediction accuracy of the model is 37.5%, and the true positive prediction accuracy is 94.4%. Wald Chi-square (3.98) for the variable in the equation is statistically significant at 5% level of significance (p=0.04<0.05). The Exp(B) for the variable construction equipment practices is 9.9 which indicates that for a one-unit increase in the score of the construction equipment management practices, the odd of exceeding the productivity factor of 0.90 increases by a factor of 9.9. The results of the reliability test using 1000 samples show the coefficient of 2.29, constant = -0.98, and the *p-values* of the coefficient and the constant = 0.03 < 0.05 (Table 8-6). Thus, the model of construction equipment management practices and productivity is reliable.

By using the variable's coefficient and the constant indicated in Table 8-6, the model's equation is constructed as follows:

$$\mathbf{Log(Odds) = Logit(P_i) = Ln\left(\frac{P_i}{1\text{-}P_i}\right) = 2.29CEMP_i\text{-}0.98}$$

Where P_i=probability of exceeding PF=0.90 for an i^{th} project, and $CEMP_i$ = score of construction equipment management practice for an i^{th} project. For the sake of computing the probabilities easily, the above equation is simplified and represented by Equation 8-3.

$$\mathbf{P_i = \frac{e^{2.29CEMP_i-0.98}}{1+e^{2.29CEMP_i-0.98}}} \quad \text{Equation 8-3}$$

Logistic Regression Model of Management Practices Related to Construction Methods and Productivity

The results of the logistic regression analysis of productivity and the management practices related to construction methods are presented in Table 8-7. Accordingly, among the 15 models developed using the 3-fold cross-validation technique, 3 of them have higher predictive accuracy and statistically significant coefficients (p=0.01<0.05). The 3 models have a similar predictive accuracy of 80.8% and coded K, L, and M for further analysis. Model-K is developed by using the model building dataset coded 21 and 31 (Appendix-5 A4), and PF=0.90 as a baseline productivity factor. Model-L is built using similar datasets as Model-K but using PF=0.95 as the cut-off value. Model-M is also developed using similar datasets as Model-L but using PF=1.00 as baseline PF. Using the 4-fold cross validation technique, 3 models are found to have the higher predictive capacity (86.2%, 82.8%, and 80.0%). However, as the coefficients of the models are not statistically significant (p=0.2>0.05, p=0.07>0.05, and p=0.53>0.05 respectively), the models are not selected as good models. The other 17 models in the 4-fold cross-validation analysis have lower predictive accuracy as compared to the models selected using 3-fold cross-validation technique (Table 8-7). Finally, Model-K is considered as the best model since the ROCs for Model-L and Model-M cannot be drawn, or the models are not suitable for prediction purpose.

Table 8-7 Selection of the Logistic Regression Model of the Management Practices Related to Construction Methods and Productivity

Alternative Models Using 3-fold Cross Validation				
		Predictive Accuracy and Significance of the Models		
		Trial-1	*Trial-2*	*Trial-3*
		Validation Dataset^{11}	Model Building Dataset	Model Building Dataset ^{13}
		Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
Baseline Productivity Factors (PFs)		Model Building Dataset^{31}	Model Building Dataset	Validation Dataset ^{33}
Cut-off	Predictive Accuracy (%)	80.8	80.8	76.9
PF$_1$=0.85	Significance of β	0.037	0.346	0.518
Cut-off	Predictive Accuracy (%)	**80.80** (K)	65.4	65.4
PF$_2$=0.90	Significance of β	**0.014**	0.505	0.348
Cut-off	Predictive Accuracy (%)	**80.80** (L)	69.2	69.2
PF$_3$=0.95	Significance of β	**0.011**	0.225	0.216
Cut-off	Predictive Accuracy (%)	**80.80**(M)	76.9	73.1
PF$_4$=1.00	Significance of β	**0.01**	0.038	0.052
Cut-off	Predictive Accuracy (%)	76.9	76.9	61.5
PF$_5$=1.05	Significance of β	0.067	0.215	0.208

Alternative Models Using 4-fold Cross Validation					
		Predictive Accuracy and Significance of the Models			
		Trial-4	*Trial-5*	*Trial-6*	*Trial-7*
		Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
		Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
		Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
Baseline Productivity Factors (PFs)		Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
Cut-off	Predictive Accuracy (%)	79.3	**86.2**	72.4	**80**
PF1=0.85	Significance of β	0.06	**0.2**	0.16	**0.53**
Cut-off	Predictive Accuracy (%)	72.4	75.9	65.5	70
PF2=0.90	Significance of β	0.02	0.48	0.1	0.37
Cut-off	Predictive Accuracy (%)	75.9	65.5	69	70
PF3=0.95	Significance of β	0.01	0.23	0.07	0.15
Cut-off	Predictive Accuracy (%)	75.9	75.9	75.9	73.3
PF4=1.00	Significance of β	0.01	0.04	0.01	0.04
Cut-off	Predictive Accuracy (%)	75.9	69	**82.8**	60
PF5=1.05	Significance of β	0.12	0.18	**0.07**	0.23

Note: K, L and M are codes of good models in 3-fold cross validation; 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation.

The results of the logistic regression analysis of the selected model (Model-K) are shown in Table 8-8. In Block-0, the true negative percentage = 0.0%, the true positive percentage = 100.0%, and overall model accuracy = 69.2%. These indicate that all projects with productivity factors (PFs) greater than 0.90 are correctly predicted, and no project with PF less than 0.90 is correctly predicted. The variable in the equation (p=0.06>0.05) is insignificant, and the variable not in the equation is statistically significant (p=0.01<0.05). This shows that the model in Block 1 is better than the model in Block 0.

Table 8-8 Outputs of the Logistic Regression Analysis of Management Practices Related to Construction Methods

Block-0

Classification Table

	Observed		Predicted		
			PF		Percentage Correct
			0	1	
Step 0	PF	0	0	8	0
		1	0	18	100
	Overall Percentage				69.2

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	0.811	0.425	3.642	1	0.056	2.25

Variables not in the Equation

		Score	df	Sig.
Step 0	Mgt. Practices Related to Con. Methods	9.093	1	0.003
	Overall Statistics	9.093	1	0.003

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	10.34	1	0.001
	Block	10.34	1	0.001
	Model	10.34	1	0.001

Hosmer and Lemeshow Test

	Chi-square	df	Sig.
Step 1	3.626	7	0.822

Classification Table

	Observed		Predicted		
			PF		Percentage Correct
			0	1	
Step 1	PF	0	5	3	62.5
		1	2	16	88.9
	Overall Percentage				80.8

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	Mgt. Practices Related to Con. Methods	1.513	0.616	6.033	1	0.014	4.542
	Constant	-5.791	2.639	4.816	1	0.028	0.003

Bootstrapping

		Bootstrap Based on 1000 Samples			
		B	Bias	SE	Sig.
Step 1	Mgt. Practices Related to Con. Methods	1.513	4.514	47.685	0.002
	Constant	-5.791	-17.98	185.33	0.002

As indicated in Table 8-8, in Block-1, the Chi-square (10.34) of the Omnibus test is statistically significant ($p=0.001<0.05$), and the *p-value* of the Chi-square (3.63) in Hosmer and Lemeshow test of goodness is greater than 5% ($p=0.82>0.05$). Thus, the model in Block-1 is acceptable. The overall prediction accuracy (80.8%) of the model in Block-1 is greater than the prediction accuracy (69.2%) of the model in Block-0. The true negative prediction accuracy of the model is 62.5%, and the true positive prediction accuracy is 88.9%. Wald Chi-square (6.03) for the variable in the equation is statistically significant ($p=0.01<0.05$). Similarly, the Wald Chi-square (4.82) for the constant is statistically significant ($p=0.03<0.05$). The Exp(B) for the variable 'management practices related to construction methods' is 4.54 which indicates that for a unit increase in the score of the management practices related to construction methods, the odd of exceeding the productivity factor of 0.90 increases by a factor of 4.82.

The results of bootstrapping of the management practices related to construction methods' data by using 1000 samples are presented in Table 8-8. The p-values of both the variable and the constant are found to be statistically significant ($p=0.002<0.05$). Therefore, the logistic regression model of the management practices related to construction methods and productivity is reliable. Finally, by using the variable's coefficient and the constant, the model's equation is constructed as follows:

$$\mathbf{Log(Odds) = Logit(P_i) = Ln\left(\frac{P_i}{1\text{-}P_i}\right) = 1.51MPRCM_i\text{-}5.79}$$

P_i = probability of exceeding PF=0.90 for an ith project, and $MPRCM_i$ = score of management practices related to construction methods for an ith project. The above equation can be simplified as:

$$\mathbf{P_i=\frac{e^{1.51MPRCM_i\text{-}5.79}}{1+e^{1.51MPRCM_i\text{-}5.79}}} \quad \text{Equation 8-4}$$

Logistic Regression Model of Pre-Construction Phase Management Practices and Productivity

In Table 8-9, 35 alternative pre-construction phase management practices and productivity models are presented. Accordingly, using the 3-fold cross-validation analysis, two models with better overall prediction accuracy and statistically significant coefficients are chosen. The model with a predictive accuracy of 76.9% is coded N, and the model with a predictive accuracy of 73.1% is coded O for comparison with models developed using 4-fold cross-validation technique. Using the 4-fold cross validation technique, four models with better predictive accuracy are selected. The first model has a predictive accuracy of 86.2% and coded P; the second model having the predictive accuracy of 75.9% is coded Q; the third model with the predictive accuracy of 72.4% and a *p-value* of 0.02 is coded R, and the fourth model having the predictive accuracy of 72.4% and a p-value of 0.04 is coded S (Table 8-9).

Table 8-9 Selection of the Logistic Regression Model of the Pre-Construction Phase Management Practices and Productivity

Alternative Models Using 3-fold Cross Validation				
		Predictive Accuracy and Significance of the Models		
		Trial-1	*Trial-2*	*Trial-3*
Baseline Productivity Factors (PFs)		Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
		Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
		Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
Cut-off PF$_1$=0.85	Predictive Accuracy	80.8	80.8	76.9
	Significance of β	0.06	0.27	0.35
Cut-off PF$_2$=0.90	Predictive Accuracy	**76.9** (N)	69.2	65.4
	Significance of β	**0.02**	0.46	0.17
Cut-off PF$_3$=0.95	Predictive Accuracy	69.2	61.5	69.2
	Significance of β	0.04	0.36	0.14
Cut-off PF$_4$=1.00	Predictive Accuracy	**73.1** (O)	61.5	73.1
	Significance of β	**0.03**	0.1	0.05
Cut-off PF$_5$=1.05	Predictive Accuracy	84.6	80.8	76.9
	Significance of β	0.06	0.16	0.08

Alternative Models Using 4-fold Cross Validation					
		Predictive Accuracy and Significance of the Models			
		Trial-4	*Trial-5*	*Trial-6*	*Trial-7*
Baseline Productivity Factors (PFs)		Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
		Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
		Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
		Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
Cut-off PF1=0.85	Predictive Accuracy	82.8	89.7	72.4	80
	Significance of β	0.12	0.11	0.14	0.45
Cut-off PF2=0.90	Predictive Accuracy	**75.9** (Q)	79.3	69	**70**
	Significance of β	**0.03**	0.21	0.07	**0.25**
Cut-off PF3=0.95	Predictive Accuracy	65.5	65.5	65.5	56.7
	Significance of β	0.06	0.23	0.06	0.21
Cut-off PF4=1.00	Predictive Accuracy	**72.4** (S)	75.9	**72.4** (R)	**66.7**
	Significance of β	**0.04**	0.07	**0.02**	**0.09**
Cut-off PF5=1.05	Predictive Accuracy	79.3	69	**86.2** (P)	73.3
	Significance of β	0.09	0.1	**0.03**	0.13

Note: N and O are codes for good models in 3-fold cross validation; 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation (Appendix-5 A4); Q, R, S and T are codes for good models in 4-fold cross-validation ; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation (Appendix-5 A4).

Comparison of the Selected Models

Model's code	*Overall accuracy*	*Sig. of Model's AUC*	*Coefficient (β)*	*Sig. of β*	*Constant (β_o)*	*Sig of β_o*	*Cut-off PF*	*Model's dataset code*	*Validation dataset code*
P	86.20%	0.13	1.7	0.03	-10.3	0.02	1.05	16+26+46	36
N	76.90%	0.2	1.03	0.02	-3.3	0.06	0.9	21+31	11
Q	75.90%	0.09	0.75	0.03	-2.53	0.1	0.9	24+34+44	14
O	73.10%	0.05	0.86	0.03	-3.32	0.05	1	21+31	11
R	**72.40%**	**0.02**	**1.1**	**0.02**	**-5.26**	**0.02**	**1**	**16+26+46**	**36**
S	72.40%	0.08	0.71	0.04	-2.88	0.07	1	24+34+44	14

The six good models (N, O, P, Q, R, and S) which are identified using 3-fold and 4-fold cross validation techniques are compared among each other to choose the best model of the pre-construction phase management practices and productivity. The Receiver Operating Characteristic (ROC) curves for the six models are drawn, and the Area Under the Curves (AUCs) are computed (Table 8-9). Furthermore, the statistical significance of the models' constants and AUCs are considered in the comparisons.

As shown in Table 8-9, Model-P has a better predictive accuracy (86.2%), but its AUC is insignificant (*p*=0.13>0.05). Thus, it was not chosen as the best model. Model-N, Model-Q, Model-O, and Model-S have insignificant p-values for both AUC and β_o-values. Hence, Model-R is chosen for further analysis as it has significant values for AUC, β, and β_o (Table 8-9). Thus, the cut-off PF is 1.00, the datasets coded as 16, 26, and 46 are used in logistic regression analysis and dataset coded 36 is kept for validation purpose (refer Appendix-5 A4 for the raw data). The results of the selected model (Model-R) are provided in Table 8-10.

In Table 8-10, the results of the logistic regression analysis of productivity and pre-construction phase management practices in Block-0 are presented. Accordingly, the true negative percentage is 100%, the true positive percentage is 0.0%, and overall model accuracy is 55.2%. These imply that all projects with productivity factor less than 1.00 are correctly predicted, and no project with PF greater than 1.00 is correctly predicted. The variable in the equation is insignificant (*p*=0.58>0.05), and the variable not in the equation is significant (*p*=0.01<0.05) which indicates that the model in Block-1 is better than the model in Block-0.

In Block-1, the Chi-square (9.33) of the Omnibus test is statistically significant at 5% level of significance (*p*=0.002<0.05) which shows that the model is better than the null model (Block-0). The significance value of the Chi-square (9.78) of Hosmer and Lemeshow test of goodness is greater than rejection percentage of the null hypothesis (p=0.28>0.05), and the null hypothesis which states the model is good in fitting the data is accepted. Thus, the model in Block-1 is good.

The overall prediction accuracy of the model is 72.4% which is better than the null model's predictive accuracy (55.2%). The true negative prediction accuracy of the model is 75.0%, and the true positive prediction accuracy is 69.2%. Wald Chi-square (5.82) for the variable in the equation is statistically significant (*p*=0.02<0.05). Similarly, the Wald Chi-square (5.77) for the constant is statistically significant (*p*=0.02<0.05). The Exp(B) for the variable pre-construction phase management practices is 3.0 which indicates that for a one-unit increase in the score of the pre-construction phase management practices, the odd of exceeding the productivity factor of 1.00 increases by a factor of 3.0.

Table 8-10 Outputs of the Logistic Regression Analysis of the Pre-Construction Phase Management Practices

Block-0

Classification Table

Observed			Predicted PF 0	Predicted PF 1	Percentage Correct
Step 0	PF	0	16	0	100
		1	13	0	0
	Overall Percentage				55.2

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	-0.208	0.373	0.309	1	0.578	0.813

Variables not in the Equation

		Score	df	Sig.
Step 0	Pre-Con. Phase Management Practices	7.848	1	0.005
	Overall Statistics	7.848	1	0.005

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	9.336	1	0.002
	Block	9.336	1	0.002
	Model	9.336	1	0.002

	Chi-square	df	Sig.
Step 1	9.78	8	0.281

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 1	PF	0	12	4	75
		1	4	9	69.2
	Overall Percentage				72.4

Cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	Pre-Con. Phase Management Practices	1.1	0.456	5.817	1	0.016	3.005
	Constant	-5.255	2.188	5.768	1	0.016	0.005

Bootstrapping

		B	Bootstrap Bias	Bootstrap SE	Bootstrap Sig.	95% Confidence Interval Lower	95% Confidence Interval Upper
Step 1	Pre-Con. Phase Management	1.1	2.092	60.761	0.005	0.47	2.772
	Constant	-5.255	-9.421	274.06	0.003	-12.51	-2.508

Bootstrapping to rest the reliability of the pre-construction phase management practices and productivity model is conducted, and the results are presented in Table 8-10. Accordingly, the coefficient of the model (1.10) is found to be statistically significant (p=0.005<0.05). Similarly, the constant (-5.26) is also found to be statistically significant (p=0.003<0.05) which implies that the model is reliable. By using the coefficient and the constant, the model's equation is constructed as follows.

$$\mathbf{Log(Odds) = Logit(P_i) = Ln\left(\frac{P_i}{1\text{-}P_i}\right) = 1.10PCPMP_i\text{-}5.26}$$

Where P_i = probability of exceeding PF=1.00 of an ith project, and $PCPMP_i$ = a score of pre-construction phase management practices of an ith project. The above equation can be simplified as indicated in Equation 8-5.

$$\mathbf{P_i = \frac{e^{1.10PCPMP_i-5.26}}{1+e^{1.10PCPMP_i-5.26}}} \quad \text{Equation 8-5}$$

Logistic Regression Model of the Human Resource Management Practices and Productivity

The results of the logistic regression analysis of the human resource management practices and productivity using 3-fold and 4-fold cross-validation techniques are presented in Table 8-11. Accordingly, among 15 models in 3-fold cross-validation, five models are chosen based on their predictive accuracy and statistical significance. The model with highest predictive accuracy (code T) is obtained by analysing the datasets coded 21 and coded 31 and using cut-off PF value of 0.85. The second model (code U) is developed using the same datasets as Model-T but using PF=0.90 as the cut-off value. The third model (coded V), fourth model (coded W) and fifth model (coded X) are built using similar datasets as that of Model-T but using cut-off PF values of 0.95, 1.0 and 1.05 respectively.

The 20 models developed using 4-fold cross-validation are also shown in Table 8-11. Among them, the model which is statistically significant and having the better predictive capacity (72.4%) is chosen and coded Y. Finally, six models (coded T, U, V, W, X and Y) are compared to select the best HRM practices and productivity model. To choose the best model among the six models, the ROC is drawn, and the Area under Curve (AUC) for each model is computed using SPSS-24.

Model-T has the highest predictive capacity (84.6%) and AUC (0.96), but its constant is insignificant (p=0.18>0.05). Thus, Model-T cannot be the best model. Model-U has good predictive capacity (80.8%); its coefficient of the independent variable (β) is statistically significant (p=0.02<0.05); its AUC is greater than 0.5; and its p-values of both the variable and constant are statistically significant (Table 8-11). Model-V, Model-W, and Model-X have low prediction accuracy as compared to Model-U's prediction accuracy; as a result, they cannot be best models.

Table 8-11 Selection of the Logistic Regression Model of the Human Resource Management Practices and Productivity

Alternative Models Using 3-fold Cross Validation

Baseline Productivity Factors (PFs)		*Predictive Accuracy and Significance of the Models*		
		Trial-1	*Trial-2*	*Trial-3*
		Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
		Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
		Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
Cut-off PF$_1$=0.85	Predictive Accuracy (%)	**84.6** (T)	80.8	76.9
	Significance of β	**0.04**	0.25	0.89
Cut-off PF$_2$=0.90	Predictive Accuracy (%)	**80.8** (U)	65.4	65.4
	Significance of β	**0.02**	0.55	0.87
Cut-off PF$_3$=0.95	Predictive Accuracy (%)	**76.9** (V)	61.5	53.8
	Significance of β	**0.02**	0.23	0.67
Cut-off PF$_4$=1.00	Predictive Accuracy (%)	**73.1** (W)	61.5	61.5
	Significance of β	**0.03**	0.12	0.24
Cut-off PF$_5$=1.05	Predictive Accuracy (%)	**73.1** (X)	76.9	76.9
	Significance of β	**0.04**	0.25	0.17

Alternative Models Using 4-fold Cross Validation

Baseline Productivity Factors (PFs)		*Predictive Accuracy and Significance of the Models*			
		Trial-4	*Trial-5*	*Trial-6*	*Trial-7*
		Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
		Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
		Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
		Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
Cut-off PF1=0.85	Predictive Accuracy (%)	86.2	89.7	72.4	80
	Significance of β	0.07	0.09	0.31	0.86
Cut-off PF2=0.90	Predictive Accuracy (%)	**72.4** (Y)	79.3	58.6	70
	Significance of β	**0.03**	0.2	0.35	0.83
Cut-off PF3=0.95	Predictive Accuracy (%)	69	69	69	56.7
	Significance of β	0.03	0.09	0.17	0.55
Cut-off PF4=1.00	Predictive Accuracy (%)	65.5	69	58.6	70
	Significance of β	0.04	0.04	0.08	0.18
Cut-off PF5=1.05	Predictive Accuracy (%)	75.9	58.6	82.8	60
	Significance of β	0.06	0.1	0.17	0.13

Note: T, U, V, W and X are codes for good models developed using 3-fold cross validation; 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation (Appendix-5 A5); Y is code for good model in 4-fold cross-validation ; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation (Appendix-5 A5).

Comparison of the Selected Models

Model's code	*Overall accuracy*	*Model AUC*	*Sig. of Model's AUC*	*Coefficient (β)*	*Sig. of β*	*Constant (β_o)*	*Sig of β_o*	*Cut-off PF*	*Model Building dataset code*	*Validation dataset*
T	84.60%	0.96	0.001	0.99	0.04	-2.657	0.18	0.85	21+31	11(3-fold)
U	**80.80%**	**0.9**	**0.001**	**1.5**	**0.02**	**-5.677**	**0.04**	**0.9**	**21+31**	**11(3-fold)**
V	76.90%	0.84	0.002	1.34	0.02	-5.616	0.03	0.95	21+31	11(3-fold)
W	73.10%	0.83	0.003	0.92	0.03	-5.06	0.03	1	21+31	11(3-fold)
X	73.10%	0.83	0.013	1.12	0.04	-4.745	0.04	1.05	21+31	11(3-fold)
Y	72.40%	0.66	0.18	0.95	0.03	-3.611	0.07	0.9	24+34+44	14(4-fold)

Model-Y has insignificant constant and AUC. Therefore, Model-U is selected as the best model. The cut-off productivity factor (PF) of 0.90 and the datasets coded as 21, 31 are used in logistic regression analysis, and the dataset coded 11 is used for validation purpose. The results of the logistic regression analysis of the selected model (Model-U) are provided in Table 8-12.

Table 8-12 Outputs of the Logistic Regression Analysis of the Human Resource Management Practices

Block-0

Classification Table

			Predicted		
			PF		Percentage Correct
Observed			0	1	
Step 0	PF	0	0	8	0
		1	0	18	100
	Overall Percentage				69.2

The cut value = 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	0.811	0.425	3.642	1	0.056	2.25

Variables not in the Equation

		Score	df	Sig.
Step 0	HRM Practices	9.353	1	0.002
	Overall Statistics	9.353	1	0.002

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	11.21	1	0.001
	Block	11.21	1	0.001
	Model	11.21	1	0.001

Hosmer and Lemeshow Test

	Chi-square	df	Sig.
Step 1	3.278	7	0.858

Classification Table

			Predicted		
			PF		Percentage Correct
	Observed		0	1	
Step 1	PF	0	4	4	50
		1	1	17	94.4
	Overall Percentage				80.8

The cut value is 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	HRM Practices	1.504	0.656	5.256	1	0.022	4.5
	Constant	-5.677	2.817	4.062	1	0.044	0.003

Bootstrapping

		Bootstrap					
						95% Confidence Interval	
		B	Bias	SE	Sig.	Lower	Upper
Step 1	HRM Practices	1.504	1.676	18.708	0.006	0.779	5.982
	Constant	-5.677	-6.702	76.568	0.013	-21.42	-2.374

As shown in Table 8-12, in Block-0, the true negative percentage is 0%, the true positive percentage is 100%, and overall model accuracy is 69.2%. The variable in the equation is insignificant (p=0.06>0.05) and the variable not in the equation is significant (p=0.02<0.05). The variables not in the equation in Block-0 refer to the independent variable or HRM practices. Thus, the model which incorporates the independent variable or the model in Block-1 is more significant.

In Block-1, the Chi-square (11.2) of the Omnibus test is statistically significant at 5% level of significance (p=0.001<0.05) which shows that the model is better than the null model (model in Block-0). The p-value of the Chi-square (3.28) of Hosmer and Lemeshow test of goodness is greater than rejection percentage of the null hypothesis (p=0.86>0.05). Thus, the null hypothesis which states 'the HRM practices and productivity model' is good in fitting the data is accepted.

By using the coefficients presented in the Table 8-12, the equation for the logistic regression model of Productivity and HRM practices is constructed as follows.

$$\mathbf{Log(Odds) = Logit(P_i) = Ln\left(\frac{P_i}{1\text{-}P_i}\right) = 1.5HRMP_i\text{-}5.68}$$

P_i = probability of exceeding PF=0.9 for an ith project, and $HRMP_i$ = a score of HRM practices for an ith project. The above equation can be simplified as indicated in Equation 8-6.

$$\mathbf{P_i = \frac{e^{1.5HRMP_i\text{-}5.68}}{1+e^{1.5HRMP_i\text{-}5.68}}} \qquad \text{Equation 8-6}$$

The reliability test results for the HRM practices and productivity model is presented in Table 8-12. The coefficient (1.50) and the constant (-5.68) obtained after bootstrapping using 1000 sample were found to be similar to the model's coefficient (1.50) and constant (-5.68). Moreover, the bootstrapped coefficient and constant are found to be statistically significant (p=0.01<0.05). Therefore, the model is reliable.

Logistic Regression Model of Safety and Health Practices and Productivity

The 35 alternative logistic regression models of safety and health practices and productivity are shown in Table 8-13. Accordingly, using 3-fold cross-validation, two models with the predictive accuracy of 88.5% and 80.8% are selected, and they are coded AB and CD. The p-values of the two models' coefficients are statistically significant. Both models are obtained during the first trial in which the model building datasets coded 21 and 31 were used in model development, and the validation dataset coded 11 was kept for validation purpose (refer Appendix-5 A6 for the raw data and the respective codes). By using the 4-fold cross-validation technique, only one model is found to be statistically significant, and the model was coded EF for further analysis.

Table 8-13 Selection of the Logistic Regression Model of the Safety and Health Practices and Productivity

Alternative Models Using 3-fold Cross Validation

Baseline Productivity Factors (PFs)		*Predictive Accuracy and Significance of the Models*		
		Trial-1	*Trial-2*	*Trial-3*
		Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
		Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
		Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
Cut-off PF_1=0.85	Predictive Accuracy (%)	**88.5** (AB)	80.8	80.8
	Significance of β	**0.03**	0.47	0.13
Cut-off PF_2=0.90	Predictive Accuracy (%)	**80.8** (CD)	65.4	69.2
	Significance of β	**0.03**	0.54	0.24
Cut-off PF_3=0.95	Predictive Accuracy (%)	**73.1**	65.4	69.2
	Significance of β	**0.08**	0.28	0.15
Cut-off PF_4=1.00	Predictive Accuracy (%)	65.4	57.7	65.4
	Significance of β	0.14	0.29	0.09
Cut-off PF_5=1.05	Predictive Accuracy (%)	**65.4**	76.9	57.7
	Significance of β	**0.07**	0.22	0.08

Alternative Models Using 4-fold Cross Validation

Baseline Productivity Factors (PFs)		*Predictive Accuracy and Significance of the Models*			
		Trial-4	*Trial-5*	*Trial-6*	*Trial-7*
		Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
		Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
		Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
		Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
Cut-off PF1=0.85	Predictive Accuracy (%)	86.2	86.2	79.3	83.3
	Significance of β	0.05	0.12	0.04	0.13
Cut-off PF2=0.90	Predictive Accuracy (%)	75.9	79.3	62.1	73.3
	Significance of β	0.07	0.07	0.19	0.25
Cut-off PF3=0.95	Predictive Accuracy (%)	65.5	72.4	65.5	66.7
	Significance of β	0.17	0.08	0.08	0.22
Cut-off PF4=1.00	Predictive Accuracy (%)	62.1	69	58.6	66.7
	Significance of β	0.26	0.09	0.08	0.14
Cut-off PF5=1.05	Predictive Accuracy (%)	69	69.0 (EF)	82.8	66.7
	Significance of β	0.15	0.04	0.12	0.07

Note: AB, and CD are codes for good models in 3-fold cross validation; 11, 21, 31, 12, 22, 32, 13, 23, and 33 are codes for the datasets each with 13 elements in 3-fold cross validation (Appendix-5 A6); EF is code for good model in 4-fold cross-validation ; 14, 24, 34, 44, 15, 25, 35, 45, 16, 26, 36, 46, 17, 27, 37, 47 are codes for the groups of data each with 10 data points in 4-fold cross validation (Appendix-5 A6).

Comparison of the Selected Models

Model's code	*Overall accuracy*	*Model AUC*	*Sig. of Model's AUC*	*Variable's β*	*Sig. of β*	*Constant (β_o)*	*Sig of β_o*	*Cut-off PF*	*Model Building dataset code*	*Validation dataset* code
AB	88.50%	0.94	0.04	1.85	0.03	-8.071	0.07	0.85	21+31	11
CD	**80.80%**	**0.83**	**0.03**	**1.81**	**0.03**	**-8.787**	**0.04**	**0.9**	**21+31**	**11**
EF	69.00%	0.71	0.06	1.69	0.04	-9.843	0.04	1.05	15+35+45	25

Model-AB, Model-CD, and Model-EF are compared to choose the best safety and health and productivity model (Table 8-13). Model-AB has the highest overall predictive accuracy (88.5%), acceptable AUC (0.94>0.5), and statistically significant p-value (p = 0.03 < 0.05) for the variable (safety and health practices). However, the constant of the Model-AB is not statistically significant (p = 0.07 > 0.05); as a result, it is not selected as the best model. Model-CD has a better overall predictive accuracy (80.8%), acceptable AUC (0.83>0.5), statistically significant p-values for the independent variable (p = 0.03< 0.05) and constant (p = 0.04 < 0.05). Model-EF has insignificant AUC (p = 0.06>0.05) and lowest overall predictive accuracy as compared to Model-CD. Therefore, Model-CD is chosen as the best safety and health practices and productivity model. The results of the analysis for the selected model are presented in Table 8-14.

Table 8-14 Outputs of the Logistic Regression Analysis of Safety and Health Practices

Block-0

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 0	PF	0	0	8	0
		1	0	18	100
	Overall Percentage				69.2

The cut value is 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig	Exp(B)
Step 0	Constant	0.811	0.425	3.642	1	0.056	2.25

Variables not in the Equation

		Score	df	Sig.
Step 0	Safety and Health Practices	7.459	1	0.006
	Overall Statistics	7.459	1	0.006

Block-1

Omnibus Test for Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	7.966	1	0.005
	Block	7.966	1	0.005
	Model	7.966	1	0.005

Hosmer and Lemeshow Test

	Chi-square	df	Sig.
Step 1	7.192	6	0.303

Classification Table

	Observed		Predicted PF 0	Predicted PF 1	Percentage Correct
Step 1	PF	0	4	4	50
		1	1	17	94.4
	Overall Percentage				80.8

The cut value is 0.50

Variables in the Equation

		B	S. E	Wald	df	Sig.	Exp(B)
Step 1	Safety and Health Practices	1.813	0.817	4.921	1	0.027	6.126
	Constant	-8.787	4.342	4.096	1	0.043	0

Bootstrapping

		B	Bootstrap Bias	Bootstrap SE	Bootstrap Sig.	95% Confidence Interval Lower	95% Confidence Interval Upper
Step 1	Safety and Health Practices	1.813	1.813	17.73	0.005	0.709	5.041
	Constant	-8.787	-9.62	81.61	0.006	-25.24	-3.047

As shown in Table 8-14, the results of the logistic regression analysis in Block-0 show the true negative percentage of 0%, the true positive percentage of 100%, and overall model accuracy of 69.2%. The variable in the equation is insignificant (p=0.06>0.05) and the variable not in the equation is significant (p=0.02<0.05) which implies that the model in Block-1 is better. In Block-1, the Chi-square (7.97) of the Omnibus test is statistically significant at 5% level of significance (p=0.005<0.05) which shows that the model in Block-1 is better than the null model (the model in Block-0). Similarly, the *p*-

value (0.30) of the Chi-square (7.19) of Hosmer and Lemeshow test is greater than 5% which indicates that the model in Block-1 is good.

The overall prediction accuracy of the model in Block-1 is 80.8% which is better than the model in Block-0's prediction accuracy (69.2%). The true negative prediction accuracy of the model is 50.0%, and the true positive prediction accuracy is 94.4%. The Wald Chi-square (4.92) for the variable in the equation is statistically significant at 5% level of significance (p=0.03<0.05). The Wald Chi-square (4.10) for the constant is also statistically significant (p=0.04<0.05). The Exp(B) of the variable safety and health practices is 6.1 which implies that for a unit increase in the score of the safety and health practice, the odd of exceeding the productivity factor of 0.90 increases by a factor of 6.1.

By using the coefficients shown in the Table 8-14, the equation for safety and health practices and productivity model is constructed as follows. In the model, P_i is the probability of exceeding productivity factor of 0.9 for an i^{th} project, SHP_i refers to a score of safety and health practices for an i^{th} project, and Ln= natural logarithm.

$$\mathbf{Log(Odds)=Logit(P_i)=Ln\left(\frac{P_i}{1\text{-}P_i}\right)=1.81SHP_i\text{-}8.79}$$

or

$$\mathbf{P_i=\frac{e^{1.81SHP_i 8.79}}{1+e^{1.81SHP_i\text{-}8.79}}} \qquad \text{Equation 8-7}$$

In Table 8-14, the results of the test to check the reliability of the logistic regression model of the safety and health practices and productivity are presented. Accordingly, the coefficient of the independent variable (1.81) and the constant (-8.79) after bootstrapping using 1000 samples are found to be statistically significant at 1% level of significance. This indicates that the safety and health practices and productivity model is reliable.

8.2.2 Linear Regression Models of the Construction Management Practices and Productivity

To investigate the proportion of variance in the productivity factor explained by the construction management practices and to develop linear regression model of productivity and the construction management practices, bivariate linear regression analysis was conducted. Before running the analysis, the scatter plots of the productivity factors and the overall scores of the construction management practices were analysed (Figure 8-1). The graph indicates that the data can be represented by the linear model.

The 3-fold and 4-fold cross-validation techniques were used, and seven alternative linear regression models of the 47 construction management practices and productivity were developed (Table 8-15). The models are compared based on their p-values and coefficient of determination (R-squared). The raw data and the corresponding codes are shown in Appendix-5 A7. Model-a is selected as the best linear regression model of construction management practices and productivity since it has the highest R^2 and a statistically significant p-value.

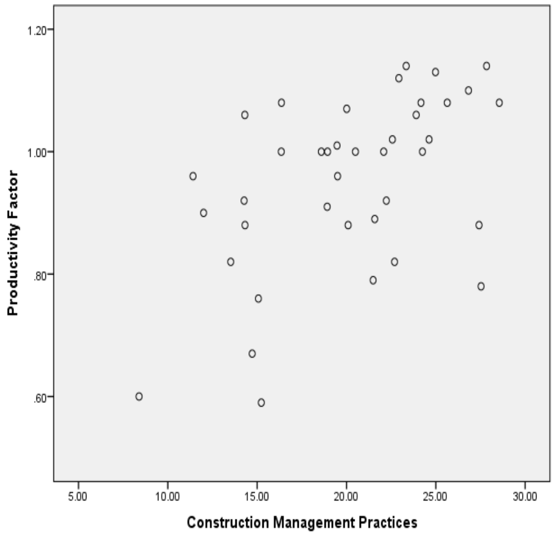


Figure 8-1 Scatter Plot of Productivity Factors and Construction Management Practices

Table 8-15 Alternative Linear Regression Models of Productivity and Construction Management Practices

	3-Fold Cross Validation			
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}	
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}	
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}	
	Model-a	*Model-b*	*Model-c*	
R^2	**0.479**	0.229	0.15	
P-value	**<0.001**	0.013	0.05	
B	**0.02**	0.014	0.01	
Bo	**0.575**	0.658	0.744	
	4-Fold Cross Validation			
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-e	*Model-f*	*Model-g*	*Model-h*
R^2	0.414	0.269	0.294	0.132
P-value	<0.001	0.004	0.002	0.048
B	0.017	0.014	0.014	0.009
Bo	0.561	0.644	0.607	0.751

The results of the linear regression analysis of the selected model (Model-a) are presented in Table 8-16. Accordingly, $R^2 = 0.479$ and a p-value less than 0.001 are found. The findings imply that there is a significant relationship between productivity and the management practices, and about 48% of the total variance in productivity factor can be explained by the management practices and the remaining variance could be explained by factors such as advance in technology and government regulations among others.

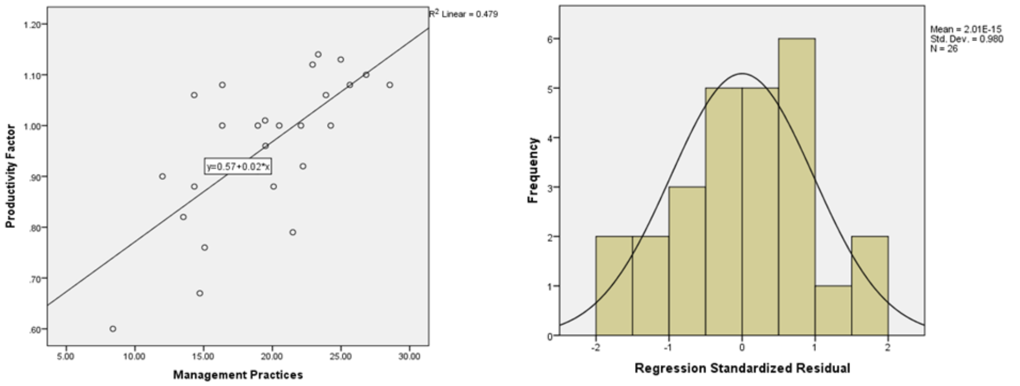
Table 8-16 Outputs of the Linear Regression Analysis of the Construction Management Practices

Model Summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.692	0.479	0.458	0.104

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.214	1	0.241	22.092	< 0.001
Residual	0.262	24	0.011		
Total	0.503	25			

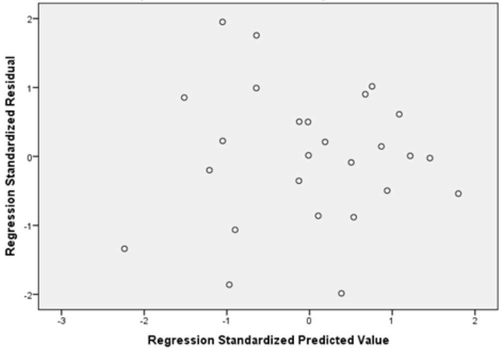
Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.575	0.084		6.812	< 0.001
Construction Management Practices	0.02	0.004	0.692	4.7	< 0.001

The residuals were analysed to check the assumptions of the linear regression model of productivity and the overall or the 47 construction management practices (Figure 8-2). The Durbin-Watson statistic of 1.92 is found, and the value is close to 2 indicating that the assumption of independence of errors has been met (Thomas and Sudhakumar, 2014). The histogram in Figure 8-2 shows the residuals are normally distributed. The plot of the standardised residuals and standardised predicted values indicates that the points are randomly distributed, and the assumption of homoscedasticity (equality of variances) is met. The scatter plot of the productivity factor and the construction management practices shows a linear relationship. Therefore, the assumption of linearity, independence of errors, homoscedasticity and normality of the errors are satisfied.



Scatter Plot of Productivity Factors and the 47 Construction Management Practices Scores

Histogram of the Residuals of the Linear Regression Model of the 47 Construction Management Practices and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the 47 Construction Management Practices and Productivity Model

Figure 8-2 Outputs of the Tests Conducted to Confirm the Assumptions of the Linear Regression Model of Productivity and the Overall Construction Management Practices

Finally, by using the coefficients indicated in Table 8-16, the equation for the linear regression model of the overall construction management practices and productivity is constructed as follows:

$$\mathbf{PF_i = 0.02CMP_i + 0.58}$$

Where PF_i refers to the productivity factor of an i^{th} project and CMP_i is the overall score of the 47 construction management practices for an i^{th} project.

Linear regression analyses were also conducted to develop the regression models of the six categories of the construction management practices, and the results are presented in the following subsections.

Linear Regression Model of Construction Materials Management Practices and Productivity

The results of the bivariate linear regression analysis conducted to choose the best construction materials management practices and productivity model are shown in

Table 8-17. Accordingly, Model-l is selected as the best model since it has the highest R-squared value and statistically significant coefficients.

Table 8-17 Alternative Linear Regression Models of Construction Materials Management Practices and Productivity

3-Fold Cross Validation				
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}	
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}	
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}	
	Model-i	*Model-j*	*Model-k*	
R^2	0.243	0.114	0.17	
P-value	0.01	0.091	0.04	
B (Cofficient)	0.088	0.059	0.061	
Bo (Constant)	0.749	0.795	0.811	
4-Fold Cross Validation				
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-l	*Model-m*	*Model-n*	*Model-o*
R^2	**0.262**	0.12	0.181	0.133
P-value	**0.01**	0.07	0.02	0.048
B (Cofficient)	**0.09**	0.059	0.072	0.054
Bo (Constant)	**0.741**	0.821	0.751	0.836

The results of the analysis carried out to develop Model-l are shown in Table 8-18. R^2 value of 0.262 and *p-value* of 0.01 < 0.05 are found. Thus, the model is significant. The finding indicates that about 26.2% of the variances in the productivity factor can be explained by construction materials management practices and the remaining percentage could be explained by other management practices and technology among others.

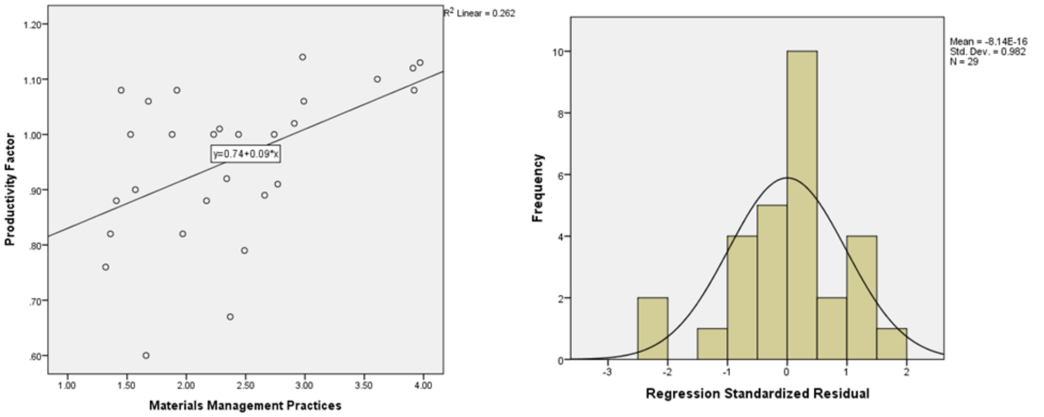
Table 8-18 Outputs of the Linear Regression Analysis of the Construction Materials Management Practices

Model Summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.512	0.262	0.235	0.12

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.139	1	0.139	9.594	0.005
Residual	0.391	27	0.014		
Total	0.53	28			

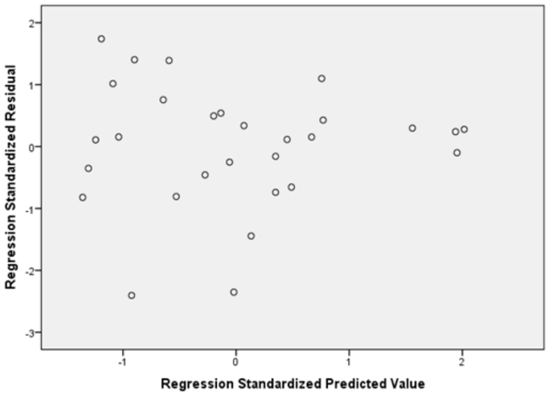
Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.741	0.073		10.201	< 0.001
Construction Materials Management Practices	0.09	0.029	0.512	3.097	0.005

The scatter plot of productivity factor and the construction materials management practices, and the results of the residuals analyses are indicated in Figure 8-3. The Durbin-Watson statistic of 2.08 is obtained indicating that the errors are independent. The residuals are approximately normally distributed (Figure 8-3). The plot of the standardised residuals and standardised predicted value shows that the errors are randomly distributed, and the assumption of homoscedasticity is satisfied.



Scatter Plot of Productivity Factors and Construction Materials Management Practices Scores

Histogram of the Residuals of the Linear Regression Model of the Construction Materials Management Practices and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the Construction Materials Management Practices and Productivity Model

Figure 8-3 Outputs of the Tests Conducted to Check the Assumptions of the Linear Regression Model of Productivity and Construction Materials Management Practices

Based on the outputs presented in Table 8-18, the linear regression model of productivity and construction materials management practices can be represented by the following equation.

$$\mathbf{PF_i = 0.09CMMP_i + 0.74}$$

PF_i = the productivity factor of an i^{th} project and $CMMP_i$ = a score of the construction materials management practices for an i^{th} project.

Linear Regression Model of Construction Equipment Management Practices and Productivity

In Table 8-19, the results of the linear regression analysis carried out to choose the most appropriate linear regression model of construction equipment management practices and productivity are presented. The model with the highest coefficient of determination (0.234) is chosen (Model-q), and the results of the analysis made to develop the model are shown in Table 8-20.

Table 8-19 Alternative Linear Regression Models of Construction Equipment Management Practices and Productivity

3-Fold Cross Validation				
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}	
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}	
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}	
	Model-q	*Model-r*	*Model-s*	
R^2	**0.234**	0.123	0.104	
P-value	**0.012**	0.08	0.11	
Bo (Constant)	**0.844**	0.815	0.875	
B (Cofficient)	**0.13**	0.132	0.085	
4-Fold Cross Validation				
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-t	*Model-u*	*Model-v*	*Model-w*
R^2	0.198	0.183	0.122	0.077
P-value	0.016	0.02	0.063	0.138
Bo (Constant)	0.845	0.826	0.825	0.896
B (Cofficient)	0.121	0.139	0.111	0.073

As shown in Table 8-20, the R^2 of the selected model is 0.234 which indicates that construction equipment management practices can explain about 23.4% of the variances in productivity factor. The coefficient and constant of the model have *p-values* of 0.012 and < 0.001 respectively indicating that the model is significant.

Table 8-20 Outputs of the Linear Regression Analysis of the Construction Equipment Management Practices

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.692	0.234	0.202	0.127

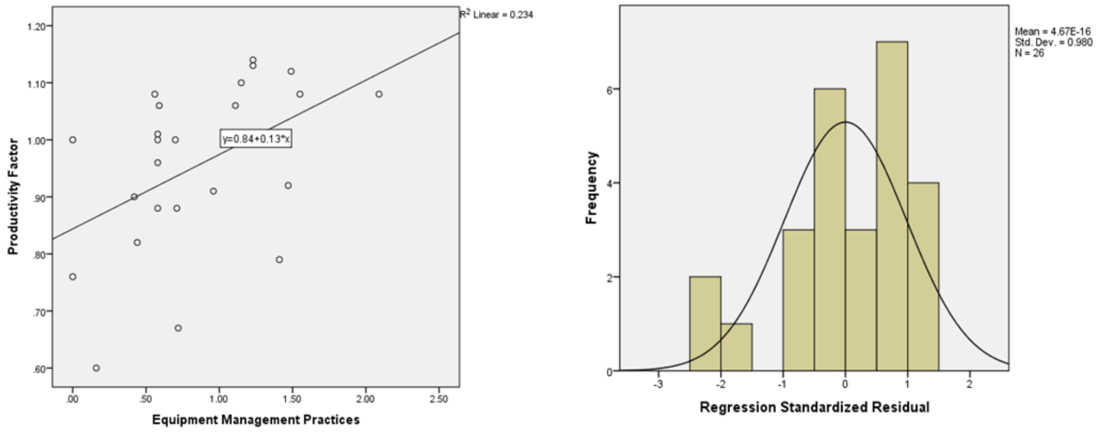
ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.117	1	0.117	7.314	0.012
Residual	0.385	24	0.016		
Total	0.503	25			

Coefficients

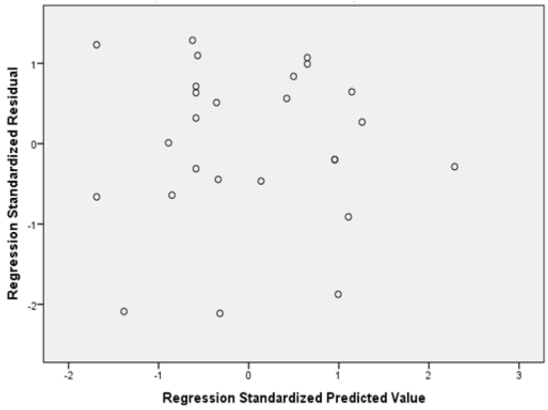
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.844	0.049		17.052	< 0.001
Construction Equipment Management Practices	0.13	0.048	0.483	2.704	0.012

The Durbin-Watson statistic is found to be 2.09, and the value is close to 2 indicating that the errors are not auto-correlated. The histogram of the residuals of the construction equipment management practices and productivity model is approximately normally distributed (Figure 8-4). The scatterplot of residuals and predicted values indicates that the variances of the errors are homogeneous. Therefore, the assumptions of the linear regression models are satisfied, and the model is acceptable.



Scatter Plot of Productivity Factors and Construction Equipment Management Practices Scores

Histogram of the Residuals of the Linear Regression Model of the Construction Equipment Management Practices and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the Construction Equipment Management Practices and Productivity Model

Figure 8-4 Outputs of the Tests Conducted to Analyse the Assumptions of the Linear Regression Model of Productivity and Construction Equipment Management Practices

Based on the results indicated in Table 8-20, the linear regression model of productivity and the construction equipment management practices is constructed as shown in the following equation.

$$\mathbf{PF_i = 0.13CEMP_i + 0.84}$$

In the equation PF_i = the productivity factor of an i^{th} project and $CEMP_i$ = a score of the construction equipment management practices for an i^{th} project.

Linear Regression Model of Management Practices Related to Construction Methods and Productivity

Among the seven alternative linear models developed using 3-fold and 4-fold cross validation techniques, the model coded ‘x’ is chosen as the most appropriate model as it has the highest R-squared (Table 8-21).

Table 8-21 Outputs of the Linear Regression Analysis of the Management Practices Related to Construction Methods

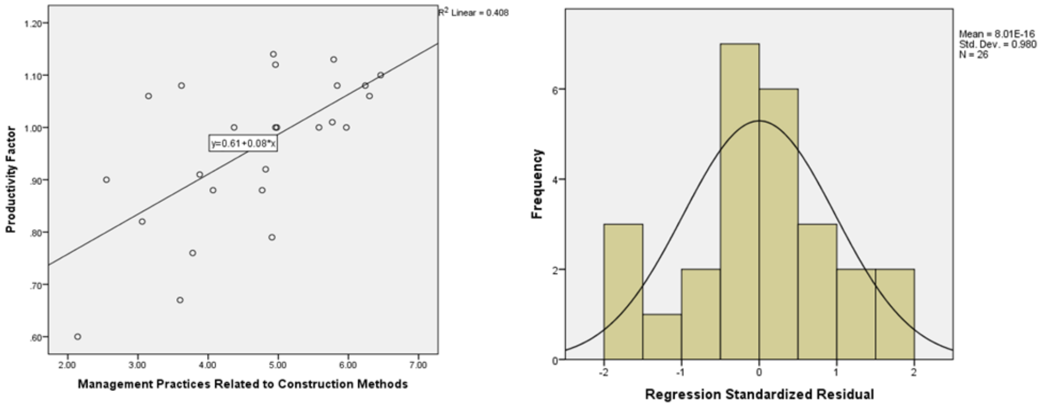
3-Fold Cross Validation				
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}	
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}	
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}	
	Model-x	*Model-y*	*Model-z*	
R^2	**0.408**	0.194	0.097	
P-value	**<0.001**	0.024	0.121	
Bo (Constant)	**0.605**	0.698	0.799	
B (Cofficient)	**0.076**	0.049	0.032	
4-Fold Cross Validation				
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-ab	*Model-cd*	*Model-ef*	*Model-gh*
R^2	0.346	0.175	0.26	0.09
P-value	0.001	0.024	0.005	0.108
Bo (Constant)	0.63	0.732	0.657	0.817
B (Cofficient)	0.069	0.048	0.055	0.03

The outputs of the analysis for the selected model (Model-x) is shown in Table 8-22. Accordingly, R^2 = 0.408 and p < 0.001 are found. The findings indicate that the model is significant and 40.8% of the variance in PF can be explained by management practices related to construction methods.

Table 8-22 Outputs of the Linear Regression Analysis of the Management Practices Related to Construction Methods

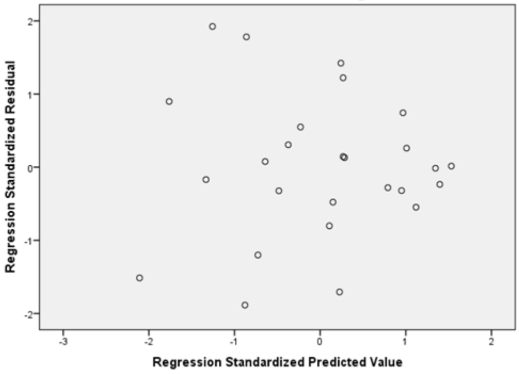
Model Summary					
R	R Square		Adjusted R Square		Std. Error of the Estimate
0.639	0.408		0.383		0.111
ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.205	1	0.205	16.533	<0.001
Residual	0.288	24	0.012		
Total	0.503	25			
Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.605	0.09		6.738	< 0.001
Management Practices Related to Construction Methods	0.076	0.019	0.639	4.066	< 0.001

The analysis of the residuals indicates the Durbin-Watson statistic of 2 which implies that the errors are independent. The histogram of the errors is approximately normally distributed (Figure 8-5). The scatter plot of the standardised residuals and predicted value shows that the assumption of the homoscedasticity is fulfilled since the points in the graph are randomly distributed (Figure 8-5).



Scatter Plot of Productivity Factors and Management Practices Related to Construction Methods Scores

Histogram of the Residuals of the Linear Regression Model of the Management Practices Related to Construction Methods and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the Management Practices Related to Construction Methods and Productivity Model

Figure 8-5 Outputs of the Tests Conducted to Verify the Assumptions of the Linear Regression Model of Productivity and the Management Practices Related to Construction Methods

The equation for the linear regression model of productivity and the management practices related to construction methods is constructed as follows.

$$\mathbf{PF_i = 0.08MPRCM_i + 0.61}$$

PF_i is the productivity factor of an i^{th} project, and $MPRCM_i$ represents a score of the management practices related to construction methods for an i^{th} project.

Linear Regression Model of Pre-Construction Phase Management Practices and Productivity

The results of the linear regression analysis of the preconstruction phase management practices conducted using the 3-fold and 4-fold cross-validation techniques are shown in Table 8-23. Model-kl in the 3-fold cross-validation has the highest R-squared, but the model’s constant (-2.16) is statistically insignificant (p=0.1>0.05), and it is not chosen as the best model. Model-ij is selected as the most appropriate model as it has the second highest R-squared (Table 8-23).

Table 8-23 Outputs of the Linear Regression Analysis of the Pre-Construction Phase Management Practices

3-Fold Cross Validation			
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
	Model-ij	*Model-kl*	*Model-mn*
R^2	**0.342**	0.43	0.156
P-value	**0.002**	<0.001	0.046
Bo (Constant)	**0.711**	-2.155	0.769
B (Cofficient)	**0.058**	1.147	0.039

4-Fold Cross Validation				
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-op	*Model-qr*	*Model-st*	*Model-uv*
R^2	0.273	0.232	0.305	0.109
P-value	0.004	0.08	0.002	0.075
Bo (Constant)	0.725	0.731	0.661	0.812
B (Cofficient)	0.053	0.052	0.058	0.033

The results of the detailed analysis of the Model-ij are presented in Table 8-24. Accordingly, R^2 value of 0.342 and *p-value* of $0.002 < 0.05$ are obtained. The findings show that the regression model is statistically significant and about 34.2% of the variance in productivity factor can be explained by the pre-construction phase management practices. The following equation can represent the model. In the equation, PF_i is the productivity factor of an i^{th} project, and $PCPM_i$ is a score of the pre-construction phase management practices for an i^{th} project.

$$\mathbf{PF_i = 0.06PCPM_i + 0.71}$$

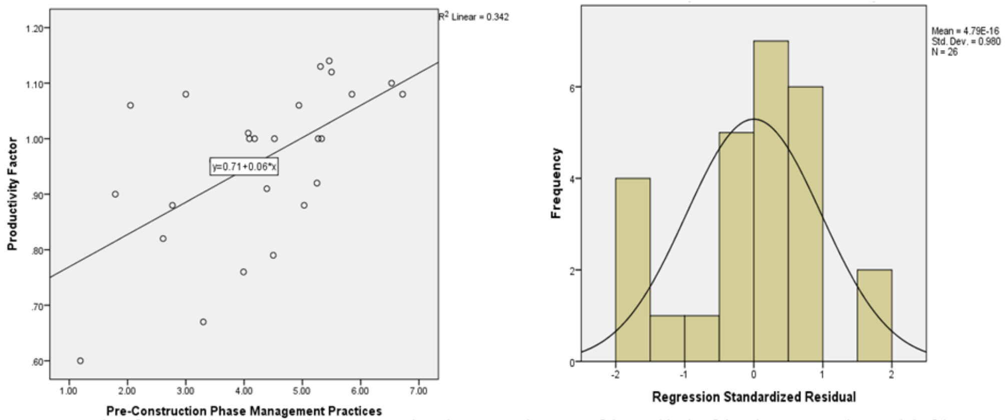
Table 8-24 Outputs of the Linear Regression Analysis of the Pre-Construction Phase Management Practices

Model Summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.585	0.342	0.314	0.117

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.172	1	0.172	12.454	0.002
Residual	0.331	24	0.012		
Total	0.503	25			

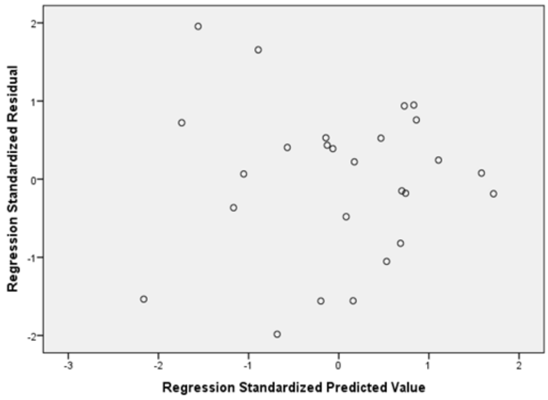
Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.711	0.074		9.598	< 0.001
Pre-Construction Phase Management Practices	0.058	0.016	0.585	3.529	0.002

The outputs of the test conducted to verify the assumption of the linear regression model of productivity and the pre-construction phase management practices are indicated in Figure 8-6. Accordingly, the assumptions of linearity of the data, as well as the normality, homoscedasticity and the independence of errors are satisfied (Figure 8-6). The residuals are normally distributed, and the residuals are not related to the predicted values. The Durbin-Watson statistic is found to be 2.1. The value is close to 2 indicating that the errors are not dependent.



Scatter Plot of Productivity Factors and Pre-Construction Phase Management Practices Scores

Histogram of the Residuals of the Linear Regression Model of the Pre-Construction Phase Management Practices and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the Construction Pre-Construction Phase Management Practices and Productivity Model

Figure 8-6 Outputs of the Tests Conducted to Confirm the Assumptions of the Linear Regression Model of Productivity and the Pre-Construction Phase Management Practices

Linear Regression Model of the Human Resource Management Practices and Productivity

In Table 8-25, the outputs of the analysis carried out to select the most suitable linear regression model of the human resource management practices and productivity are presented. Accordingly, Model-wx is chosen since it has the highest coefficient of determination and its coefficients are statistically significant (Table 8-25). The results of the analysis conducted to develop Model-wx are shown in Table 8-26.

Table 8-25 Outputs of the Linear Regression Analysis of the Human Resource Management Practices

3-Fold Cross Validation				
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}	
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}	
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}	
	Model-wx	*Model-yz*	*Model-ac*	
R^2	**0.48**	0.187	0.032	
P-value	**<0.001**	0.027	0.38	
Bo (Constant)	**0.642**	0.757	0.874	
B (Cofficient)	**0.069**	0.04	0.018	
4-Fold Cross Validation				
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-ad	*Model-ae*	*Model-af*	*Model-ah*
R^2	0.39	0.232	0.183	0.035
P-value	<0.001	0.008	0.021	0.32
Bo (Constant)	0.662	0.761	0.742	0.877
B (Cofficient)	0.063	0.044	0.04	0.019

As indicated in Table 8-26, the R^2 of the HRM practices and productivity model is 0.48; the constant has a *p-value* less than 0.001; and the coefficient also has a p-value less than 0. 001. The findings imply that the model is statistically significant and about 48% of the variance in the productivity factor can be explained by human resource management practices. The model's equation can be constructed as follows.

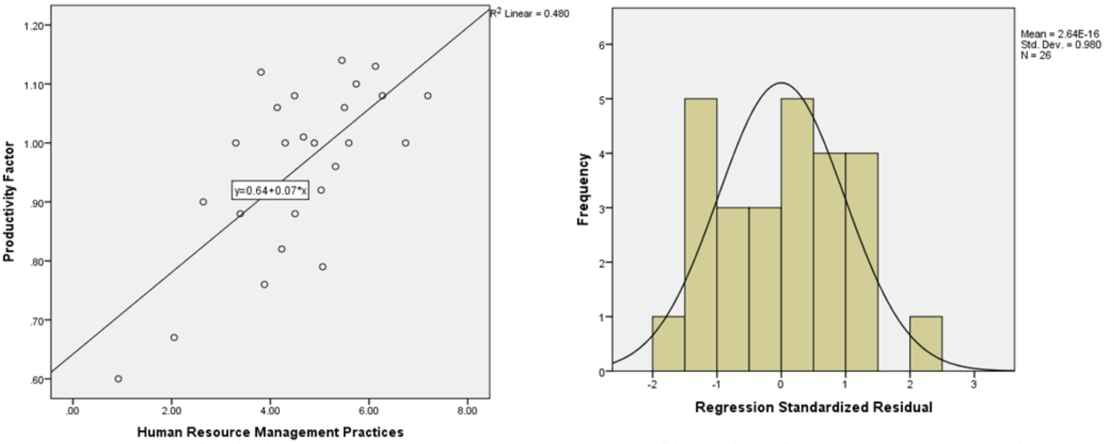
$$\mathbf{PF_i = 0.07HRMP_i + 0.64}$$

Where PF_i = the productivity factor of an ith project and $HRMP_i$ = a score of the human resource management practices for an ith project.

Table 8-26 Outputs of the Linear Regression Analysis of the Human Resource Management Practices

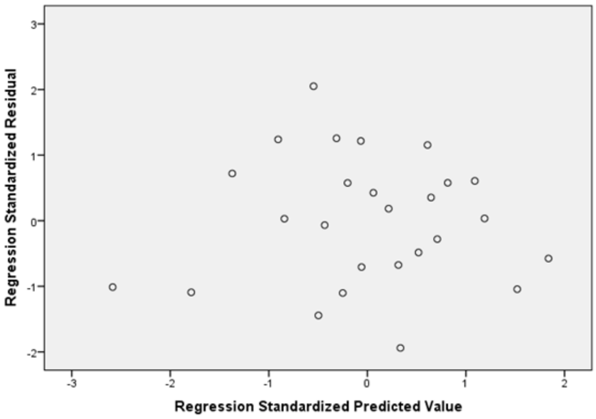
Model Summary					
R	R Square		Adjusted R Square		Std. Error of the Estimate
0.693	0.48		0.458		0.104
ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.241	1	0.241	22.145	<0.001
Residual	0.262	24	0.11		
Total	0.503	25			
Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.642	0.071		9.1	< 0.001
Human Resource Management Practices	0.069	0.015	0.693	4.706	< 0.001

The residuals of the model were analysed to check the assumptions of the linear regression analysis and the results are shown in Figure 8-7. The residuals are normally distributed. The Durbin-Watson statistic (1.75) is approximately close to 2 indicating that the errors are not auto-correlated. In the graph of the standardised residuals and standardised predicted values, the residuals are randomly scattered indicating that the assumptions of the homoscedasticity are satisfied.



Scatter Plot of Productivity Factors and Human Resource Management Practices Scores

Histogram of the Residuals of the Linear Regression Model of the Human Resource Management Practices and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the Human Resource Management Practices and Productivity Model

Figure 8-7 Outputs of the Tests Conducted to Verify the Assumptions of the Linear Regression Model of Productivity and the Human Resource Management Practices

Linear Regression Model of the Safety and Health Practices and Productivity

Seven alternative linear regression models of safety and health practices and productivity were developed before selecting the final model (Table 8-27). Model-am has the highest R^2, but the constant of the model is statistically insignificant (p=0.07>0.05) and it is not selected as the best model. Thus, the model with the second highest R-squared (Model-ai) is chosen. The outputs of the selected model are shown in Table 8-28. Accordingly, R^2 value of 0.268, *p-value* of the constant = 0.006 < 0.05, and the *p-value* of the coefficient = 0.007 < 0.05 are found. Thus, the model is significant. The proportion of variance in productivity factor explained by safety and health practices is 26.8%.

Table 8-27 Outputs of the Linear Regression Analysis of the Safety and Health Practices

3-Fold Cross Validation			
	Validation Dataset^{11}	Model Building Dataset ^{12}	Model Building Dataset ^{13}
	Model Building Dataset^{21}	Validation Dataset ^{22}	Model Building Dataset ^{23}
	Model Building Dataset^{31}	Model Building Dataset ^{32}	Validation Dataset ^{33}
	Model-ai	*Model-aj*	*Model-ak*
R^2	**0.268**	0.158	0.202
P-value	**0.007**	0.044	0.021
Bo (Constant)	**0.486**	0.508	0.574
B (Cofficient)	**0.088**	0.079	0.07

4-Fold Cross Validation				
	Validation Dataset^{14}	Model Building Dataset^{15}	Model Building Dataset^{16}	Model Building Dataset^{17}
	Model Building Dataset^{24}	Validation Dataset^{25}	Model Building Dataset^{26}	Model Building Dataset^{27}
	Model Building Dataset^{34}	Model Building Dataset^{35}	Validation Dataset^{36}	Model Building Dataset^{37}
	Model Building Dataset^{44}	Model Building Dataset^{45}	Model Building Dataset^{46}	Validation Dataset^{47}
	Model-al	*Model-am*	*Model-an*	*Model-ao*
R^2	0.187	0.276	0.201	0.17
P-value	0.019	0.003	0.015	0.024
Bo (Constant)	0.563	0.362	0.528	0.613
B (Cofficient)	0.072	0.111	0.073	0.064

Based on the constant and coefficient shown in Table 8-28, the linear regression model of safety and health practices and productivity can be expressed using the following equation. In the equation, PF_i stands for the productivity factor of an i^{th} project, and SHP_i is a score of the safety and health practices for an i^{th} project.

$$\mathbf{PF_i = 0.09SHP_i + 0.49}$$

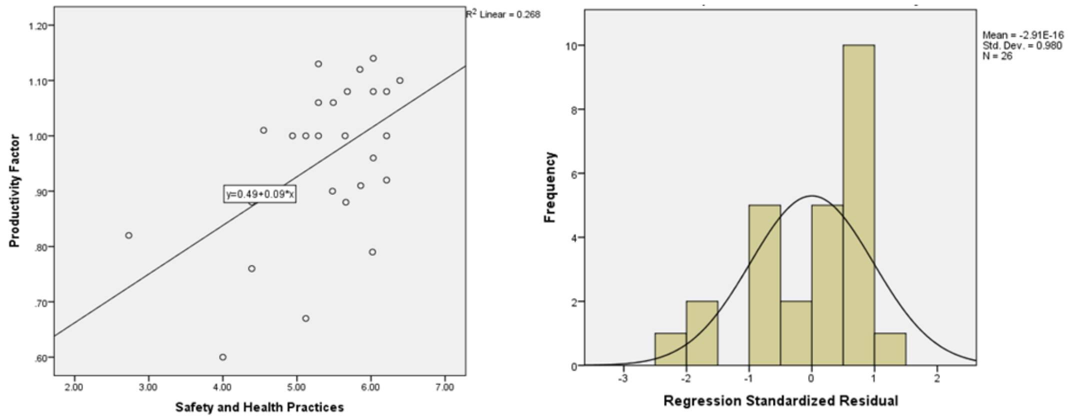
Table 8-28 Outputs of the Linear Regression Analysis of the Safety and Health Practices

Model Summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.517	0.268	0.237	0.124

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.135	1	0.135	8.773	0.007
Residual	0.368	24	0.015		
Total	0.503	25			

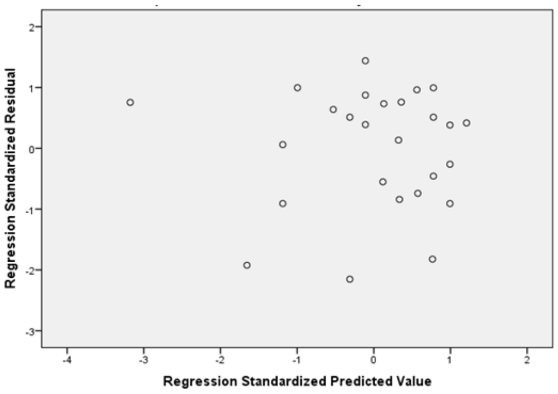
Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig
(Constant)	0.486	0.162		3.01	0.006
Safety and Health Practices	0.088	0.03	0.517	2.96	0.007

The Durbin-Watson statistic is found to be 2.2 which is close to two indicating that the errors are independent. The histogram of the residuals shows that the errors are approximately normally distributed (Figure 8-8). The scatter plot of the regression standardised residuals and regression standardised predicted value indicates that the errors are homogenous. Hence, the assumptions of the linear regression analysis are met.



Scatter Plot of Productivity Factors and Safety and Health Practices Scores

Histogram of the Residuals of the Linear Regression Model of the Safety and Health Practices and Productivity



Scatter Plot of the Standardized Residuals and the Standardized Predicted Values of the Safety and Health Practices Practices and Productivity Model

Figure 8-8 Outputs of the Tests Conducted to Confirm the Assumptions of the Linear Regression Model of Productivity and the Safety and Health Practices

8.3 Validating the Regression Models

8.3.1 Validation of the Logistic Regression Model of the Construction Management Practices and Productivity

To validate the logistic regression model of the overall construction management practices and productivity, probabilities of exceeding baseline productivity factor of 0.90 was predicted by using the validation dataset coded ‘11’ in Table 8-1 as inputs to the model, the Receiver Operating Characteristic (ROC) curve was plotted, and the Area under the Curve (AUC) was computed using SPSS-24. Figure 8-9 indicates the ROC curve and the diagonal line which is used as a reference line. The curve is above the reference line, and the AUC value of 0.73 which is greater than 0.5 is found. Thus, the model is valid. The minimum acceptable value of the AUC is 0.5, and the graph should be above the diagonal line (Hanley and McNeil, 1982).

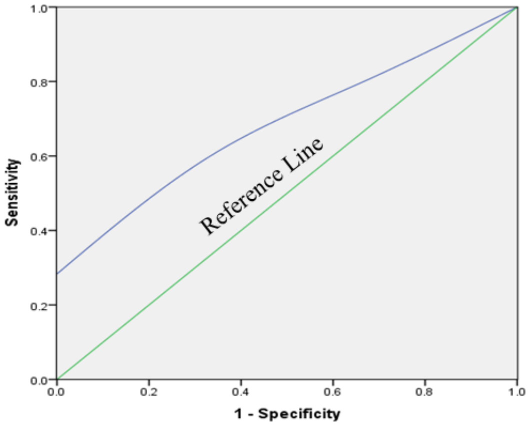


Figure 8-9 ROC Curve for Validating the Logistic Regression Model of the Overall Construction Management Practices and Productivity

By using the model's equation (Equation 8-1), probabilities are computed, and the sigmoid graph indicated in Figure 8-10 is drawn so that users can easily read probability that corresponds to an overall score of the construction management practices. Some parts of the data used in constructing the graph are indicated in Table 8-29.

Table 8-29 Predicted Probabilities Using Construction Management Practices and Productivity Model

B_0	-7.65									
B_1	0.41									
CMP Score	0	5	10	15	20	25	27	29	30	31
$B_0+B_1 \times CMP$	-7.65	-5.62	-3.58	-1.55	0.49	2.52	3.34	4.15	4.56	4.96
P (%)	0.05	0.36	2.70	17.52	61.62	92.56	96.56	98.45	98.96	99.31

Note: B_0 = the constant, B_1= the coefficient of the variable, CMP = Construction Management Practices Score, and P = probability of exceeding PF=0.90.

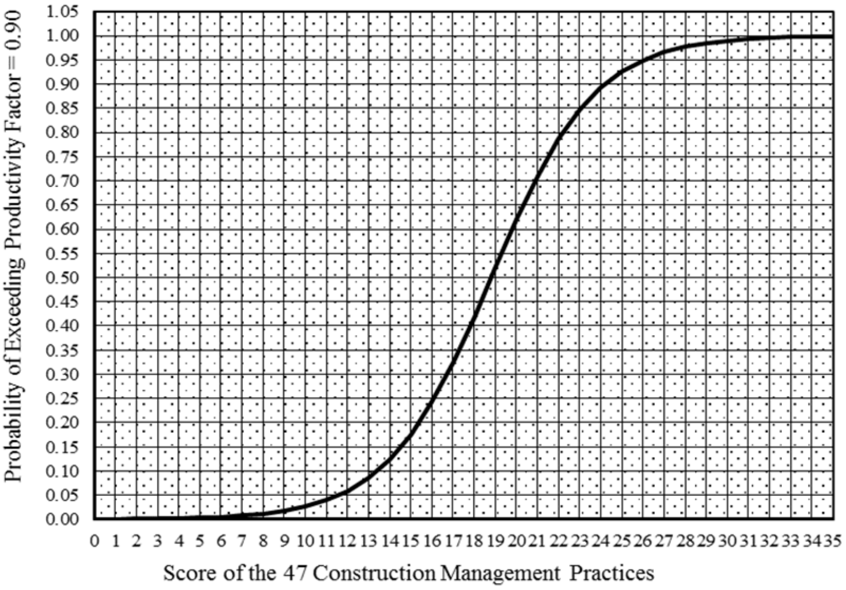


Figure 8-10 Sigmoid Graph of the Overall Construction Management Practices

The results of the analysis conducted to validate the logistic regression models of the six categories of the construction management practices are explained in the subsequent sections.

Validation of the Logistic Regression Model of the Construction Materials Management Practices and Productivity

During the validation process of the logistic regression model of the construction materials management practices and productivity, probabilities of exceeding baseline productivity factor of 1.05 were predicted by using the validation dataset coded '36' in Table 8-3 as inputs to Equation 8-2 (Materials Management Practices and Productivity Model). The Receiver Operating Characteristic (ROC) of the data was plotted, and its Area under the Curve (AUC) was calculated. As shown in Figure 8-11, the ROC curve is above the diagonal line indicating that the model is valid. The AUC= 0.81 > 0.5 which also indicates that the model is valid.

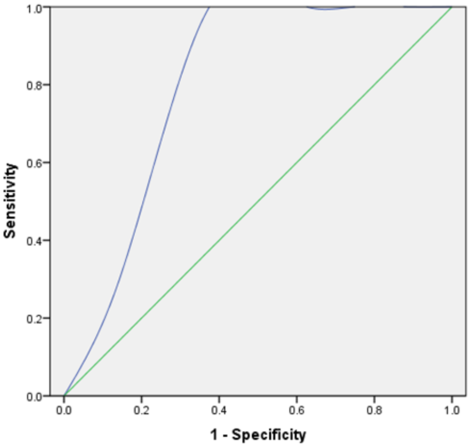


Figure 8-11 ROC Curve for Validating the Logistic Regression Model of the Construction Materials Management Practices and Productivity

After validation, the model's equation (Equation 8-2) is used to predict the probabilities of exceeding PF=1.05, and the sigmoid graph is plotted as shown in Figure 8-12. In Table 8-30, the data used to draw the probability graph is presented.

Table 8-30 Predicted Probabilities Using Construction Materials Management Practices Model

B_0	-6.416											
B_1	1.808											
MMP Score	0	1	2	3	4	4.5	5	5.5	6	6.5	7	8
$B_0+B \times MMP$	-6.42	-4.65	-2.85	-1.04	0.77	1.68	2.58	3.48	4.39	5.29	6.20	8.00
P (%)	0.16	0.94	5.49	26.17	68.37	86.48	92.95	97.02	98.77	99.50	99.80	99.97

Note: B_0= the constant, B= the coefficient of the variable, MMP= Construction Materials Management Practices Score, and P= probability of exceeding PF=1.05.

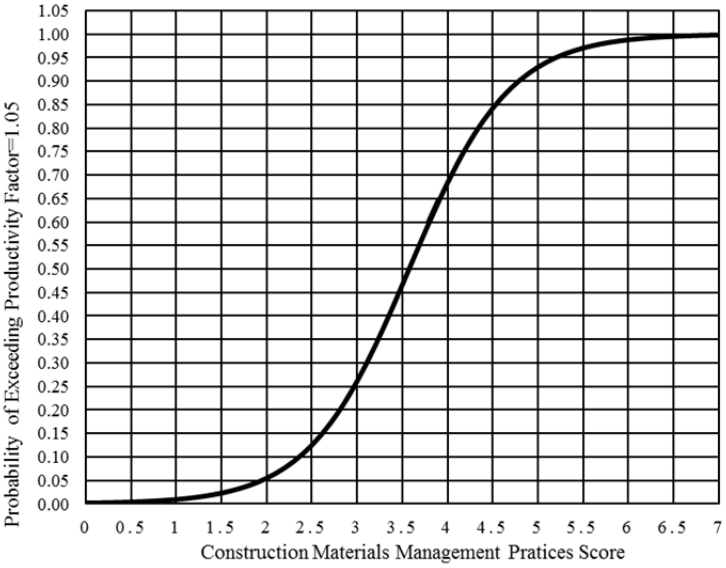


Figure 8-12 Probability Graph of the Construction Materials Management Practices

Validation of the Logistic Regression Model of Construction Equipment Management Practices and Productivity

To validate the logistic regression model of the construction equipment management practices and productivity, probabilities of validation dataset coded '11' in Table 8-5 were computed; productivity factors were predicted as binary values (1, 0) and compared with the actual productivity factors; Receiver Operating Characteristic (ROC) curve was drawn and compared with the reference line; and Area under the ROC Curve (AUC) was computed. Accordingly, about 85% of the PF's are correctly predicted indicating the strength of the model (Table 8-31).

Table 8-31 Predictive Accuracy of the Logistic Regression Model of the Construction Equipment Management Practices and Productivity

Respondents' Code	*Actual PF*	*B_0*	*B_1*	*CEMP Score*	*(B_0+B_1*CEMP) or L*	*$P=(e^L)/(1+e^L)$*	*Predicted PF*	*Binary Equivalent for Actual PF*	*Remark*
R33	0.90	-0.98	2.29	0.42	-0.024	0.51	1	1.00	Correct
R18	1.00			0.00	-0.980	0.27	0	1.00	Incorrect
R14	0.82			0.44	0.021	0.48	0	0.00	Correct
R12	0.79			1.41	2.249	0.90	1	0.00	Incorrect
R39	1.10			1.15	1.651	0.83	1	1.00	Correct
R26	0.76			0.00	-0.980	0.27	0	0.00	Correct
R38	1.00			0.70	0.615	0.65	1	1.00	Correct
R30	1.12			1.49	2.437	0.92	1	1.00	Correct
R9	1.14			1.23	1.843	0.86	1	1.00	Correct
R27	1.08			1.55	2.567	0.93	1	1.00	Correct
R37	1.08			2.09	3.800	0.98	1	1.00	Correct
R29	0.92			1.47	2.397	0.92	1	1.00	Correct
R35	1.06			0.59	0.382	0.59	1	1.00	Correct
Percentage Correctly predicted									85%

Note: B_0= the constant, B_1= the coefficient of the variable, CEMP= Construction Equipment Management Practices Score, and P= probability of exceeding PF=0.90.

ROC curve is drawn, and the curve of the graph is greater than the reference line indicating that the model is good in prediction (Figure 8-13). Furthermore, the area under the curve was computed to be 0.85 which is greater than the minimum acceptable value of 0.5.

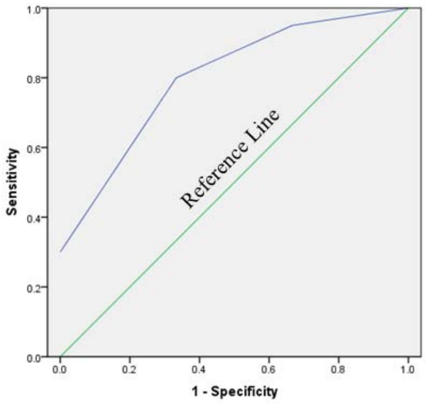


Figure 8-13 ROC Curve for Validating the Construction Equipment Management Practices and Productivity Model

After validating the model, the probabilities of exceeding PF=0.90 are predicted and the sigmoid graph is plotted (Figure 8-14).

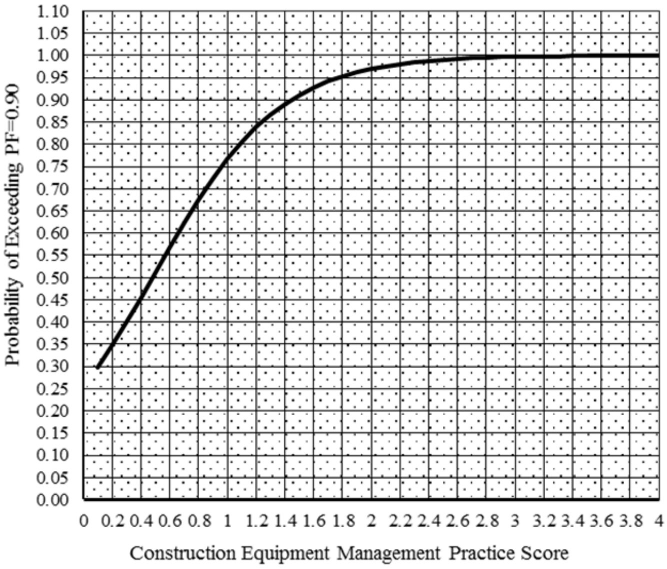


Figure 8-14 Probability Graph of the Construction Equipment Management Practices

Validation of the Logistic Regression Model of the Management Practices Related to Construction Methods and Productivity

The logistic regression model of the management practices related to construction methods and productivity is validated by predicting the probabilities of exceeding baseline productivity factor of 0.90 by using the validation dataset coded ‘11’ in Table 8-7 as input to the model’s equation (Equation 8-4). After that, the ROC curve was plotted, and AUC was computed. Figure 8-15 below indicates the ROC curve and the diagonal line which is used as a baseline. Since the graph is above the reference line and AUC=0.77 > 0.5, the model is valid.

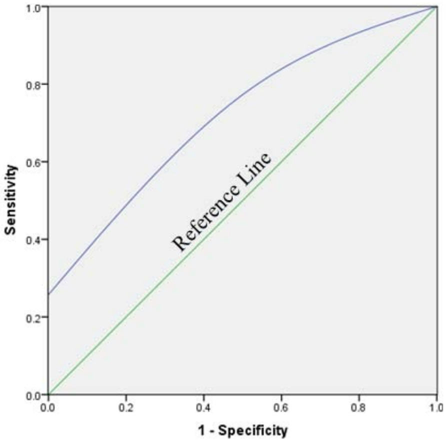


Figure 8-15 ROC Curve for Validating Management Practices Related to Construction Methods and Productivity Model

After validation, the model's equation (Equation 8-4) was used to predict the probabilities of exceeding PF=0.90, and the sigmoid graph was plotted as shown in Figure 8-16. In Table 8-32, the data used to draw the probability graph is presented.

Table 8-32 Predicted Probabilities Using Management Practices Related to Construction Methods and Productivity Model

B_0	-5.791											
B	1.513											
MPCM Score	0	1	2	3	4	4.5	5	5.5	6	6.5	7	7.5
$B_0+B\times MPCM$	-5.79	-4.28	-2.77	-1.25	0.26	1.02	1.77	2.53	3.29	4.04	4.80	5.56
P (%)	0.30	1.37	5.92	22.24	56.49	73.45	85.50	92.63	96.40	98.28	99.18	99.62

Note: B_0= the constant, B= the coefficient of the variable, MPCM= Management Practices Related to Construction Methods, and P= probability of exceeding PF=0.90.

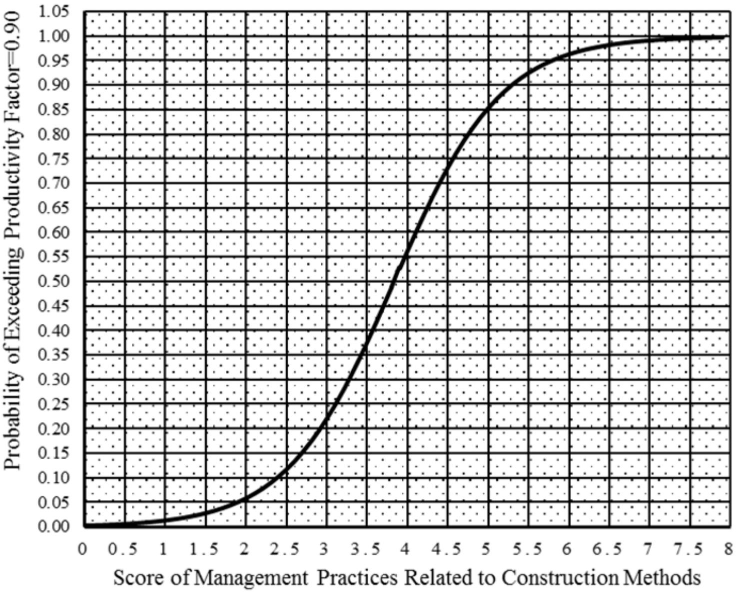


Figure 8-16 Probability Plot of Management Practices Related to Construction Methods

Validation of the Logistic Regression Model of Pre-Construction Phase Management Practices and Productivity

To validate the logistic regression model of the pre-construction phase management practices and productivity, the procedures used in validating the logistic regression model of other categories of the construction management practices were followed. However, the validation dataset coded ‘36’ in Table 8-9 is used (refer Appendix-5 for the codes of the datasets). In Table 8-33, the results of the comparison of observed and predicted productivity factors are provided. Accordingly, about 80% of the PF’s are correctly predicted indicating the strength of the model. The curve of the graph is greater than the reference line which shows that the model is good in prediction (Figure 8-17). Furthermore, the area under the curve (AOC) is computed to be 0.81, and the AOC value is greater than the minimum acceptable value of 0.5. Therefore, the model is valid.

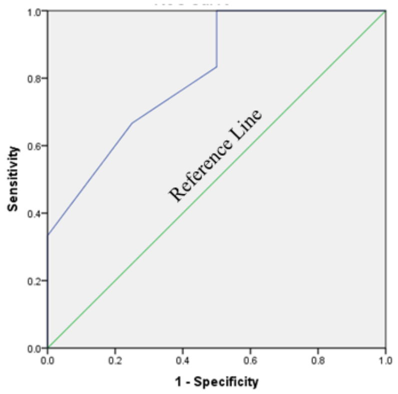


Figure 8-17 ROC Curve for Validating the Pre-Construction Phase Management Practices and Productivity Model

Table 8-33 Predictive Accuracy of the Pre-Construction Phase Management Practices and Productivity Model

Respondents' Code	*Actual PF*	*B_0*	*B_1*	*PCMP Score*	*(B_0+B_1*PCMP) or L*	*$P=(e^L)/(1+e^L)$*	*Predicted PF*	*Binary Equivalent for Actual PF*	*Remark*
R30	1.12	-5.255	1.100	5.50	0.790	0.688	1	1.00	Correct
R9	1.14			5.46	0.747	0.679	1	1.00	Incorrect
R27	1.08			5.85	1.179	0.765	1	1.00	Correct
R37	1.08			6.72	2.135	0.894	1	1.00	Correct
R29	0.92			5.25	0.525	0.628	0	0.00	Correct
R35	1.06			2.05	-3.003	0.047	0	1.00	Incorrect
R8	1.06			4.94	0.182	0.545	1	1.00	Correct
R31	0.91			4.39	-0.427	0.395	0	0.00	Correct
R19	1.08			3.00	-1.952	0.124	0	1.00	Incorrect
R5	1.01			4.07	-0.775	0.315	1	1.00	Correct
Percentage Correctly predicted									80%

Note: B_0= the constant, B_1= the coefficient of the variable, PCMP= Pre-Construction Phase Management Practices Score, and P= probability of exceeding PF=1.0.

By using Equation 8-5, the probabilities of exceeding PF=1.0 are predicted, and the sigmoid graph is plotted as shown in Figure 8-18.

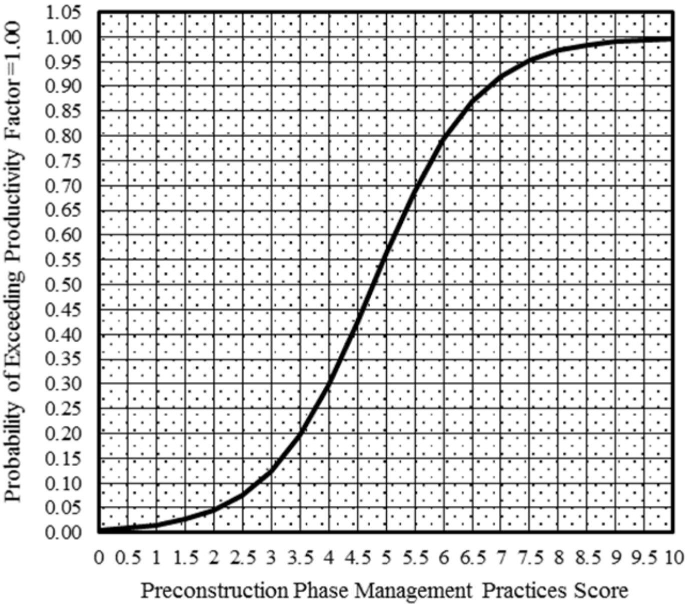


Figure 8-18 Probability Plot of the Preconstruction Phase Management Practices

Validation of the Logistic Regression Model of the Human Resource Management Practices and Productivity

In the process of validation of the logistic regression model of productivity and HRM practices, the probabilities of exceeding PF= 0.90 for the validation dataset coded '11' in Table 8-11were predicted using the model's equation (Equation 8-6); ROC curve was drawn as shown in Figure 8-19 and interpreted with respect to the reference line; and the AUC was computed. Accordingly, the curve is greater than the reference line indicating that the model is good in prediction. Furthermore, the area under the curve is calculated to be 0.67 which is higher than the minimum acceptable value of 0.5. Thus, the model is valid.

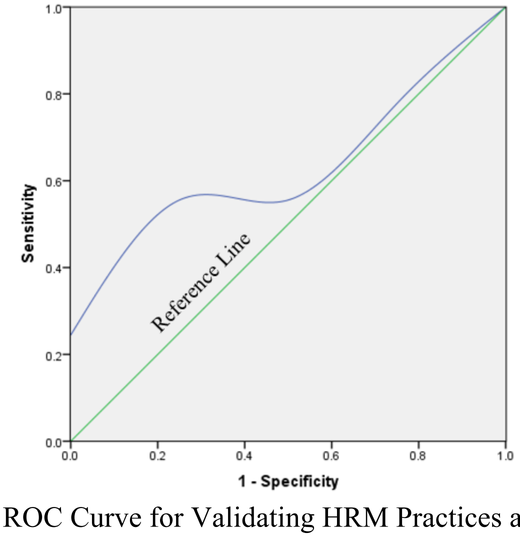


Figure 8-19 ROC Curve for Validating HRM Practices and Productivity Model

By using Equation 8-6, probabilities were computed, and the sigmoid graph indicated in Figure 8-20 was drawn so that users can easily read probability that corresponds to a score of HRM practices for a particular building project. The portion of the data used in constructing the graph is indicated in Table 8-34.

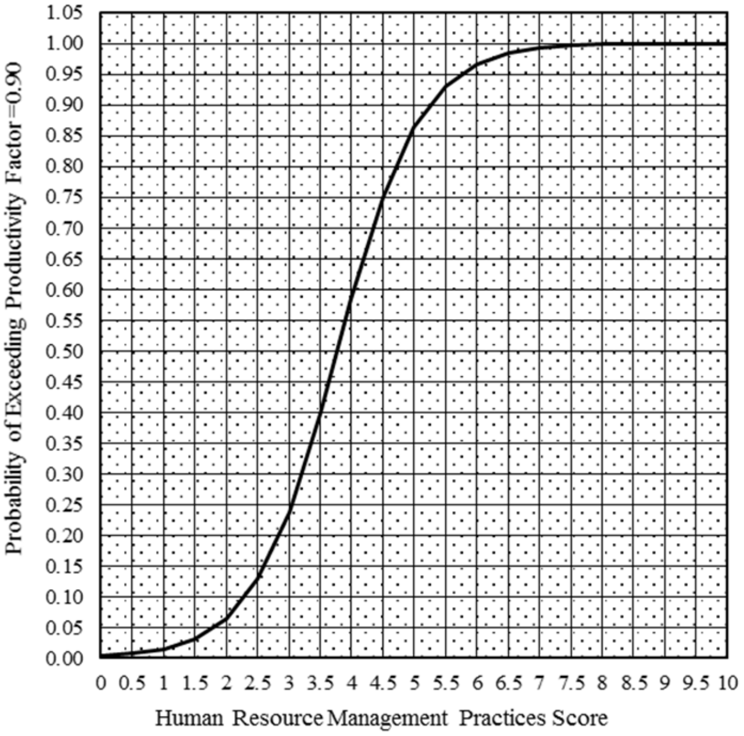


Figure 8-20 Probability Plot of the Human Resource Management Practices

Table 8-34 Predicted Probabilities Using HRM Practices Model

B_0				-5.68						
B				1.50						
HRM Score	0	1	2	3	4	5	6	7	7.5	8
B_0+B×HRM	-5.68	-4.17	-2.67	-1.17	0.34	1.84	3.34	4.85	2.99	3.55
P (%)	0.34	1.52	6.48	23.78	58.39	86.33	96.60	99.22	95.23	97.19

Note: B_0 = the constant, B = the coefficient of the variable, HRM= Human Resource Management Practices Score, and P = probability of exceeding PF=0.90.

Validation of the Logistic Regression Model of Safety and Health Practices and Productivity

To validate the logistic regression model of productivity and safety and health practices, the probabilities of exceeding baseline productivity factor of 0.90 were predicted by using the validation dataset coded ‘11’ in Table 8-13 as input to the model, and the AUC of the data was computed. Figure 8-21 shows the ROC and the diagonal line which is used as a baseline. Accordingly, the graph is above the reference line indicating that the model is valid. Moreover, the AUC= 0.73 > 0.5 which also shows that the model is valid.

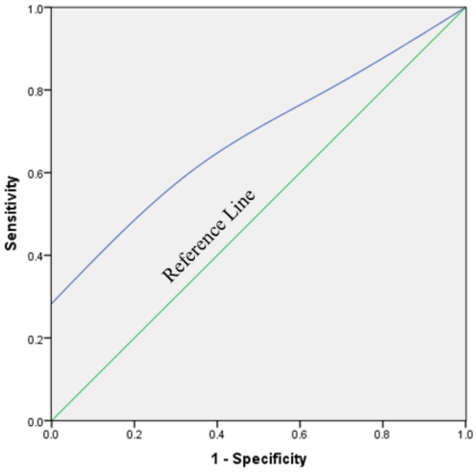


Figure 8-21 ROC Curve for Validating the Safety and Health Practices and Productivity Model

The sigmoid graph (Figure 8-22) is plotted by using Equation 8-7, and the data used in constructing the graph is indicated Table 8-35.

Table 8-35 Predicted Probabilities Using Safety and Health Practices and Productivity Model

B_0				-8.79						
B_1				1.81						
SHP Score	0	1	2	3	4	5	6	6.5	7	7.5
$B_0+B_1\times SHP$	-8.79	-6.97	-5.16	-3.35	-1.54	0.28	2.09	3.00	3.90	4.81
P (%)	0.02	1.52	0.57	8.01	17.73	56.91	89.00	95.25	98.02	99.19

Note: B_0= the constant, B_1= the coefficient of the variable, SHP= Safety and Health Practice Score, and P = probability of exceeding PF=0.90.

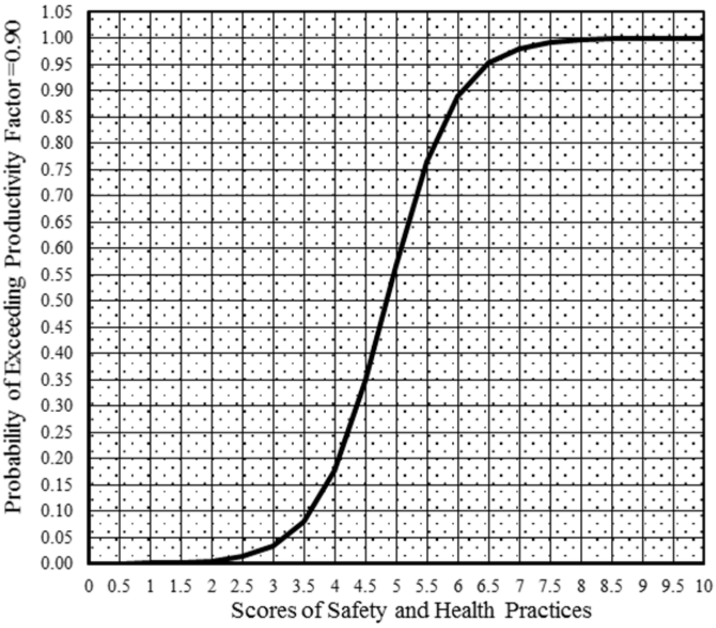


Figure 8-22 Probability Plot of Safety and Health Practices

8.3.2 Validation of Linear Regression Models of Construction Management Practices and Productivity

To validate the linear regression model of the overall construction management practices and productivity, the productivity factors of the validation dataset were predicted using the model's equation (PF = 0.02× a score of the construction management practices + 0.58), and the mean squared prediction error (MSPR) was computed and compared with the model building data sets' mean squared error (MSE). If the values of MSPR and MSE are similar, then the model is valid (Thomas and Sudhakumar, 2014, Yan and Su, 2009). The following formula is used to compute MSPR (Thomas and Sudhakumar, 2014).

$$\text{MSPR}=\frac{\sum_{i=1}^{n}(\text{PF}_i-\text{PF}_{pi})^2}{n}$$

Where PF_i is the observed productivity factor of an ith validation data point, PF_{pi} is the predicted productivity factor an ith validation data point, and n refers to the number of validation data points.

Table 8-36 Validation of the Linear Regression Model of Productivity and the Construction Management Practices

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.58	0.02	R33	12.00	0.90	0.82	0.08	0.006	R7	27.53	0.78	1.13	-0.35	0.12
		R18	18.94	1.00	0.96	0.04	0.002	R34	24.17	1.08	1.06	0.02	0.00
		R14	13.52	0.82	0.85	-0.03	0.001	R11	15.23	0.59	0.88	-0.29	0.08
		R12	21.49	0.79	1.01	-0.22	0.048	R32	27.84	1.14	1.14	0.01	0.00
		R39	26.83	1.10	1.12	-0.02	0.000	R25	11.41	0.96	0.81	0.15	0.02
		R26	15.07	0.76	0.88	-0.12	0.014	R24	14.27	0.92	0.87	0.06	0.00
		R38	20.50	1.00	0.99	0.01	0.000	R2	27.42	0.88	1.13	-0.25	0.06
		R30	22.93	1.12	1.04	0.08	0.006	R16	18.59	1.00	0.95	0.05	0.00
		R9	23.34	1.14	1.05	0.09	0.008	R4	24.62	1.02	1.07	-0.06	0.00
		R27	25.64	1.08	1.09	-0.01	0.000	R13	20.01	1.07	0.98	0.09	0.01
		R37	28.55	1.08	1.15	-0.08	0.006	R3	22.57	1.02	1.03	-0.02	0.00
		R29	22.23	0.92	1.02	-0.10	0.010	R23	21.58	0.89	1.01	-0.13	0.02
		R35	14.31	1.06	0.87	0.19	0.038	R6	22.69	0.82	1.03	-0.22	0.05
		R8	23.90	1.06	1.06	0.00	0.000	Mean Squared Prediction Error					**0.029**
		R31	18.92	0.91	0.96	-0.05	0.002						
		R19	16.36	1.08	0.91	0.18	0.032						
		R5	19.47	1.01	0.97	0.04	0.001						
		R10	24.98	1.13	1.08	0.05	0.003						
		R28	8.39	0.60	0.75	-0.15	0.023						
		R20	14.32	0.88	0.87	0.01	0.000						
		R1	16.35	1.00	0.91	0.09	0.009						
		R15	20.09	0.88	0.98	-0.10	0.011						
		R36	22.08	1.00	1.02	-0.02	0.000						
		R17	14.72	0.67	0.87	-0.21	0.044						
		R22	24.25	1.00	1.06	-0.06	0.004						
		R21	19.50	0.96	0.97	-0.01	0.000						
						Mean Squared Error	**0.0103**						

The results of the analysis conducted to validate the linear regression model of the 47 construction management practices and productivity are presented in Table 8-36.

Accordingly, the values of *MSE* (0.01) and *MSPR* (0.029) are both close to zero. Thus, the model is valid.

The results of the analyses carried out to validate the linear regression models of the six categories of the construction management practices are presented in the following subsections.

Validation of the Linear Regression Model of the Construction Management Practices and Productivity

The outputs of the analysis conducted to validate the linear regression model of productivity and construction materials management practices are presented in Table 8-37. The finding indicates that *MSE* (0.01) and *MSPR* (0.03) are close to each other. Thus, the model is valid.

Table 8-37 Validation of the Linear Regression Model of Productivity and the Construction Materials Management Practices

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.74	0.09	R3	2.91	1.02	1.00	0.01	0.00	R7	3.49	0.78	1.05	-0.28	0.08
		R23	2.66	0.89	0.98	-0.09	0.01	R34	2.97	1.08	1.01	0.07	0.01
		R6	1.36	0.82	0.86	-0.05	0.00	R11	1.53	0.59	0.88	-0.28	0.08
		R33	1.57	0.90	0.88	0.02	0.00	R32	3.81	1.14	1.08	0.06	0.00
		R18	2.23	1.00	0.94	0.06	0.00	R25	1.08	0.96	0.84	0.12	0.01
		R14	1.97	0.82	0.92	-0.10	0.01	R24	1.18	0.92	0.85	0.08	0.01
		R12	2.49	0.79	0.96	-0.17	0.03	R2	3.77	0.88	1.08	-0.20	0.04
		R39	3.61	1.10	1.06	0.04	0.00	R16	1.79	1.00	0.90	0.10	0.01
		R26	1.32	0.76	0.86	-0.10	0.01	R4	3.14	1.02	1.02	-0.01	0.00
		R38	1.53	1.00	0.88	0.12	0.01	R13	1.84	1.07	0.91	0.17	0.03
		R30	3.91	1.12	1.09	0.03	0.00	Mean Squared Prediction Error					**0.03**
		R9	2.98	1.14	1.01	0.13	0.02						
		R27	1.92	1.08	0.91	0.17	0.03						
		R37	3.92	1.08	1.09	-0.02	0.00						
		R29	2.34	0.92	0.95	-0.03	0.00						
		R35	1.68	1.06	0.89	0.17	0.03						
		R8	2.99	1.06	1.01	0.05	0.00						
		R31	2.77	0.91	0.99	-0.08	0.01						
		R19	1.45	1.08	0.87	0.21	0.05						
		R5	2.28	1.01	0.94	0.06	0.00						
		R10	3.97	1.13	1.10	0.04	0.00						
		R28	1.66	0.60	0.89	-0.29	0.09						
		R20	1.41	0.88	0.87	0.01	0.00						
		R1	1.88	1.00	0.91	0.09	0.01						
		R15	2.17	0.88	0.94	-0.06	0.00						
		R36	2.74	1.00	0.99	0.01	0.00						
		R17	2.37	0.67	0.95	-0.29	0.08						
		R22	2.44	1.00	0.96	0.04	0.00						
		R21	2.66	0.96	0.98	-0.02	0.00						
Mean Squared Error							**0.01**						

Validation of the Linear Regression Model of the Construction Equipment Management Practices and Productivity

As shown in Figure 8-38, the *MSE* (0.01) and *MSPR* (0.02) are similar. Thus, the linear regression model of productivity and construction equipment management practices is valid.

Table 8-38 Validation of the Linear Regression Model of Productivity and the Construction Equipment Management Practices

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.84	0.13	R33	0.42	0.90	0.89	0.00	0.00	R7	1.67	0.78	1.06	-0.28	0.08
		R18	0.00	1.00	0.84	0.16	0.03	R34	1.08	1.08	0.98	0.10	0.01
		R14	0.44	0.82	0.90	-0.08	0.01	R11	0.58	0.59	0.91	-0.32	0.10
		R12	1.41	0.79	1.02	-0.23	0.05	R32	1.69	1.14	1.06	0.08	0.01
		R39	1.15	1.10	0.99	0.11	0.01	R25	0.68	0.96	0.93	0.03	0.00
		R26	0.00	0.76	0.84	-0.08	0.01	R24	0.58	0.92	0.91	0.01	0.00
		R38	0.70	1.00	0.93	0.07	0.00	R2	1.35	0.88	1.02	-0.14	0.02
		R30	1.49	1.12	1.03	0.08	0.01	R16	0.59	1.00	0.92	0.08	0.01
		R9	1.23	1.14	1.00	0.14	0.02	R4	1.08	1.02	0.98	0.04	0.00
		R27	1.55	1.08	1.04	0.04	0.00	R13	0.97	1.07	0.97	0.11	0.01
		R37	2.09	1.08	1.11	-0.04	0.00	R3	0.83	1.02	0.95	0.07	0.00
		R29	1.47	0.92	1.03	-0.11	0.01	R23	1.37	0.89	1.02	-0.13	0.02
		R35	0.59	1.06	0.92	0.14	0.02	R6	0.89	0.82	0.96	-0.14	0.02
		R8	1.11	1.06	0.98	0.08	0.01	Mean Squared Prediction Error Error					**0.02**
		R31	0.96	0.91	0.96	-0.05	0.00						
		R19	0.56	1.08	0.91	0.17	0.03						
		R5	0.58	1.01	0.91	0.09	0.01						
		R10	1.23	1.13	1.00	0.13	0.02						
		R28	0.16	0.60	0.86	-0.26	0.07						
		R20	0.58	0.88	0.91	-0.03	0.00						
		R1	0.58	1.00	0.91	0.09	0.01						
		R15	0.71	0.88	0.93	-0.05	0.00						
		R36	1.39	1.00	1.02	-0.02	0.00						
		R17	0.72	0.67	0.93	-0.27	0.07						
		R22	1.39	1.00	1.02	-0.02	0.00						
		R21	0.58	0.96	0.91	0.05	0.00						
					Mean Squared Error		**0.01**						

Validation of the Linear Regression Model of the Management Practices Related to Construction Methods and Productivity

The *MSPR* (0.03) and *MSE* (0.02) computed using the linear regression equation of the management practices related to construction methods and productivity are close to each other indicating that the model is valid (Table 8-39).

Table 8-39 Validation of the Linear Regression Model of Productivity and the Management Practices Related to Construction Methods

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.61	0.08	R33	2.55	0.90	0.81	0.08	0.01	R7	6.78	0.78	1.15	-0.37	0.14
		R18	4.98	1.00	1.01	-0.01	0.00	R34	6.32	1.08	1.12	-0.04	0.00
		R14	3.06	0.82	0.85	-0.04	0.00	R11	3.76	0.59	0.91	-0.32	0.10
		R12	4.91	0.79	1.00	-0.21	0.04	R32	6.82	1.14	1.16	-0.01	0.00
		R39	6.46	1.10	1.13	-0.03	0.00	R25	2.19	0.96	0.79	0.17	0.03
		R26	3.78	0.76	0.91	-0.15	0.02	R24	3.96	0.92	0.93	-0.01	0.00
		R38	5.58	1.00	1.06	-0.06	0.00	R2	6.80	0.88	1.15	-0.28	0.08
		R30	4.96	1.12	1.01	0.11	0.01	R16	5.42	1.00	1.04	-0.04	0.00
		R9	4.93	1.14	1.00	0.13	0.02	R4	5.40	1.02	1.04	-0.03	0.00
		R27	5.84	1.08	1.08	0.01	0.00	R13	4.15	1.07	0.94	0.13	0.02
		R37	6.24	1.08	1.11	-0.03	0.00	R3	6.32	1.02	1.12	-0.10	0.01
		R29	4.82	0.92	1.00	-0.07	0.01	R23	4.36	0.89	0.96	-0.07	0.01
		R35	3.15	1.06	0.86	0.20	0.04	R6	5.69	0.82	1.06	-0.25	0.06
		R8	6.30	1.06	1.11	-0.05	0.00	Mean Squared Prediction Error					**0.03**
		R31	3.88	0.91	0.92	-0.01	0.00						
		R19	3.62	1.08	0.90	0.19	0.03						
		R5	5.77	1.01	1.07	-0.07	0.00						
		R10	5.79	1.13	1.07	0.06	0.00						
		R28	2.14	0.60	0.78	-0.19	0.03						
		R20	4.07	0.88	0.94	-0.06	0.00						
		R1	4.37	1.00	0.96	0.04	0.00						
		R15	4.77	0.88	0.99	-0.11	0.01						
		R36	4.96	1.00	1.01	-0.01	0.00						
		R17	3.60	0.67	0.90	-0.23	0.05						
		R22	5.97	1.00	1.09	-0.09	0.01						
		R21	4.20	0.96	0.95	0.02	0.00						
					Mean Squared Error		**0.01**						

Validation of the Linear Regression Model of the Pre-Construction Phase Management Practices and Productivity

As shown in Table 8-40, the values of *MSE* (0.01) and *MSPR* (0.02) are very close to each other indicating that the pre-construction phase management practices and productivity model is valid.

Table 8-40 Validation of the Linear Regression Model of Productivity and the Pre-Construction Phase Management Practices

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.711	0.06	R33	1.79	0.90	0.82	0.08	0.01	R7	5.69	0.78	1.05	-0.28	0.08
		R18	4.52	1.00	0.98	0.02	0.00	R34	6.01	1.08	1.07	0.01	0.00
		R14	2.61	0.82	0.87	-0.05	0.00	R11	3.65	0.59	0.93	-0.34	0.11
		R12	4.50	0.79	0.98	-0.19	0.04	R32	7.11	1.14	1.14	0.01	0.00
		R39	6.53	1.10	1.10	0.00	0.00	R25	2.80	0.96	0.88	0.08	0.01
		R26	3.99	0.76	0.95	-0.19	0.04	R24	3.85	0.92	0.94	-0.02	0.00
		R38	5.27	1.00	1.03	-0.03	0.00	R2	6.10	0.88	1.08	-0.20	0.04
		R30	5.50	1.12	1.04	0.08	0.01	R16	5.15	1.00	1.02	-0.02	0.00
		R9	5.46	1.14	1.04	0.10	0.01	R4	5.36	1.02	1.03	-0.02	0.00
		R27	5.85	1.08	1.06	0.02	0.00	R13	4.40	1.07	0.97	0.10	0.01
		R37	6.72	1.08	1.11	-0.04	0.00	R3	4.90	1.02	1.00	0.01	0.00
		R29	5.25	0.92	1.03	-0.10	0.01	R23	4.61	0.89	0.99	-0.10	0.01
		R35	2.05	1.06	0.83	0.23	0.05	R6	5.68	0.82	1.05	-0.24	0.06
		R8	4.94	1.06	1.01	0.05	0.00	Mean Squared Prediction Error					**0.02**
		R31	4.39	0.91	0.97	-0.06	0.00						
		R19	3.00	1.08	0.89	0.19	0.04						
		R5	4.07	1.01	0.96	0.05	0.00						
		R10	5.31	1.13	1.03	0.10	0.01						
		R28	1.19	0.60	0.78	-0.19	0.03						
		R20	2.77	0.88	0.88	0.00	0.00						
		R1	4.18	1.00	0.96	0.04	0.00						
		R15	5.03	0.88	1.01	-0.13	0.02						
		R36	4.09	1.00	0.96	0.04	0.00						
		R17	3.30	0.67	0.91	-0.24	0.06						
		R22	5.33	1.00	1.03	-0.03	0.00						
		R21	3.46	0.96	0.92	0.04	0.00						
Mean Squared Error							**0.01**						

Validation of the Linear Regression Model of the Human Resource Management Practices and Productivity

The HRM practices and productivity linear regression model is valid since the values of *MSE* (0.02) and *MSPR* (0.03) are similar (Table 8-41).

Validation of the Linear Regression Model of the Safety and Health Practices and Productivity

Table 8-42 presents the results of the analysis conducted to validate the linear regression model of the safety and health practices and productivity. Accordingly, the *MSPR* value of 0.02 and *MSE* value of 0.01 are found. The findings show that the model is valid.

Table 8-41 Validation of the Linear Regression Model of Productivity and the Human Resource Management Practices

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.64	0.07	R33	2.64	0.90	0.82	0.07	0.01	R7	6.57	0.78	1.10	-0.32	0.10
		R18	4.30	1.00	0.94	0.06	0.00	R34	4.54	1.08	0.96	0.12	0.01
		R14	4.23	0.82	0.94	-0.12	0.01	R11	3.52	0.59	0.89	-0.29	0.09
		R12	5.06	0.79	0.99	-0.20	0.04	R32	5.14	1.14	1.00	0.14	0.02
		R39	5.74	1.10	1.04	0.06	0.00	R25	2.04	0.96	0.78	0.17	0.03
		R26	3.88	0.76	0.91	-0.15	0.02	R24	2.48	0.92	0.81	0.11	0.01
		R38	4.89	1.00	0.98	0.02	0.00	R2	6.52	0.88	1.10	-0.22	0.05
		R30	3.81	1.12	0.91	0.21	0.04	R16	2.59	1.00	0.82	0.18	0.03
		R9	5.45	1.14	1.02	0.12	0.01	R4	6.96	1.02	1.13	-0.11	0.01
		R27	7.19	1.08	1.14	-0.06	0.00	R13	5.36	1.07	1.02	0.06	0.00
		R37	6.27	1.08	1.08	0.00	0.00	R3	4.47	1.02	0.95	0.06	0.00
		R29	5.03	0.92	0.99	-0.07	0.00	R23	5.27	0.89	1.01	-0.12	0.01
		R35	4.14	1.06	0.93	0.13	0.02	R6	5.73	0.82	1.04	-0.23	0.05
		R8	5.50	1.06	1.03	0.03	0.00	Mean Squared Prediction Error					**0.03**
		R31	3.97	0.91	0.92	-0.01	0.00						
		R19	4.49	1.08	0.95	0.13	0.02						
		R5	4.67	1.01	0.97	0.04	0.00						
		R10	6.13	1.13	1.07	0.06	0.00						
		R28	0.92	0.60	0.70	-0.11	0.01						
		R20	3.39	0.88	0.88	0.00	0.00						
		R1	3.30	1.00	0.87	0.13	0.02						
		R15	4.50	0.88	0.95	-0.08	0.01						
		R36	5.59	1.00	1.03	-0.03	0.00						
		R17	2.05	0.67	0.78	-0.12	0.01						
		R22	6.74	1.00	1.11	-0.11	0.01						
		R21	5.32	0.96	1.01	-0.05	0.00						
Mean Squared Error							**0.01**						

Table 8-42 Validation of the Linear Regression Model of Productivity and the Safety and Health Practices

Model Building Data Sets								Validation dataset					
B (Constant)	Bo (Coefficient)	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared	Project Code	Project Score	Actual PF	Predicted PF	Error	Error Squared
0.49	0.09	R33	5.48	0.90	0.98	-0.08	0.01	R7	6.39	0.78	1.07	-0.29	0.08
		R18	5.65	1.00	1.00	0.00	0.00	R34	5.85	1.08	1.02	0.06	0.00
		R14	2.73	0.82	0.74	0.08	0.01	R11	4.01	0.59	0.85	-0.26	0.07
		R12	6.02	0.79	1.03	-0.24	0.06	R32	6.03	1.14	1.03	0.11	0.01
		R39	6.39	1.10	1.07	0.03	0.00	R25	4.76	0.96	0.92	0.04	0.00
		R26	4.39	0.76	0.89	-0.12	0.02	R24	4.03	0.92	0.85	0.07	0.00
		R38	5.12	1.00	0.95	0.05	0.00	R2	5.31	0.88	0.97	-0.09	0.01
		R30	5.85	1.12	1.02	0.10	0.01	R16	5.49	1.00	0.98	0.02	0.00
		R9	6.03	1.14	1.03	0.11	0.01	R4	5.29	1.02	0.97	0.05	0.00
		R27	6.03	1.08	1.03	0.05	0.00	R13	6.03	1.07	1.03	0.04	0.00
		R37	6.21	1.08	1.05	0.03	0.00	R3	6.03	1.02	1.03	-0.02	0.00
		R29	6.21	0.92	1.05	-0.12	0.02	R23	6.21	0.89	1.05	-0.16	0.03
		R35	5.29	1.06	0.97	0.09	0.01	R6	6.39	0.82	1.07	-0.25	0.06
		R8	5.49	1.06	0.98	0.08	0.01	Mean Squared Prediction Error					**0.02**
		R31	5.86	0.91	1.02	-0.11	0.01						
		R19	5.68	1.08	1.00	0.08	0.01						
		R5	4.55	1.01	0.90	0.11	0.01						
		R10	5.29	1.13	0.97	0.17	0.03						
		R28	4.00	0.60	0.85	-0.25	0.06						
		R20	4.39	0.88	0.88	0.00	0.00						
		R1	4.94	1.00	0.93	0.07	0.00						
		R15	5.66	0.88	1.00	-0.12	0.01						
		R36	6.21	1.00	1.05	-0.05	0.00						
		R17	5.12	0.67	0.95	-0.29	0.08						
		R22	5.29	1.00	0.97	0.03	0.00						
		R21	6.03	0.96	1.03	-0.07	0.00						
Mean Squared Error							**0.01**						

8.4 Summary

In this chapter, the quantitative data has been analysed and Objective 3 of the study or 'to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices' is achieved. Logistic regression model of the overall or the 47 construction management practices and productivity was developed and validated. Moreover, logistic regression models of productivity and the six categories of the construction management practices were built and validated. The reliability tests for the logistic regression models were conducted and acceptable results were found.

Linear regression model of productivity and the overall construction management practices was also developed and validated. The finding shows that about 48% of the variance in the productivity factor can be explained by the construction management practices and the remaining percentage could be explained by changes in technology and government regulations among others. The linear regression models of the six categories of the construction management practices and productivity have been built and validated. Thus, productivity factor of a project can be estimated based on the scores of the construction materials management practices, construction equipment management practices, management practices related to construction methods, pre-construction phase management practices, human resource management practices and safety and health practices. The next chapter provides the discussion of the findings of the study.

CHAPTER NINE

9 DISCUSSION OF FINDINGS

9.1 Introduction

In this chapter, the findings of the study are discussed. Section 9.2 presents the discussions on the relative importance of the construction management practices. Section 9.3 explains the relationships among the construction management practices. In section 9.4, the uses of the scoring tools and the regression models are demonstrated. The applications of the logistic regression models, the linear regression models, the scoring tools during the project planning, construction and closure phases are described in Section 9.4. Finally, the chapter is summarised in Section 9.5.

9.2 Relative Importance of the Construction Management Practices

In this section, the discussions of the findings obtained to achieve Objective 1 of the study or 'to identify and prioritise the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia' are presented.

Relative Importance of the Overall Construction Management Practices

Overall, 47 management practices that could improve productivity in multi-storey building construction projects are identified. These include six construction materials management practices, three construction equipment management practices, 10 management practices related to construction methods, 10 preconstruction phase management practices, 11 human resource management practices, and seven safety and health practices. The findings of this study have been compared with previous similar studies conducted in the context of infrastructure and industrial projects in North America (Table 9-1).

As shown in Table 9-1, the construction equipment management practices are found to be less important to improve productivity in multi-storey building projects as compared to industrial and infrastructure projects. For instance, in the context of multi-storey building projects, the practice 'construction equipment productivity analysis is ranked 44th among the 47 practices. However, in industrial projects, the practice is ranked 5th among 53 practices, and in infrastructure projects, the practice is ranked 6th among 61 practices.

Table 9-1 Relative Importance of the Overall Construction Management Practices

Buildability Projects (This Study)		**Industrial Projects** (CII, 2013a)		**Infrastructure Projects** (CII, 2013b)	
Practices	**Rank**	**Practices**	**Rank**	**Practices**	**Rank**
Well-Defined Scope of Work	1	Equipment Maintenance	1	Formal Health and Safety Policy	1
Safety and Health Policy	2	Substance Abuse Programs	2	Health and Safety Plans/Zero Accident Techniques	1
Safety and Health Plan	3	Toolbox Safety Meeting	3	Innovations & New Technologies	3
Hazards Analysis	3	Short Interval Planning	4	Hazards Planning	3
Long-Lead Materials Identification	5	Construction Machinery Productivity Analysis	5	Health and Safety Training Programs	3
Safe Work Method Statement	6	Design Readiness for Construction	5	Construction Machinery Productivity Analyses	6
Toolbox Safety Meetings	7	Material Inspection Process	7	Construction Machinery and Equipment Maintenance	6
Housekeeping	8	OSHA Compliance Training	8	Hazards Analysis	8
Safety and Health Training	8	Material Delivery Schedule	9	Task Safety Analysis	9
Short Interval Plan	10	Procurement Plan for Materials and Equipment	10	Crews Composition/Crew Formation	10
Buildability Review	10	Post receipt Preservation and Maintenance	11	Dynamic site layout plan	11
Construction Work Packages	12	Material Inspection Team	12	Environmental Requirements	12
Traffic Control Plan	13	Trades Technical Training	13	Skills Assessment and Evaluation	13
Project Start -up Plan	13	Integrated Schedule	13	Communications, Coordination, & Agreements	13
Regulatory Requirement	13	Retention Plan for Experienced Personnel	15	Long-Lead/Critical Equipment & Materials Identification	15
Procurement Plans for Materials	16	Schedule Execution and Management	15	Tools & Equipment Tracking	15
Clear Delegation of Responsibility	17	On-site Material Tracking Technology	17	Employees / Trades Technical Training	15
Project Completion Plan	18	PPMOF Evaluation	18	Social Activities	18
Machinery Positioning Strategy	19	Site Tool and Consumables Management Strategy	19	Toolbox Safety Meetings	19
Dynamic Site Layout Plan	20	Dynamic Site Layout Plan	19	Regulatory Requirements/Permitting Requirements	20
Stability of Organizational Structure	20	Zero Accident Techniques	19	Housekeeping	21
Construction Equipment Maintenance	22	Project Team Material Status Database	22	Design readiness for construction	22
Contract Types	23	Clear Delegation of Responsibility	22	Financial Incentive Programs	23
Schedule Control	24	Planning for Start-up	22	Utility Alignment & Adjustments	24
Crew Composition	24	Equipment Positioning Strategy	22	Contract Types/Strategies	25
Use of Software in Planning Work Packages	26	Task Safety Analysis	22	Procurement Procedures & Plans for Construction Machinery	26
Retention Plan for Experienced Personnel	26	System Turnover Procedure	27	Dedicated Planner	26
Utilities Alignment	28	Identification of Potential Hazards	27	Site Tools and Equipment Management Strategy	28
Materials Delivery Schedule	29	Career Development	29	Procurement Procedures and Plans for Materials and Equipment	29
Employees Training	29	Maintain Stability of Organizational Structure	30	Career development	29
Skill Assessment and Evaluation	31	Housekeeping	31	Integrated Schedule	29
Work Schedule Strategies	32	Work Schedule Strategies	32	Exit Interview	32
Site Security Plan	32	Tool Tracking Systems	33	Nonfinancial Incentive Programs	33
Career Development	34	Site Security Plan	33	Retention Plan for Experienced Personnel	34
Material Inspection Process	35	On-site Tool Maintenance	35	Project Team Materials Status Database	35
Procurement Plan for Construction Equipment	36	Financial Incentive Programs	35	Well defined scope of work	35
Financial Incentive Programs	37	Testing Procedures	35	Project Completion Plan	35
Social Activities	37	Control System for Tool Delays	38	Traffic Control Plan	38
Materials Status Database	39	Nonfinancial Incentive Programs	39	Utility Agreements	39
Integrated Schedules	40	System Test Hazards Planning	39	Short Interval Planning	40
Non-Financial Incentive Programs	41	Exit Interviews	41	Clear Delegation of Responsibility	41
Innovations and New Technologies	42	New Equipment Investigation	42	Materials Delivery Schedule	42
Dedicated Planner	43	Well Defined Scope of Work	43	Procurement Team	43
Construction Equipment Productivity Analysis	44	New Materials Technologies Investigation	44	Machinery and Equipment positioning strategy	43
Exit Interviews	45	Social Activities	45	Construction Work Packages (CWP)	45
Materials Inspection Team	46	New Information System Investigation	45	Project start-up plan	45
Model Development	47	Dedicated Planner	47	Contracts & Agreements with Agencies	47
		Construction Work Packages (CWP)	47	Drugs and Alcohol Testing Program	47
		Installation Work Packages (IWP)	47	Work Schedule Strategies	49
		Engineering Work Packages (EWP)	50	Materials Inspection Process	50
		Identify Required Permitting	51	On-site Tools Maintenance	50
		Project Model Requirements	52	Construction Machinery & Equipment Utility Requirements	50
		Utilization of Software to Assist in Generating Work packages	53	Use of Software	50
				Right of Way, Land, and Utilities Acquisition Strategy	50
				On-Site Material Tracking Technology	55
				Model Requirements/3D Visualization	55
				Site security plan	55
				Maintain Stability of Organization Structure	58
				Materials Inspection Team	59
				Schedule Execution and Management	59
				Post Receipt Preservation & Maintenance	61

Similarly, ‘construction equipment maintenance’ is found to be one of the most important practices that could enhance productivity in industrial and infrastructure projects. Nonetheless, the practice is considered to be less important for enhancing productivity in the context of multi-storey building construction projects. The finding implies that since industrial and infrastructure construction projects (engineering projects) are equipment intensive as compared to multi-storey building construction projects, the implementation of the construction equipment management practices is more important for the engineering projects than for the building projects.

Relative Importance of the Construction Materials Management Practices

After analysing the qualitative data (Phase I), six construction materials management practices that could improve productivity in multi-storey building projects in the context of Victoria, Australia are identified. These are Procurement Plans for Materials, Long-Lead Materials Identification, Materials Status Database, Materials Delivery Schedule, Material Inspection Process, and Materials Inspection Team. The quantitative data analysis (Phase II) also revealed that all the six practices are positively correlated with productivity. Comparisons of the findings of this study with previous similar studies are made in Table 9-2.

As indicated in Table 9-2, all the construction materials management practices that have the potential to improve productivity in infrastructure and industrial construction projects are not suitable to enhance productivity in multi-storey building projects. Moreover, the relative importance of the practices is different.

Table 9-2 The Relative Importance of Materials Management Practices in Infrastructure, Industrial and Multi-Storey Building Construction Projects

Infrastructure Projects (CII, 2013b)		**Industrial Projects** (CII, 2013a)		**This Study**	
Construction Materials Management Practices	*Rank*	*Construction Materials Management Practices*	*Rank*	*Construction Materials Management Practices*	*Rank*
Long-Lead/Critical Equipment and Materials Identification	1	Material Inspection Process	1	Long-Lead Materials Identification	1
Procurement Procedures and Plans for Materials and Equipment	2	Material Delivery Schedule	2	Procurement Plans for Materials	2
Project Team Materials Status Database	3	Procurement Plan for Materials and Equipment	3	Materials Delivery Schedule	3
Materials Delivery Schedule	4	Post-receipt Preservation and Maintenance	4	Material Inspection Process	4
Procurement Team	5	Materials Inspection Team	5	Materials Status Database	5
Materials Inspection Process	6	On-Site Material Tracking Technology	6	Materials Inspection Team	6
On-Site Material Tracking Technology	7	Project Team Materials Status Database	7		
Materials Inspection Team	8				
Post Receipt Preservation and Maintenance	9				

While the practice ‘material inspection process’ is given top priority for improving productivity in industrial projects in North America, the practice ‘long-lead materials identification' is found to be the most important materials management practice that could enhance productivity in multi-storey building projects in Victoria. This could be due to the materials supply chain systems in Australia in which most construction materials are imported from abroad. Wheeldon (2012) reported that most construction materials in Australia are imported from overseas due to increasing investment costs in the manufacturing sector. The findings of the qualitative data analysis revealed that tiles and façade items such as glass and aluminium are some of the most commonly imported materials because of the rising cost of these materials locally. According to Australian Bureau of Statistics, the manufacturing prices of architectural aluminium, paint and coatings, ceramic products, and glass products increases at the rates of 2.56%, 0.88%, 1.14%, and 0.71% respectively (Australian Bureau of Statistics, 2017). Thus, if the critical (long-lead) materials are not identified early, and their procurement and delivery schedules are not prepared accordingly, the project could be delayed. Therefore, contractors in Victoria State, Australia provide the highest weight for the practice 'identification of long-lead materials' to reduce the associated project delays.

The practices 'on-site material tracking technology' and 'post-receipt preservation and maintenance' are found to be not suitable for improving productivity in multi-storey building construction projects in the context of Victoria State, Australia. The findings of Phase I of the study show that most multi-storey building projects in Victoria are located in cities where there are shortages of storage spaces, and most construction materials are not stored on the building construction sites. The interview results revealed that materials are brought to the construction sites when they are needed, and they are placed close to their installation area. If more materials are stored on the multi-storey building project sites, the sites could be congested, and the potential hazards increase. The occurrence of hazards, in turn, increases the possibility of accidents which could reduce the productivity of the projects. Therefore, most contractors do not prefer to store materials on-sites. Hence,'on-site material tracking technology' and 'post receipt preservation and maintenance' are found to be not essential practices for enhancing productivity in multi-storey building projects.

By using the construction materials management practices indicated in Table 9-2 column-3, the framework which can assist contractors' project managers to improve the productivity of the multi-storey building projects is developed (Figure 9-1). The framework relates the factors which negatively influence productivity and the construction materials management practices. For instance, the shortage of construction materials has been identified as one of the critical factors that can reduce the productivity of the construction projects (Rivas et al., 2011, Jarkas and Bitar, 2012, El-Gohary and Aziz, 2014, Hughes and Thorpe, 2014). However, before the commencement of the projects, identification of the long-lead materials and preparation of the materials procurement plan; and during the construction phase, monitoring the status of the materials could assist the project managers to reduce the loss of productivity due to the shortage of materials (Figure 9-1). Moreover, delay in the delivery of construction materials is also frequently mentioned as one of the critical factors which negatively influence productivity in construction projects (Lim and Alum, 1995, Kaming et al., 1997, Thomas and Sanvido, 2000, Ghoddousi and Hosseini, 2012). On the other hand, listing all the materials required for a building project and preparing a master delivery schedule for all materials; identifying the long lead materials; and preparing separate critical materials' procurement and delivery schedules which are integrated with work schedule can help contractors to reduce the loss of productivity due to the delay in the delivery of materials (Figure 9-1).

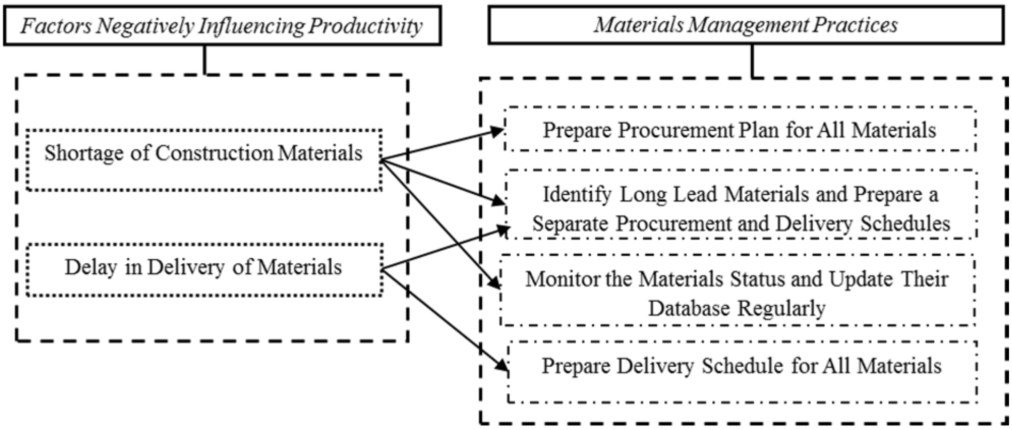


Figure 9-1 Framework of Factors Negatively Influencing Productivity and Construction Materials Management Practices

Relative Importance of the Construction Equipment Management Practices

After analysing the qualitative data, it is found that the practices construction equipment procurement plan, construction equipment productivity analysis and construction equipment maintenance are found to be the three construction equipment management practices that could improve productivity in multi-storey building projects. The results of quantitative data analysis also confirmed that the three equipment management practices are positively associated with productivity, and the relationships are statistically significant.

The findings of this study confirmed that not all construction equipment and tools management that are identified for enhancing productivity in infrastructure and industrial projects are suitable to improve productivity in multi-storey building projects. Moreover, the priorities of the practices are different. The comparisons among the construction equipment management practices for the three project types are shown in Table 9-3.

Table 9-3 Relative Importance of the Construction Equipment Management Practices in Industrial, Infrastructure, and Multi-Storey Building Construction Projects

Infrastructure Projects (CII, 2013b)		**Industrial Projects** (CII, 2013a)		**This Study**	
Construction Equipment and Tools Management Practices	*Rank*	*Construction Equipment and Tools Management Practices*	*Rank*	*Construction Equipment Management Practices*	*Rank*
Equipment Maintenance	1	Construction Machinery Productivity Analyses	1	Construction Equipment Maintenance	1
Construction Machinery Productivity Analysis	2	Construction Machinery and Equipment Maintenance	1	Construction Equipment Procurement plan	2
Site Tool and Consumables Management	3	Tools and Equipment Tracking	3	Construction equipment productivity analysis	3
Tool Tracking Systems	4	Procurement Procedures and Plans for Construction	4		
On-site Tool Maintenance	5	Site Tools and Equipment Management Strategy	5		
Control System for Tool Delays	6	Construction Machinery and Equipment Utility Requirements	6		
		On-site Tools Maintenance	6		

The practices 'site tools management strategy,' 'tools tracking systems' and 'on-site tools maintenance' are the three practices that are common to infrastructure and industrial projects (Caldas et al., 2014, Nasir et al., 2015). However, these tools management systems are found to be not suitable for enhancing productivity in multi-storey building projects. The findings of the qualitative data analysis revealed that most tools and construction materials are not stored on sites due to the shortage of the storage areas. The interviewees explained that most contractors prefer to include the cost of tools in the labour cost instead of purchasing the tools by themselves. The tradespersons bring the tools to the project sites when required. Hence, the number of tools stored on sites is minimal.

Construction equipment maintenance is found to be the most important practice that has the potential to enhance productivity in multi-storey building projects. This could be due to the presence of the local regulations which oblige contractors to carry out construction equipment inspection and maintenance. For instance, according to Clause 253 of the Work Safety and Health Regulations 2011, any person conducting a business or undertaking involving the management or control of equipment must ensure that maintenance, inspection, and testing of the equipment is carried out by a competent person. Failure to perform such tasks is an offence against the Regulation and result in a financial penalty of AUD18,000 (Work Health and Safety Regulations, 2011). Construction works could also be suspended due to the contravention of the Regulation.

In the category of construction equipment management practices, 'construction equipment procurement plan' and 'construction equipment productivity analysis' are ranked second and third respectively. The finding of the study suggests that contractors involved in multi-storey building construction in Victoria, Australia focus on selecting and hiring of the major construction equipment such as cranes and hoists to reduce the loss of productivity due to unavailability of the equipment. When the demand for construction equipment is greater than its supply, there could be shortage the machinery in the local building industry. Consequently, productivity could be negatively influenced.

Based on the findings of this study, a framework which integrates the construction equipment management practices and factors negatively influencing productivity in construction projects is developed (Figure 9-2).

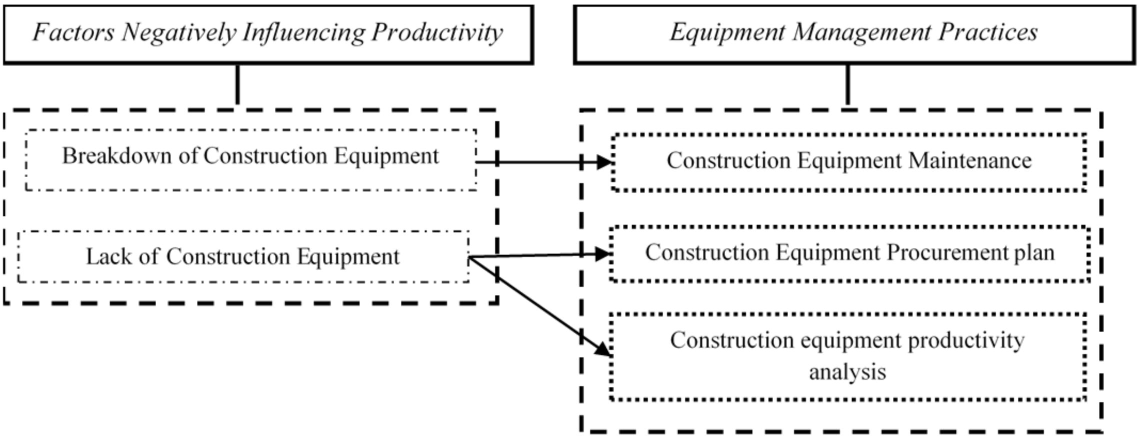


Figure 9-2 Framework of Factors Negatively Influencing Productivity and Construction Equipment Management Practices

In Australian construction industry, Hughes and Thorpe (2014) found that the lack of equipment is one of the construction projects' productivity impediments. In international contexts shortage of equipment is also mentioned as productivity deterrent (Durdyev and Mbachu, 2011, Rivas et al., 2011, Ghoddousi and Hosseini, 2012). However, the implementation of the practice 'construction equipment procurement plan' prior to starting the construction project could mitigate the loss of productivity due to the lack of construction equipment (Figure 9-2). Construction equipment procurement planning could help contractors to ensure the availability of the right equipment such as hoists with suitable speed and cranes having appropriate capacity to lift the heaviest materials on a particular site. The availability of the right equipment, in turn, facilitates the transportation of construction materials to the desired working levels; consequently, the labour productivity could be enhanced. Thus, the development of the construction equipment acquisition strategy and preparation of the equipment usage schedule on a daily basis could reduce the loss of productivity due to unavailability of the construction equipment. The practice of analysing the productivity of the construction equipment before its procurement is also essential. For instance, the procurement of hoists having low-speed and cranes with low lifting capacity could negatively influence the labour productivity. If the machinery is slow, it takes a longer time to transport the materials from ground to the required working level, and productivity can be reduced due to unavailability of the construction materials at the specific working area.

The breakdown of the construction equipment is another major factor which reduces the productivity of construction projects (Liberda et al., 2003, Makulsawatudom et al., 2004, Dai et al., 2009a, Hughes and Thorpe, 2014). However, the implementation of the practice ‘construction equipment maintenance’ can reduce the adverse effects of the problem (Figure 9-2). Preparing the maintenance schedule for equipment used in the construction of multi-storey buildings and updating the maintenance records regularly and electronically could help to reduce the breakage of construction machinery. Thus, the loss of productivity due to the breakdown of the construction equipment can be minimised.

Relative Importance of the Management Practices Related to Construction Methods

The analysis of the qualitative data revealed 10 management practices related to construction methods. These include ‘integrated schedule,’ ‘work schedule strategies,’ ‘schedule control,’ ‘dynamic site layout plan,’ ‘traffic control plan,’ ‘site security plan,’ ‘machinery positioning strategy,’ ‘project start-up plan,’ ‘project completion plan,’ and ‘innovations and new technologies.’ However, the practice ‘innovations and new technologies’ is weakly correlated with productivity. This finding is similar to the conclusion made by Rojas and Aramvareekul (2003) in which the authors stated that introduction of new techniques or technologies may be a necessary, but not a sufficient, condition to improve productivity in construction projects.

The quantitative data analysis indicated that 'traffic control plan,' 'project start-up project plan,' 'machinery positioning strategy,' 'project completion plan' and 'dynamic site layout plan' are among the five most important practices that have the potential to improve productivity in multi-storey building projects (Table 9-4 column-2). Moreover, no discernible differences among these five practices are found which implies that they should be implemented jointly to improve productivity in multi-storey building projects. For instance, the optimum location of construction machinery might not be obtained without considering the surrounding traffic and the layout of a project. Similarly, good project completion plan might not be prepared without developing clear project start-up plan.

The findings of this study confirmed that the practices that are given top priority in other project types are considered as less important to enhance productivity in multi-storey building construction projects. The comparison of the practices in industrial, infrastructure and multi-storey building construction projects is presented in Table 9-4.

Table 9-4 Comparison of the Management Practices Related to Construction Methods in Industrial, Infrastructure, and Multi-Storey Building Construction Projects

Management Practices Related to Construction Methods	**Ranks of the Practices**		
	Multi-Storey Building Projects (this study)	Infrastructure Projects (CII, 2013b)	Industrial Projects (CII, 2013a)
Traffic Control Plan	1	7	Not included
Project start-up plan	1	9	4
Machinery Positioning Strategy	3	8	4
Project Completion Plan	4	6	Not included
Dynamic Site Layout Plan	5	2	3
Schedule control	6	12	2
Work Schedule Strategies	7	10	7
Site Security Plan	7	11	8
Integrated Schedule	9	5	1
Innovations and New Technologies	10	1	10

As shown in Table 9-4, the practice 'traffic control plan' is found to be the most important practice that could enhance the productivity of multi-storey building projects; however, in infrastructure projects, the practice is not given top priority. In industrial projects, the practice is not included in the list of practices that have the potential to enhance productivity in construction projects. In Victoria State, Australia, regulations oblige contractors that use public roads during the construction periods to prepare traffic management plan. Failure to prepare the plan will result in a financial penalty and the suspension of works if accidents occur. According to Road Safety (Traffic Management) Regulations (2009), any person conducting an activity on a road or road related areas must maintain a copy of the traffic management plan on the worksite at all times when the work is undertaken, and it should be available for inspection on request by an authorised person. The absence of the plan is an offence against the Regulation. Therefore, to reduce project delay and related penalty, the contractors operating in Victoria considered traffic control plan as the most important practice.

'Project start-up plan' is found to be among the crucial practices that could enhance productivity in multi-storey building projects. The finding implies that contractors in Victoria, Australia, attempt to reduce the initial project delay by using project start-up plan which could be used as a checklist to remind the project team regarding information that is required to start a project. In the plan, the pre-commencement meeting dates, resource requirements, and any other information which could be forgotten during the commencement date can be included.

'Machinery positioning strategy' is considered as the most important practice for improving productivity in multi-storey building projects. However, the practice is rated as having less importance for enhancing productivity in infrastructure projects (Table 9-4). The finding implies that, in multi-storey building projects, the location of the critical machinery such as tower cranes should be carefully analysed for the sake of enhancing productivity. The construction systems in building projects in Victoria such as the use of heavy precast concrete panels could influence the location of the cranes. If the machine is not positioned in a suitable location, the concrete elements might not be placed as per the scheduled time. The contractor might change the design of the panels to reduce their weights or look for other alternatives to place them. Moreover, since most multi-storey building projects are in a city where there are confined spaces, the practice 'machinery positioning strategy' is found to be one of the important practices.

A framework which can assist contractors' project managers to enhance productivity is shown in Figure 9-3. The framework comprises of the management practices related to construction methods and the factors which negatively influence productivity.

The implementation of the management practices indicated in the framework (Figure 9-3) can help contractors to improve the construction projects' productivity by mitigating the adverse effects of the productivity impediments. Previous researchers identified inadequate sequencing of works as one of the productivity problems (Chan and Kaka, 2007, Dai et al., 2009a, Rivas et al., 2011, El-Gohary and Aziz, 2014). On the other hand, the implementation of the practice 'integrated schedule' can mitigate the problem. The construction schedule which integrates the commencement and completion dates of each activity, the quantity as well as the delivery dates of materials and machinery, schedules of other resources required for the execution of the activities, and the status of the activities is essential to improve productivity. Furthermore, updating the main schedule regularly and integrating the work programs of the subcontractors is significant to reduce the loss of productivity due to the overlapping of the works executed by various subcontractors.

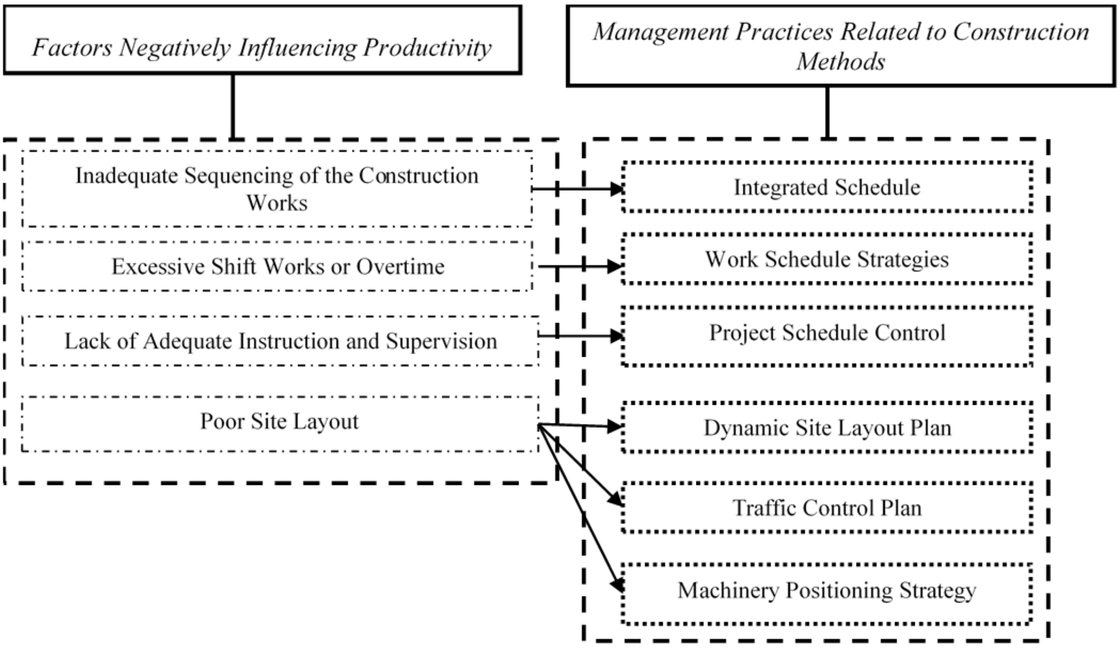


Figure 9-3 Framework of the Management Practices Related to Construction Methods and Factors Negatively Influencing Productivity

The use of excessive shift work can cause the physical tiredness that could result in the loss of productivity in construction projects (Ghoddousi and Hosseini, 2012, Jarkas and Bitar, 2012, Hughes and Thorpe, 2014). This problem can be reduced by developing different working hour strategies such as reducing the daily working hours and negotiating the suitable working hours with workers or their unions. Lack of adequate instruction and supervision is also cited as the most common factor reducing construction projects' productivity (Zakeri et al., 1996, Kaming et al., 1997, Alinaitwe et al., 2007, Rivas et al., 2011, Naoum, 2016). However, monitoring the construction works regularly, taking corrective actions and updating the construction schedules periodically can assist contractors' project managers to reduce the loss of productivity associated with supervision (Figure 9-3).

Previous researchers have confirmed that poor site layout has an adverse impact on construction productivity (Rivas et al., 2011, Ghoddousi and Hosseini, 2012, Hughes and Thorpe, 2014, Naoum, 2016). However, the implementation of dynamic site layout plan which is subjected to changes based on the phases of the building construction project, the integration of the traffic control plan with the site layout plans, and careful investigation of the position of the critical construction equipment such as cranes have the potential to improve productivity by reducing the problems associated with a site layout (Figure 9-3).

Relative Importance of the Pre-Construction Phase Management Practices

Ten preconstruction phase management practices that have the potential to improve productivity in multi-storey building construction projects in the context of Victoria, Australia are identified. These are ‘Short Interval Plan,’ ‘Well-Defined Scope of Work,’ ‘Use of Software in Planning Work Packages,’’ Dedicated Planner,’ ‘Construction Work Packages,’ ‘Buildability Review,’ ‘Utilities Alignment,’ ‘Contract Types,’ ‘Model Development,’ and ‘Regulatory Requirement.’ The quantitative data analysis showed that all the 10 preconstruction phase management practices are positively correlated with productivity.

The practice ‘Well-Defined Scope of Work’ is found to be the most important preconstruction phase management practice (Table 9-5 column-3). However, the implementation of the practice is not given top priority to enhance productivity in industrial and infrastructure projects (Table 9-5 column 1 and 2). The finding implies that scope definition is a fundamental practice in multi-storey building projects. If the scope of a building project is defined well, the more accurate completion time of each activity can be estimated, better work schedules can be prepared, variations during the construction phase could be reduced, disputes due to change orders could be minimised, and productivity can be improved. Moselhi et al. (2005) found that change orders due to not defining the scope of works have a substantial impact on the productivity of construction projects. Therefore, to reduce the loss of productivity associated with change orders, contractors operating in Victoria, Australia give priority for the implementation of the practice well-defined scope of work.

As indicated in Table 9-5, this research confirmed that the preconstruction phase management practices and their relative importance vary from project to project. Thus, implementing practices which are given more importance in one project type might not improve productivity in another project type. For instance, the implementation of the practice 'environmental requirements' is crucial to enhance productivity in infrastructure construction projects but the practice is not significant for increasing productivity in multi-storey building projects.

Table 9-5 Comparison of the Preconstruction Phase Management Practices in Industrial, Infrastructure, and Multi-Storey Building Construction Projects

Infrastructure Projects (CII, 2013b)		**Industrial Projects (CII, 2013a)**		**This Study**	
Management Practices	*Rank*	*Management Practices*	*Rank*	*Management Practices*	*Rank*
Environmental Requirements	1	Short Interval Plan	1	Well-Defined Scope of Works	1
Regulatory Requirements/ Permitting Requirements	2	Design Readiness for Construction	2	Short Interval Plan	2
Design Readiness for Construction	3	PPMOF Evaluation	3	Buildability Review	2
Utility Alignment and Adjustment	4	Well-defined Scope of Work	4	Construction Work Packages	4
Contract Types/Strategies	5	Dedicated Planner	5	Regulatory Requirement	5
Dedicated Planner	6	Construction Work Packages	5	Contract Types	6
Well-defined Scope of Works	7	Installation Work Packages	5	Use of Software in Planning Work Packages	7
Utility Agreements	8	Engineering Work Packages	8	Utilities Alignment	8
Short Interval Planning	9	Identify Required Permitting	9	Dedicated Planner	9
Construction Work Packages	10	Project Model Requirements	10	Model Development	10
Contracts and Agreement with Agencies	11	Utilization of Software to Assist in Generating Work Packages	11		
Right-of-Way, land, and Utilities Acquisition Strategy	12				
Use of Software	12				
Model Requirements/3D Visualization	14				

The finding of this research reveals that there are no significant differences among 'short interval plan,' 'buildability review,' 'construction work packages,' and 'regulatory requirement.' This implies that breaking down the project into manageable work packages alone might not be sufficient to improve productivity, the short interval plan for the work packages should be prepared, the review of the design of the specific work package should be conducted, and any regulatory requirement which affects the execution of the work package should also be identified. This suggests that the four practices should be implemented jointly to improve productivity in multi-storey building projects.

Based on the findings of this research, a framework which assists contractors' project managers to improve productivity by mitigating the adverse effects of the factors which negatively influence productivity is developed (Figure 9-4). Inadequate or lack of construction plan/schedule is one of the major factors that decrease the productivity of construction projects (Zakeri et al., 1996, Durdyev and Mbachu, 2011, Ghoddousi and Hosseini, 2012, El-Gohary and Aziz, 2014). However, this problem can be reduced by preparing detailed day to day plan or weekly work plans (short interval plans). Similarly, disruption of utilities such as power and water is among the critical factors influencing productivity (Lim and Alum, 1995, Alinaitwe et al., 2007, Ghoddousi and Hosseini, 2012). On the other hand, reviewing and listing the existing utilities, marking the location of the utilities before excavation and getting approval for connecting to the existing utilities from the concerned authorities can minimise the loss of productivity associated with the disruption of power and water supply (Figure 9-4).

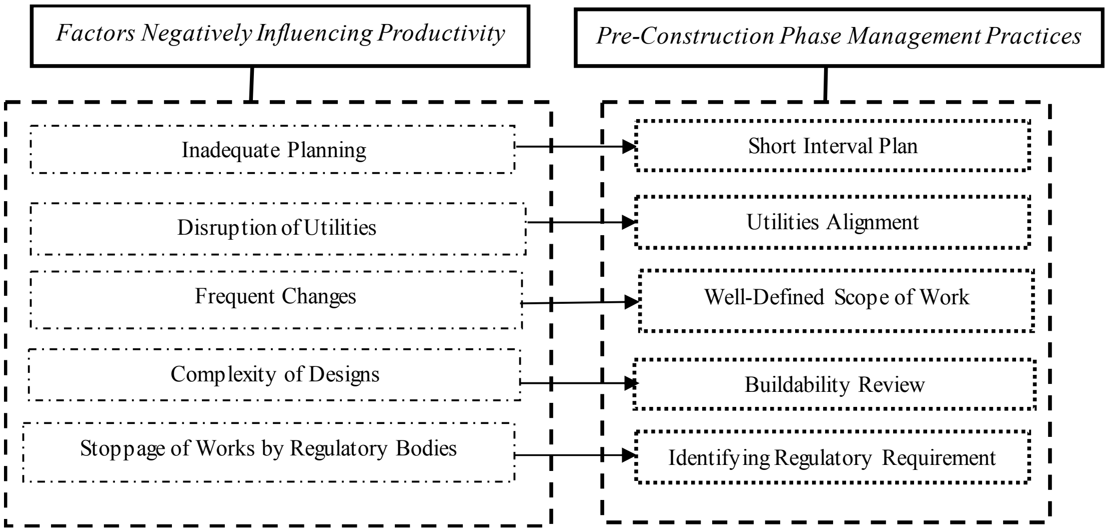


Figure 9-4 Framework of the Pre-Construction Phase Management Practices and Factors Negatively Influencing Productivity

The lack of integration between design and construction have been identified as major impediments to productivity improvement (El-Gohary and Aziz, 2014). Moreover, the complexity of designs hampers the productivity performance (Alinaitwe et al., 2007, Enshassi et al., 2009, Durdyev and Mbachu, 2011). Nevertheless, conducting buildability review before starting construction project can minimise the loss of productivity associated with the complexity of design (Figure 9-4).

Delays in getting permits and stoppage of works due to a breach of regulatory requirements are mentioned as some of the factors which negatively influence construction projects' productivity (Lim and Alum, 1995, Alinaitwe et al., 2007, Dai et al., 2009a, Durdyev and Mbachu, 2011). However, assessing the types of permits and the timeline to get them approved; integrating the expiry date of the permits in work schedule; identifying the issuing authority; and tracking the acquisition, release, and closeout of each permit could assist contractors to reduce the loss of productivity. For instance, in the city of Melbourne, contractors are required to prepare 'Construction Management Plan' and the plan should be approved before the commencement of any construction activity (City of Melbourne, 2005). In the 'Construction Management

Plan' contractors need to explain how to address issues related to public safety, amenity, and site security; operating hours; noise and vibration controls; air and dust management; storm water and sediment control; waste and materials re-use and traffic management (City of Melbourne, 2005).

Relative Importance of the Human Resource Management Practices

Eleven human resource management (HRM) practices that have the potential to improve productivity in multi-storey building projects are identified during Phase I of the research. These include 'Clear Delegation of Responsibility,' 'Stability of Organizational Structure,' 'Crew Composition,' 'Retention Plan for Experienced Personnel,' 'Employees Training,' 'Skill Assessment and Evaluation,' 'Career Development,' 'Financial Incentive Programs,' 'Social Activities,' 'Non-Financial Incentive Programs,' and 'Exit Interviews.' The findings of the quantitative data analysis (Phase II) confirmed that all the 11 HRM practices are positively associated with productivity.

The practices 'clear delegation of responsibility is found to be the most important HRM practices (Table 9-6 column-3). Naoum (2015) also found that delegation of responsibility and involvement of a site manager are the two main factors that have the greatest impact on the site manager's performance. Nitithamyong and Tan (2007) identified that clear delegation of the decision-making authority is one of the success factors for project management consulting firms in Malaysia. Thus, to enhance productivity, contractors involved in multi-storey building projects in Victoria, provide priority for the implementation of the practice 'clear delegation of responsibility.'

Table 9-6 Comparison of Human Resource Management Practices in Industrial, Infrastructure, and Multi-Storey Building Construction Projects

Infrastructure Projects (CII, 2013b)		**Industrial Projects** *(CII, 2013a)*		**This Study**	
HRM Practices	*Rank*	*HRM Practices*	*Rank*	*HRM Practices*	*Rank*
Crew Composition/ crew formation	1	Employee/ Trades Training	1	Clear Delegation of Responsibility	1
Skill Assessment and Evaluation	2	Retention Plan for Experienced Personnel	2	Stability of Organizational Structure	2
Employee/Trades Training	3	Clear Delegation of Responsibility	3	Crew Composition	3
Social Activities	4	Career Development	4	Retention Plan for Experienced Personnel	4
Financial Incentive Programs	5	Maintain Stability of Organizational Structure	5	Employees Training	5
Career Development	6	Financial Incentive Programs	6	Skill Assessment and Evaluation	6
Exit Interviews	7	Non-Financial Incentive Programs	7	Career Development	7
Non-Financial Incentive Programs	8	Exit Interviews	8	Financial Incentive Programs	8
Retention Plan for Experienced Personnel	9	Social Activities	9	Social Activities	8
Clear Delegation of Responsibility	10			Non-Financial Incentive Programs	10
Maintain Stability of Organizational Structure	11			Exit Interviews	11

As indicated in Table 9-6, the practice the 'stability of organisational structure' is one of the most important HRM practices that have the potential to improve productivity in multi-storey building projects. However, the practice is found to be one of the least important practices for enhancing productivity in infrastructure construction projects. The finding of this study suggests that contractors operating in Victoria focus on maintaining the stability of their projects' organisational structures since the frequent change in personnel could be associated with the loss of productivity due to inadequate supervision or lack of project information. There could be the loss of project information, particularly the verbal communications made with the project stakeholders if the key personnel such as project managers, site managers, and supervisors leave the project. Moreover, the recruitment of experienced construction professionals who have appropriate skills could take longer time, and the productivity of the workers is affected due to the absence of a professional who can issue the instruction.

The findings of the study revealed that there is no significant difference among the weights of the top three HRM practices: 'clear delegation of responsibility,' 'stability of organisational structure' and 'crew composition.' This implies that the three practices should be implemented jointly to improve productivity in multi-storey building projects. Thus, the practice of maintaining the stability of organisational without forming a crew that comprises of skilled personnel might not enhance productivity. Moreover, the duties and responsibilities of each staff need to be clarified.

In Figure 9-5, a framework which integrates the human resource management practices and factors negatively influencing construction projects is provided.

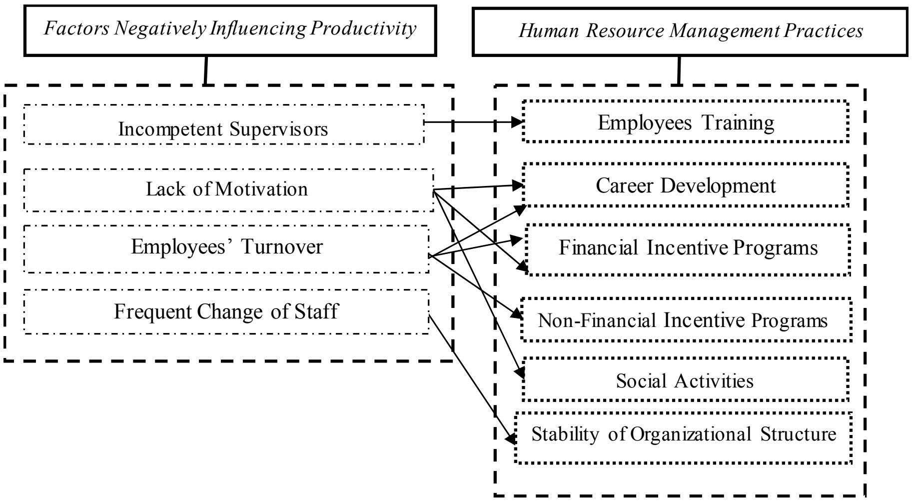


Figure 9-5 Framework of the Human Resource Management Practices and Factors Negatively Influencing Productivity

Previous researchers mentioned that the presence of incompetent or unskilled supervisors on construction sites contribute to rework and loss of productivity as they do not offer accurate information to the craftsmen (Chan and Kaka, 2007, Dai et al., 2009b, Jarkas and Bitar, 2012, Hughes and Thorpe, 2014). However, the provision of technical training after assessing the skill level of the supervisor could be an essential practice to enhance productivity (Figure 9-5). Similarly, lack of motivation by workers is frequently mentioned as one of the productivity determinants from a human resource perspective (Liberda et al., 2003, Durdyev and Mbachu, 2011, Jarkas and Bitar, 2012). On the other hand, employees could be motivated if contractor prepares the career development plan for its staff. The arrangement of financial and non-financial incentives schemes could also be essential to motivate the employees. Furthermore, the organisation of social activities at both company and project levels is necessary to motivate the employees (Figure 9-5). Loosemore et al. (2003) explained that reward is one of the reasons why the majority of individuals seek employment in the highly commercialised construction industry and those who perform well expect to be rewarded in a similar way. According to the authors, the objective of the monetary or non-monetary reward management strategy is to motivate people to work towards an organisation's goals. Thus, the implementation of the four HRM practices (Figure 9-5): ‘career development plan,’ ‘financial incentive programs,’ ‘non-financial incentive programs,’ and ‘social activities,’ have the potential to improve productivity by reducing adverse impacts of the lack of motivation of employees such as not working with full potential and absenteeism.

The other factor which negatively influences construction project’s productivity from HRM perspectives is employees’ turnover (Kaming et al., 1997, Makulsawatudom et al., 2004, Rivas et al., 2011). This problem could be reduced by the implementation of the practices ‘career development plan,’ ‘financial incentive programs,’ and ‘non-financial incentive programs’ (Figure 9-5). If the employees are motivated by using these schemes, the rate of employees’ turnover could be reduced, and the loss of construction productivity can be minimised.

Relative Importance of the Safety and Health Practices

Seven safety and health practices that have the potential to improve productivity in multi-storey building construction projects have been identified. These include ‘safety and health policy,' 'safety and health plan,' 'hazard analysis,' 'safe work method statement,' 'toolbox safety meetings,' 'housekeeping,' and 'safety and health training. The quantitative data analysis revealed that all the safety and health practices are positively correlated with productivity.

The practices 'Safety and Health Policy,' 'Safety and Health Plan,' and 'Hazards Analysis' are the top three practices in the safety and health category. However, the Friedman and Wilcoxon tests indicated that the weights of the seven safety and health practices are not significantly different from each other. This implies that all safety and health practices should be implemented jointly to enhance productivity in multi-storey building projects in the context of Victoria State, Australia. This could be due to the presence of several occupational safety and health regulations in Australia which oblige contractors to implement the safety and health practices. Failure to comply with the regulations results in financial penalty and suspension of the construction work which could be one of the causes of the loss of construction productivity. For instance, Work and Health Safety Regulations 2011 Part 6.5 Article 316 and 317 explain the duty of a contractor to ensure that the general construction induction training is provided to construction workers, and the regulation specifies the associated penalty of 18,000 Australian Dollars (AUD) for the noncompliance.

Furthermore, the presence of a strong Construction, Forestry, Mining, and Energy Union (CFMEU) could enforce contractors to implement safety and health practices. The workers might suspend the execution of the construction activities if a site is not safe. The employees can elect the health and safety representatives (HSR's) who have the power to issue Provisional Improvement Notice (PIN) and to cease work when there are urgent matters that are immediate threats to the health and safety of any person (CFMEU, 2016b). According to article 60 of the Occupational Health and Safety Act 2004, the HSR's can issue the Provisional Improvement Notice (PIN) to a contractor to remedy any contravention of the provisions of the Act. Failure to comply with the PIN can result in 2500 penalty units. Furthermore, Article 74 of the Act authorises the health and safety representatives to direct the suspension of the construction work if the work involves an immediate threat to the health or safety of any employee.

Work Health and Safety Regulations (2011) stipulates that a person conducting a business that involves high-risk construction work must, before high-risk construction work commences, prepare a ‘safe work method statement’ for the proposed work. Failure to comply would result in a financial penalty of AUD 30, 000 and suspension of the construction work. Thus, contractors in Victoria State, Australia implement the Safety and Health practices to comply with the regulations and to minimise the penalty associated with the noncompliance of the regulations such as financial penalty and suspension of works which in turn influences the productivity of the multi-storey building construction projects.

The finding of this study revealed that the relative importance of the safety and health practices in improving productivity in the multi-storey building, infrastructure, and industrial construction projects is different. Table 9-7 indicates the comparison of the safety and health practices in the three project types.

Table 9-7 Comparison of Safety and Health Practices in Industrial, Infrastructure, and Multi-Storey Building Projects

Infrastructure Projects (CII, 2013b)		**Industrial Projects** (CII, 2013a)		**Multi-Storey Building Projects** (This Study)	
Environment, Safety and Health Practices	*Rank*	*Environment, Safety and Health Practices*	*Rank*	*Safety and Health Practices*	*Rank*
Formal Safety and Health Policy	1	Substance Abuse Programs	1	Safety and Health Policy	1
Safety and Health Plan /Zero Accident Techniques	1	Toolbox Safety Meetings	2	Safety and Health Plan	2
OSHA Compliance Training	3	OSHA Compliance Training	3	Hazards Analysis	2
Hazards Planning	3	Zero Accident Techniques	4	Safe Work Method Statement	4
Hazard Analysis	5	Task Safety Analysis	5	Toolbox Safety Meetings	5
Task Safety Analysis	6	Identification of Potential Hazards	6	Housekeeping	6
Toolbox Safety Meetings	7	Housekeeping	7	Safety and Health Training	6
		System Test Hazards Planning	8		

While ‘substance abuse program’ is the most significant practice to improve productivity in industrial projects, the practice is found to be not relevant to enhance productivity in multi-storey building projects (Table 9-7). The finding of the qualitative data analysis revealed that testing construction workers for substance abuse is not common in building construction projects in Victoria, Australia. However, since September 2015 the Australian Government made amendments to the Building Code 2013 which requires contractors to have a comprehensive policy for managing drug and alcohol issues including mandatory drug and alcohol testing on Commonwealth funded projects that meets the financial threshold (Building Code (Fitness for Work/Alcohol and Other Drugs in the Workplace) Amendment Instrument, 2015). The code stipulates that if the value of a building work is at least AUD 5,000,000 and represents 50% of the total construction value or if the Commonwealth’s contribution to the project exceeds AUD 10, 000,000, drug and alcohol test should be conducted. The qualitative data of this thesis was collected prior to the amendment of the Building Code 2013, and the survey participants described that the practice is not significant for building projects. However, after the modification of the Code, the practice might be important.

Based on the findings of this study, the framework which integrates the safety and health practices and the factors negatively influencing productivity is developed (Figure 9-6).

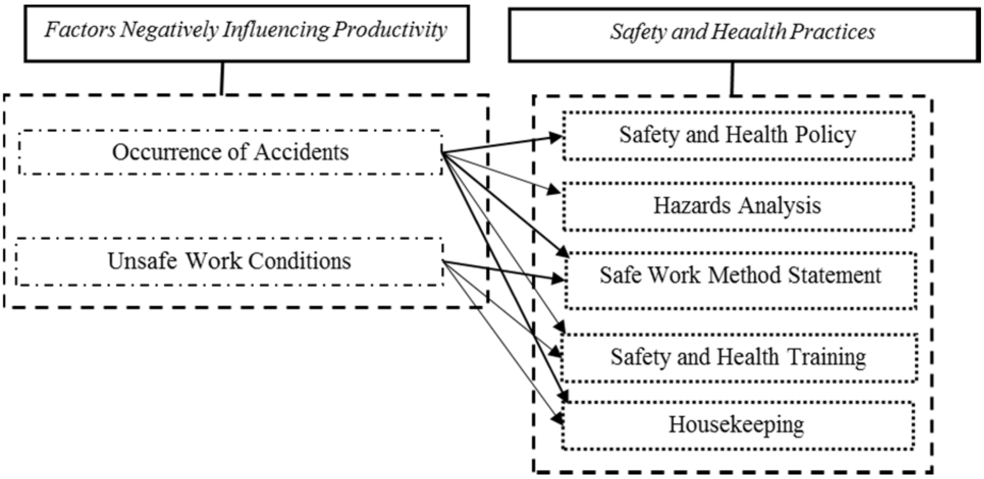


Figure 9-6 Framework of Safety and Health Practices and Factors Negatively Influencing Construction Projects' Productivity

The occurrence of accidents in construction sites is mentioned as some of the main factors negatively influencing productivity in construction projects (Enshassi et al., 2007, Kazaz and Ulubeyli, 2007, Jarkas and Bitar, 2012, Hughes and Thorpe, 2014). However, the loss of productivity due to accidents could be reduced by preparing and monitoring the implementation of safety and health policies such as drug and alcohol policy and UV protection policy on each building construction site; and by conducting a hazard analysis for both 'high-risk construction work' and 'works of minor nature' (Figure 9-6). Safe Work Australia (2014a) states that Safe Work Method Statement (SWMS) which include the hazard analysis for high-risk construction works should be prepared, and attention should also be given to the 'work of minor nature' as they could be hazardous.Therefore, conducting a hazard analysis for both low-risk and high-risk works could be essential to reduce accidents in construction sites. Moreover, conducting general induction and site specific safety training is important to create awareness for employees regarding the possible hazards on the specific project and to reduce the number of accidents. Housekeeping is also noteworthy in reducing accidents. For instance, if sharp or other unwanted materials are cleared from a building site, on a regular basis, the chance of occurring accidents on the specific project could be minimised.

Unsafe work conditions such as noise, dust, radiation, poor ventilation, low lighting, limited access, unavailability of personal protective equipment and other related conditions have negative effects on productivity (Liberda et al., 2003, Enshassi et al., 2007, Ghoddousi and Hosseini, 2012, El-Gohary and Aziz, 2014). However, the implementation of appropriate risk control measures which are proposed while preparing the SWMS's could reduce the loss of productivity due to unsafe work conditions (Figure 9-6). In the SWMS, the list of the work tasks is presented in a logical order, the potential hazards and risks associated with each task are identified, and the control measures for the potential risks are described (Safe Work Australia, 2014). Safety and health training is essential to ensure the compliance with the proposed control measures such as the proper use of the personal protective equipment (PPE). Safety training is also beneficial before using new construction equipment. Safe Work Australia (2013) explained that the risk control measures in construction projects include thorough training regarding the use of PPE and effective supervision to ensure that the workers comply with the safety requirements. Therefore, the implementation of the practices safe work method statement, safety and health training, and housekeeping in multi-storey building construction sites could minimise unsafe work conditions and improve productivity.

9.3 Relationships among the Construction Management Practices

This section presents the discussion of the findings of the correlation analyses conducted to investigate the relationships among the 47 construction management practices (subsection 9.3.1). The findings of the correlation analyses of the practices within their respective categories are discussed in this section (subsection 9.3.2).

9.3.1 Associations among All Construction Management Practices

The findings of this study indicate that the practices categorised under 'construction materials management practices' are strongly correlated with practices categorised under 'construction equipment management practices.' This could be due to the type of construction materials which are used in Victoria in which most materials are mainly prefabricated or preassembled elements which need construction equipment or cranes for lifting purpose. According to PrefabAUS (2014), the prefabricated construction system in Australia is increasing at about 5% per year. If a crane which has the capacity to lift the heaviest materials is not procured and the crane usage is not scheduled on a daily basis, there could be the loss of productivity due to unavailability of materials since the materials might not be transported to the location close to their installation area. Among the three practices which are categorised under construction equipment management practices, 'Procurement Plans for Construction Equipment' is strongly correlated with the practices categorised under 'construction materials management practices.'

The practices in the 'management practices related to construction methods' category are strongly associated with the practices in 'preconstruction phase management practices' category. The regulatory requirement (the practice categorised under pre-construction phase category) is strongly correlated with traffic control plan (the practice categorised under management practices related to construction methods). This indicates that, in the context of the Victorian construction industry, depending on the location of projects, regulatory bodies oblige contractors to prepare the traffic management plans. For instance, Road Safety (Traffic Management) Regulations (2009) dictates that any person conducting an activity on a road or road related areas must maintain a copy of the traffic management plan on the worksite at all times. The practice machinery positioning strategy (in the management practices related to construction methods category) and utilities alignment (in the pre-construction phase management practices category) are strongly associated. This shows that the contractors need to investigate the presence of the existing utilities such as electricity, water and gas before locating the construction machinery, for instance, the tower cranes. To place the foundations of the tower cranes, excavation works are carried out, and the existing utility lines could be affected. The practices project completion plan (in the management practices related to construction methods category) and buildability review (in the pre-construction phase management practices category) are also strongly correlated which indicates that conducting buildability review is essential for the completion of a building project as per the planned time. If a design is not constructible, the project could incur the loss of productivity as the modification of the design might take a long time and the operatives could wait until the design is completed. However, the intended completion date could be attained if buildability reviews are carried out. Pheng Low (2001) concluded that building projects with higher buildability scores tend to achieve correspondingly higher productivity levels.

The practices in the category of ‘human resource management practices (HRM)’ are strongly correlated with the practices categorised under ‘preconstruction phase management practices,’ ‘construction equipment management practices,’ and ‘management practices related to construction methods.’ The practices crew composition (in HRM practices category) and short interval plan (in pre-construction phase management practices category) have a strong correlation which implies that to improve productivity in building projects, the short interval plan should specify the type of crews such concreting and plastering crews as well as the number of crew members that will be deployed on a specific date. If the plan does not contain such information, there could be an overlap of the crews, and the working site might be overcrowded which could lead to the loss of productivity. Enshassi et al. (2007) found that the increment of the workforce on a construction site causes overcrowding of labour and interference among the crews which consequently reduce the labour productivity in construction projects. Thus, contractors in Victoria integrates the practices crew composition and short interval plan to improve productivity in their building projects.

The stability of organisational structure (in HRM practices category) and procurement plan for construction equipment (in construction equipment management practices category) have high correlation coefficient. This implies that if the organisational structure of a project is stable, the chance of missing information regarding the procurement of equipment such as oral communications made with equipment suppliers could be low since a person who is involved in the procurement process might not leave a project or a company. On the other hand, frequent change of the project staff who planned the procurement of equipment could lead to delay in the delivery of the equipment which could be associated with the loss of productivity and cost overrun. Manavazhi and Adhikari (2002) found that delay in the procurement of the construction equipment is one of the causes for cost overrun in the road projects. Therefore, contractors in Victoria maintain the stability of their projects’ organisational structure for the ease of monitoring the procurement process of the construction resources and minimising the loss of project information.

The HRM practices ‘career development’ and ‘employees training’ are strongly associated with the project completion plan (one of the practices in the management practices related to construction methods category).The findings indicate that motivating employees by providing training and preparing career development plan could help to achieve the planned project completion date. If employees are motivated, they might not leave a project and contribute to the successful completion of the project their full potential. Loosemore et al. (2003) explained that employees development program helps to ensure that the employees have the skills required for their current roles, and it can also be a motivating factor since the significant training and development indicate a commitment to people and the recipients are more likely to feel valued.

The practices in ‘safety and heath practices’ category are positively and strongly correlated with practices categorised under ‘construction equipment management practices.’ This implies that construction equipment is one of the major hazards that could result in accidents, and an increase in the implementation level of the construction equipment management practices could lead to increased safety and health practices. The practice hazards analysis (in Safety and Health practices category) and construction equipment maintenance (in Construction Equipment Management practices category) are strongly associated which implies that maintaining construction equipment could reduce accident rates in building construction projects. For instance, forklifts related risks such as the death of pedestrians due to being struck by the forklift or being hit by loads as well as the injury or death of operators due to tip over could be reduced by providing necessary maintenance to the equipment. WorkSafe Victoria (2006) states that forklift is one of the most dangerous pieces of equipment found at Victorian workplaces, and maintaining the equipment plays a major role in reducing the risks posed by forklifts. Work Health and Safety Regulations (2011) stipulates that contractors must ensure that the maintenance, inspection, and testing of the equipment (crane) are carried out by a competent person. Failure to comply with the provision of the regulation is an offence and results in a financial penalty or suspension of construction works. Thus, to meet the regulatory requirement and to minimise the potential hazard associated with construction equipment, contractors operating in Victoria maintain their construction equipment.

The practices safe work method statement (in safety and health practices category) and traffic control plan (in management practices related to construction methods category) are strongly related. The finding implies that by preparing effective traffic management plan, the risks associated with the execution of a particular task could be minimised as pedestrians can be separated from hazardous equipment such as forklifts and trucks. According to WorkSafe Victoria (2006), an effective traffic management plan uses a range of devices including pedestrian and forklift exclusion zones, safety zones for truck drivers, safety barriers, containment fences, and reduced speed limiting devices such as smart forklifts and traffic signs. As a result, the plan helps to reduce accidents.The strong relationship between the practices safe work method statement (SWMS) and traffic control plan implies that preparation of safe work method statement is essential to safely set up, maintain and remove the traffic control systems. The traffic control activities can be classified as high-risk construction work that requires SWMS since the activities are carried out adjacent to a road and involve the movement of the powered mobile equipment (for example, forklifts). According to Victorian Occupational Health and Safety Regulations (2007), construction work on or adjacent to roadways or railways used by road or rail traffic, or construction work conducted at workplaces where there is any movement of the powered mobile equipment is considered as high-risk, and the work requires SWMS. Article 5.1.9 of the regulation stipulates that if there is non-compliance with the SWMS, the contractor should stop the work immediately or as soon as it is safe to do so. Thus, to comply with the regulation and to avoid the stoppage of the construction activities due to unavailability of SWMS, contractors in Victoria prepare SWMS for the traffic control related tasks.

9.3.2 Inter-Relationships among the Practices within Their Categories

Relationships among the Construction Materials Management Practices

The findings of this study indicate that all the six construction materials management practices are positively correlated to each other, and the associations have various degrees of strength. This implies that as the implementation level of one construction materials management practice increases, the implementation level of another practice also increases. The quantitative data analysis revealed that ‘long-lead materials identification’ and ‘procurement plan for materials’ are strongly correlated. This shows that listing all materials required for the construction of a specific building project and preparing the overall materials procurement plan can assist the project planner/ manager to identify the most critical or long-lead materials whose delay might result in the loss of productivity. In other words, the practice of ‘preparing procurement plan for all materials’ could assist the contractor’s project team not to miss the most critical materials that are required to deliver a building project on time. In the context of Australia where most materials are imported from overseas (Wheeldon, 2012), the construction of building projects could be delayed due to the late delivery of the long-lead materials unless they are identified and ordered early. The practice ‘material inspection process’ and ‘materials inspection team’ are also strongly associated. This implies that forming the construction materials’ inspection teams, who are experienced, could help to prepare better materials inspection procedures since the team members could have better understanding of the materials’ specifications and standards.

Relationships among Construction Equipment Management Practices

The three construction equipment management practices: ‘Construction Equipment Maintenance,’ ‘Construction Equipment Procurement Plan,’ and ‘Construction Equipment Productivity Analysis’ are correlated, and the relationships are statistically significant. The practices ‘construction equipment procurement plan’ and ‘construction equipment productivity analysis’ are strongly associated. This indicates that preparation of equipment procurement plan without analysing the productivity of the machinery might not improve productivity in building projects.

Relationships among Management Practices Related to Construction Methods

The findings of this study indicated that the 10 management practices categorised under construction methods are positively correlated. However, the practices ‘traffic control plan’ and ‘site security plan;’ ‘machinery positioning strategy’ and ‘dynamic site layout plan;’ ‘project completion plan’ and ‘work schedule strategies;’ and ‘schedule control’ and ‘integrated schedule’ are strongly associated.

The findings imply that site security systems need to be considered while preparing the traffic control plan. For instance, if the traffic control plan is poor, the security cameras, their power cords, as well as the site fences could be hit by the vehicles moving in and out of the building sites. Thus, the traffic control plan and site security plan are inter-related. Similarly, effective site layout plan should consider the positions of cranes, hoist and other construction equipment that is deployed at a certain building construction project. If the two practices ('site layout plan' and 'machinery positioning strategy') are not harmonised, productivity could be affected as the location of the construction materials might be far from the position of the crane and the materials could not be transported efficiently to the required working area or level. This could result in the lack of materials which in turn influences the productivity of the construction workers.

The practices project completion plan and working schedule strategies are also strongly associated which implies that the better the working schedule strategies are, the better the project completion plan will be. The working schedule which is prepared by considering the workers' physical fatigue and by involving supervisors and/or other workers who can suggest appropriate working times could help the contractor's project manager to prepare more feasible project completion plan. The chance of achieving the planned completion dates could be higher as the supervisors who are closely monitoring the activities of the labourers are involved in the development of the most suitable working hour strategy.

The practices 'schedule control' and 'integrated schedule' are also strongly correlated. The finding indicates that if different schedules are integrated together, monitoring the progress of construction works could be easier since the supervisor or the project manager can get all the required information in one document. In the integrated schedule, the main work schedule; current work status; materials delivery status; the materials, machinery, and manpower schedule; and other information such as detailed drawings are found in one place and supervisor can easily control the works using the available information. Thus, the probability of the loss of productivity due to lack of project information could be reduced.

Relationships among Preconstruction Phase Management Practices

The findings of the correlation analysis show that the practice 'construction work packages' is strongly related to 'short interval plan' which indicates that to improve productivity in multi-storey building construction projects, short interval plan should be prepared for each work package. The practice 'regulatory requirement' and 'short interval plan' are also strongly correlated. This shows that the type of permits and the dates when the permits expire need to be incorporated in the short interval plan. The practices 'contract types' and 'well-defined scope of works' are strongly associated which implies that the level of defining the scope of the construction work package depends on the type of contracts. For example, in design and construct delivery system, the project scope might not be developed in detail at the beginning of the construction project. However, in ‘construct only’ delivery system the scope of works should be defined during the tendering phase to reduce changes and the associated productivity loss during the construction phase.

The use of software in creating work packages is also strongly associated with the short interval plan. The finding implies that the use of software could help not to miss activities within a work package which might be forgotten if the work breakdown is conducted manually. If the activities are not missed, their durations can be estimated, the volume of works can be estimated, and their execution dates and the required resources can be planned. Thus, the use of software assists in preparing better short interval plan. The practices ‘buildability review’ and ‘construction work package’ are strongly correlated which indicates that conducting buildability review for each work package could enhance productivity in multi-storey building projects. If the design of the work package is complex and could not be implemented easily, the productivity of a project could be negatively influenced.

Relationships among Human Management Practices

There is a strong association between the practices ‘crew composition’ and ‘skill assessment and evaluation’ which implies that unless the skill level of a construction worker is known, it might not be feasible to form a crew which is more productive. For instance, the skill level of the contractor’s supervisors should be assessed and evaluated before forming the supervision team. Supervisors with low skill level might not communicate the project information via drawings, specifications or other mechanisms to the operatives; as a result, there could be the inadequacy of information which could be associated with the loss of productivity. Tabassi and Bakar (2009) explained the effects of unskilled construction workers in construction projects in Iran. The authors found that project delay, extra costs, and low quality of construction are the consequences of employing unskilled employees. Similarly, Doloi et al. (2012) found that some of the causes of poor labour productivity in Indian construction projects are the employment of unskilled labour and inefficient management skills of the supervisor on the site. Therefore, integration of the practices ‘crew composition’ and ‘skill assessment and evaluation' is essential to enhance productivity in multi-storey building projects the context of Victoria State, Australia.

The practices 'Skill Assessment and Evaluation' and 'Financial Incentive Programs' are strongly associated which implies that as the skill evaluation criteria for selecting certain employee increases, the corresponding financial incentives could also be high. If the financial incentive scheme is low, the chance of getting an employee with better technical as well as managerial skill can also be low. Loosemore et al. (2003) explained that reward is one of the main reason why the majority of individuals seek employment in the construction industry, and those who perform well or highly skilled expect to be rewarded accordingly. The Australian Fairwork Commission also sets minimum wage according to the skill level of employees in the construction industry. The Commission prepared the 'building and construction general on-site award 2010' which specifies the minimum wages which correspond to the skill levels of general construction workers (Construction Workers (CW) level 1 to CW level 8) and engineering construction workers (Engineering Construction Workers (ECW) level 1 to ECW level 9)(Fair Work Commission, 2016). Accordingly, while the minimum hourly wage for CW level 1a in the year 2015/2016 is AUD 18.61, the minimum hourly wage for CW level 8 is AUD 23.69. Thus, there is a relationship between skill level and financial incentives.

'Career Development Plan' and 'Financial Incentive Programs' are among the human resource management practices which are strongly correlated. The finding implies that construction firms that have career development plans for their employees also arrange financial incentive programs to motivate their workers. The practices 'Non-Financial Incentive Programs' and 'Financial Incentive Programs' are also strongly associated. The finding indicates that financial incentive schemes alone might not motivate employees. Non-financial incentive programs should supplement the financial incentives. Fagbenle et al. (2004) found that both financial and non-financial incentive schemes have a positive impact on the productivity, but non-financial incentive scheme is more important. Loosemore et al. (2003) explained that the balance between the monetary and non-monetary rewards depend on internal and external factors such as the financial state of a company, competition within the labour market, and the policies of its rivals.The authors suggested that during the construction boom, there could be a greater emphasis on a monetary reward if rival employers are offering relatively high wages. Therefore, there is a relationship between financial and non-financial incentive schemes.

The relationship between ‘Stability of Organisational Structure’ and ‘Retention Plan for Experienced Personnel’ is strong and statistically significant.The finding shows that to have stable organisational structure, contractors should plan how to retain experienced project managers and other key staff as they could have better skills. According to Nitithamyong and Tan (2007), project management skills are aquired when the manager work with people of different organisational levels from multidisciplinary fields. The authors emphasised that besides the technical knowledge, the project managers should have better managerial skills. Thus, contractors need to retain experienced or key professionals so that the stability of the organisational structure is maintained and productivity could be improved.

Relationships among the Safety and Health Practices

The quantitative data analysis revealed that all the safety and health practices are positively correlated. However, ‘safety and health policy’ ‘safety and health training’ are strongly associated. The finding implies that to improve productivity in multi-storey building projects, safety and health training should be included in the safety and health policy prepared at company and project levels. For instance, the policy could explicitly state that workers who do not complete general induction training and get a certificate of completion or construction induction card should not start working on a particular building project. This practice could help to reduce the rate of accidents in the building projects. In Victoria, the regulatory bodies oblige contractors to accept alternative evidence of completing induction training and contractors need to consider these options in their safety policies. The ‘red card’ which shows the completion of the previous Victorian Construction Industry Basic Induction Course; the white card or a construction induction card issued by WorkSafe Victoria after the successful completion of induction training by registered training organisation (RTO); and a statement of attainment issued by an RTO until the issuance of construction induction card can be considered as evidence for completion of the safety training (WorkSafe Victoria, 2008b). Thus, safety training and safety policy can be inter-related.

9.4 Applications of the Scoring Tools and Prediction Models

This section provides the discussions of the findings obtained to achieve: Objective 2 or "to refine and validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects," and Objective 3 or "to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices." The section demonstrates how the scoring tools of the management practices and the regression models of productivity and the practices are used during the planning stage of a multi-storey building project (subsection 9.4.1). It also presents how the scoring tools are used during the construction and the project closure phases in subsection 9.4.2 and 9.4.3 respectively.

9.4.1 The Use of the Construction Management Practices Scoring Tools and the Logistic Regression Models during Project Planning Phase

The scoring tools of the overall construction management practices and the logistic regression model of productivity and the practices can assist the contractor's project manager to plan appropriate practices that can be implemented on a certain multi-storey building construction project. The project manager can make necessary decisions to improve the productivity of a certain multi-storey building project after assessing the risk of low productivity by using the tools and the model. Suppose a project manager plans to implement the practices indicated in Table 9-8. For the practice procurement plan for construction materials, the manager plans to implement "a procurement plan and schedule exists only for large materials and costly items" which is Level C, and the equivalent score for this practice is 0.34. For the practice long-lead materials identification, he/she plans "a procurement plan and schedule exists for long-lead materials" (Level C and score of 0.37) ; for materials status database, the manager plans "there is a formal paper based system to track materials status" (Level C and score of 0.26); for the practice materials delivery schedule, "materials delivery is planned early in the project and is integrated with a project schedule" has been planned (Level C and score of 0.30); for materials inspection process, "materials inspection is made for all items delivered to the site, there is a lack of organization of the inspection process and materials are not separated into stages of the receipt process nor does it record the location of the materials, and the materials are not marked for tracking" is chosen

(Level D and score of 0.42); and for the practice materials inspection team, the manager plans "materials inspections are performed by project manager or another worker rather than materials inspection team" (Level D and score of 0.34).

By using a similar procedure, based on the chosen levels of implementation of each practice, the equivalent score for other practices are computed, and the total score for the particular project is found to be 15 (Table 9-8). Then, by using the sigmoid graph of the overall management practices (Figure 9-7), the probability of exceeding PF=0.90 is 17%. This implies that the actual productivity could be low and the risk of occurring project delay is high. Thus, the project manager should plan to implement higher levels of the management practices and read the probability from the graph until the desired level of productivity is achieved. Therefore, the model and the scoring tools can assist the project manager in planning suitable management practices that are to be implemented on a certain multi-storey building project.

Table 9-8 Illustration of the use of the Scoring Tools of the Construction Management Practices

Construction Management Practices	Level	Verbal Description	Score
Procurement Plans for Materials	C	A procurement plan and schedule exists only for large materials and costly items.	0.34
Long-Lead Materials Identification	C	A procurement plan and schedule exists for long-lead materials.	0.37
Materials Status Database	C	There is a formal paper based system to track materials status.	0.26
Materials Delivery Schedule	C	Materials delivery is planned early in the project and is integrated with a project schedule.	0.30
Material Inspection Process	D	Materials inspection is made for all items delivered to the site. There is a lack of organization of the inspection process and materials are not separated into stages of the receipt process nor does it record the location of the materials. The materials are not marked for tracking.	0.42
Materials Inspection Team	D	Materials inspections are performed by project manager or other worker rather than materials inspection team.	0.34
Construction Materials Management Practices Sub-Total Score			***2.03***
Procurement Plan for Construction Equipment	B	Construction equipment procurement plan is not prepared for this building project.	0.14
Construction Equipment Productivity Analysis	A	Construction equipment is not used in this building project.	0.00
Construction Equipment Maintenance	B	Construction equipment maintenance is not planned for this building project.	0.16
Construction Equipment Management Practices Sub-Total Score			***0.30***
Integrated Schedule	D	Developing a schedule with resources present but not linked to earned percent complete progress from associated deliverables per activity.	0.39
Work Schedule Strategies	D	Strategy considers multiple work schedules considering critical and near critical activity sequences.	0.44
Schedule Control	D	Consistent follow-up to update schedules periodically, conduct critical path analysis, and prepare progress narrative as required. There is effective team participation in schedule updates. Quantity reports are regularly performed. Upon request, or as the project requires, may include any of the following: change management analysis, risks assessment analysis, date variance analysis, communication with material suppliers to ensure material will arrive on site as per the plan.	0.46
Dynamic Site Layout Plan	C	The project team examines the project schedule and assesses when Temporary Facilities (TF) will be brought in.	0.33
Traffic Control Plan	C	The project has some traffic control plans, and it is used on a reactive basis.	0.34
Site Security Plan	C	There is control during enty and exit from the site, but does not have any other formal security system throughout the site.	0.29
Machinery Positioning Strategy	C	Heavy rigging and lifting studies are accomplished on all critical lifts including evaluation of the machinery, rigging selection, and crane location.	0.33
Project start-up plan	C	A basic start-up plan has been developed with input from the project participants, but the plan has not been implemented.	0.34
Project Completion Plan	C	The project has a handover procedure that defines the parameters of project completion and delineates the requirements for the handover.	0.33
Innovations and New Technologies	C	The project does not have a formal program for the investigation of innovations and new technologies. Implementation of innovations and new systems will only occur after the industry-wide implementation.	0.25
Management Practices Related to Construction Methods Sub-Total Score			***3.51***
Short Interval Plan	D	Short interval plan indicates the required materials, tools and equipment, labour, and project information required to complete each task, and activities in the project schedule are not resource loaded.	0.53
Well-Defined Scope of Work	D	Execution is controlled with a master schedule. The design is completed and buildability review has been performed.	0.58
Use of Software in Planning Work Packages	C	The project uses a software system to generate and track work packages. The system is not integrated. Materials, drawing and other information are entered manually. Percent complete is also entered mually by reviewing the statust of workpackage.	0.31
Dedicated Planner	C	Single planner or multiple personnel who prepare initial project schedule and coordinate materials procurement process are assigned.	0.24

Continuation of Table 9-8

Construction Management Practices	**Level**	**Verbal Description**	**Score**
Construction Work Packages	D	All information required for execution of each Construction Work Package (CWP) has been addressed. The information in each sections displays no in-depth consideration.	0.51
Buildability Review	D	The contractor has prepareed a detailed schedule for all phases of construction after conducting detailed buildability review.	0.53
Utilities Alignment	C	The project has a review process for working in areas surrounding utilities. The process includes list of utilities, locations, and warning signs.	0.30
Contract Types	D	The project has a review process for the contract types. It considers fee structure and financing options. Risks associated with different contract types are also considered. Cost benefit analysis for different types of contracts are performed.	0.46
Model Development	C	A 4D Model has been established for the project.	0.22
Regulatory Requirement	C	Initial investigations based on the type of permits; timeline to get the permit approved; the validity period of the permit; the authority issuing the permit; pre-inspection requirements; and fees have been conducted.	0.34
Pre-construction Phase Management Practices Sub-Total Score			***4.02***
Crew Composition	C	Crew formation is addressed after the commencement of the construction of the building project.	0.31
Skills Assessment and Evaluation	C	Skills assessment is addressed after the beginning of the construction this project.	0.30
Employees Training	C	Employees Training is addressed on the jobsite after the beginning of the project.	0.30
Career Development	C	The organization does not have a formal career development plan for employees, but the management will discuss future plans with them infromally.	0.28
Non-Financial Incentive Programs	C	The organization has an informal recognition programs that will recognize employees occasionally, but not in a formal manner.	0.26
Financial Incentive Programs	C	The organization has an informal incentive program that provides incentives occasionally, but not in a formal manner.	0.27
Social Activities	C	The organization does not formally plan social activities for the employees, and there is only a yearly organization wide social activity.	0.27
Stability of Organizational Structure	C	The key professionals are named or defined in the contract.	0.33
Clear Delegation of Responsibility	C	There is simple and very formal delegation of responsibility.	0.33
Retention Plan for Experienced Personnel	C	Each project manager is responsible for retention of his workers.	0.31
Exit Interviews	C	There is exit interview for key personnel only.	0.23
Human Resource Management Practices Sub-Total Score			***3.18***
Housekeeping	D	Housekeeping occurs on a bi-weekly basis.	0.53
Safety and Health Policy	D	There is health and safety policy at company and project levels. The policy is documented and publicized; it deals with the health and safety of workers, and it is periodically updated based on the organizational and industry feedback.	0.57
Safety and Health Plan	D	Most but not all accident reduction techniques are utilized on the project.	0.55
Safe Work Method Statement	D	Safe Work Method Statement (SWMS) is prepared and utilized for most tasks on this project.	0.09
Hazards Analysis	D	Hazards are identified for most tasks that are not covered in SWMS.	0.10
Safety and Health Training	D	There is project specific induction regarding personal protective equipment, housekeeping and access to site, and others. Supervisors receive additional induction on safety meetings, first aid and medical treatment processes. Some employees should pass fitness for duty testing prior to starting construction of some tasks.	0.07
Toolbox Safety Meetings	D	The project conducts a weekly meeting at or near breaks. Meetings reiterate job site safety rules.	0.08
Health and Safety Practices Sub-Total Score			***2.00***
Total Construction Management Practices Score			**15.03**

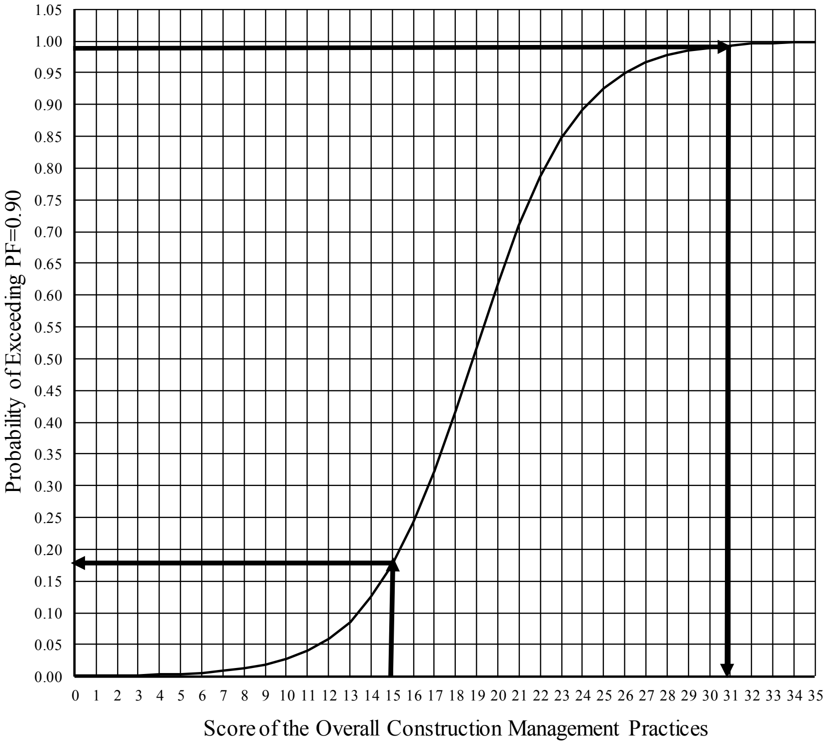


Figure 9-7 Illustration of the Application of the Probability Graph of the Overall Construction Management Practices

The project manager can also fix the desired probability of exceeding PF=0.90, read the equivalent score, and plan appropriate practices for a certain multi-storey building project. For instance, for 99% chance of exceeding the baseline PF, the corresponding construction management practices score is 31 (Figure 9-7). After reading the score from the graph, the management practices can be planned as shown in Table 9-9. For example, the implementation level of the practice long-lead materials identification can be chosen as Level F or “a separate procurement plan and schedule exists for long-lead materials. There is an established protocol for identifying reputation of potential vendors for the long-lead materials. The plan identifies necessary equipment and onsite resources to support the delivery of the long-lead materials. The procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.” The other management practices can be planned as shown in Table 9-9 to get the overall score of 31. Thus, the project managers of a multi-storey building can follow similar procedures to plan suitable practices for their projects.

Table 9-9 Planning the Management Practices Based on a Predetermined Probability Value

Construction Management Practices	**Level**	**Verbal Description**	**Score**
Procurement Plans for Materials	F	A procurement plan includes all materials and consumables. It identifies necessary equipment and onsite resources to support delivery. There is also an established protocol for identifying reputation of potential vendors. The procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.	0.85
Long-Lead Materials Identification	F	A separate procurement plan and schedule exists for long-lead materials. There is an established protocol for identifying reputation of potential vendors for the long-lead materials. The plan identifies necessary equipment and onsite resources to support the delivery of long-lead materials. The procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.	0.92
Materials Status Database	E	An available software is used to track materials, but it is only integrated internally with the company's project control systems.	0.53
Materials Delivery Schedule	F	Materials delivery is planned early in the project and is integrated with a project schedule. The schedule is automatically updated on receipt of new information as procurement proceeds. The schedule is automatically linked with procurement, materials management, and overall project scheduling systems. Materials delivery planning and management is completely integrated with other automated project processes including automated materials tracking throughout the supply chain.	0.75
Material Inspection Process	E	The materials inspection is made for all items delivered to the site. The inspection is conducted during manufacturing and onsite. Materials inspections are organized immediately upon delivery of materials, the materials are verified if they conform to the standards, and they are arranged for on-site tracking.	0.56
Materials Inspection Team	D	Materials inspections are performed by a project manager or another worker rather than materials inspection team.	0.34
Construction Materials Management Practices Sub-Total Score			***3.95***
Procurement Plan for Construction Equipment	D	Construction equipment procurement strategies such as hiring or leasing are prepared for this building project. There is a procedure for identifying reputation of potential equipment suppliers.	0.41
Construction Equipment Productivity Analysis	D	Construction equipment requirements are planned and tracked but they are not tied to a schedule. The usage is tracked against budget only. Regular meeting is conducted to assess the requirement of construction equipment.	0.37
Construction Equipment Maintenance	E	Construction equipment maintenance record is linked to individual construction equipment, and maintenance is centrally scheduled and administered. A computer program is used to record and administer equipment maintenance information such as the required and accomplished maintenance logs and usage logs.	0.63
Construction Equipment Management Practices Sub-Total Score			***1.41***
Integrated Schedule	E	Developing a schedule with resources present but not linked to earned percent complete progress from associated deliverables per activity. Resources are updated to reflect current work content or quantity adjustments.	0.53
Work Schedule Strategies	E	Strategy considers multiple work schedules considering critical and near critical activity sequences. It also considers the potential impact on worker fatigue, supervision, safety, and absenteeism.	0.58
Schedule Control	F	The schedule is rigorously updated based on manual input of quantity reports, critical and near critical path is analysed, progress narrative is prepared and there is effective team participation in schedule updates. Quantity reports rigorously done by trained individual(s). Material suppliers routinely contacted to track the status of material delivery dates.Change management analysis, risks assessment analysis, date variance analysis may be conducted as a project requires. There is progress tracking using 3D imaging and other techniques.	0.77
Dynamic Site Layout Plan	F	The project team examines the project schedule and assesses when Temporary Facilities (TF) will be brought in, analyses what sizes of the TFs will be needed prior to the start of the project, and considers the addition and removal of TFs at different stages of the project. The team also analyses the layout of the project including where the different parties will be working and place their TFs in the optimum location in order to limit travel time to and from TFs.	0.82

Continuation of Table 9-9

Construction Management Practices	Level	Verbal Description	Score
Traffic Control Plan	F	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control. There is a trained traffic control supervisor. The project has an approved contingency plan to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours and flyovers.	0.85
Site Security Plan	D	The site has established security procedures including visitor sign in and sign out procedure and security guards at every gate. The site has implemented security measures to ensure the preservation of company assets. Protocols have been identified for searching individuals and their personal property. Searching are conducted randomly.	0.44
Machinery Positioning Strategy	F	Heavy rigging and lifting studies are accomplished on all critical lifts including evaluation of the machinery, rigging selection, and crane location.There is thorough use of 3D modelling/visualization to locate machinery.	0.82
Project start-up plan	F	A start-up plan that identifies the duties and responsibilities of each stakeholder has been developed. The plan has cost analysis and detailed scheduling components, it is well communicated to all the stakeholders, and the plan will be implemented on the project by incorporating feedbacks from the stakeholders or project participants.	0.85
Project Completion Plan	F	The project has a formal handover process that defines the necessary documentation, parameters of completion and other issues to assure proper handover of a project. The procedure has been reviewed and agreed by the stakeholders. The plan is approved by project management team and is reviewed for applicability during all phases of the handover process.	0.83
Innovations and New Technologies	D	The organization has an informal program for the investigation of innovations, and they will investigate the feasibility of the new technologies on a regular basis.	0.38
		Management Practices Related to Construction Methods Sub-Total Score	***6.87***
Short Interval Plan	F	Short interval plan indicates the required materials, tools and equipment, labour, and project information required to complete each task, and activities in the project schedule are resource loaded. The short interval plan considers the effects of congestion. Alternate plans such as modified equipment schedules, shortened shifts, lengthened shifts, or added shifts in case the original plans did not work are prepared.	0.88
Well-Defined Scope of Work	F	The design is completed and buildability review has been performed; duration for the work package is estimated; material availability, testing and inspection requirements are defined; and budget and quantities are included in the scope of work.	0.96
Use of Software in Planning Work Packages	F	The project uses a software system to generate and track work packages. The system automatically includes the drawings and material delivery status. It is updated regularly and automatically, and provides current design drawing information, updated status of materials, implementation schedule with durations and quantities, test and inspection status, and percent complete. The work package status is updated electronically.	0.76
Dedicated Planner	E	Single planner or multiple personnel who prepare initial plan and coordinate with procurement are assigned. The planner initiate and maintain communication regarding the delivery and inspection of materials and continuously update the schedule. There is onsite inspection to track consumption of materials as necessary.	0.48
Construction Work Packages	F	All information required for execution of each Construction Work Package (CWP) has been addressed. All sections have received in-depth consideration. The construction work package can be performed easily based on the information documented for each CWP.	0.86
Buildability Review	F	The contractor has prepareed a detailed schedule for all phases of construction after conducting detailed buildability review. The owner is involved in buildability review process. All buidability reviews and schedules are completed before construction.	0.88
Utilities Alignment	F	The project has a review process for working in areas surrounding utilities. The process includes list of utilities, locations, and warning signs. The necessary city council approvals have been obtained and utility adjustment plan is prepared. Communication with businesses and local community have been made. Arrangements for temporary shut offs and interruptions have been made. The physical markings described to mark the horizontal route of underground facilities have been protected, detours have been constructed, and the all activities related to utilities alignments have been integrated with other project schedules.	0.76
Contract Types	F	The project has a review process for the contract types. It considers fee structure and financing options. Risks associated with different contract types are also considered. Cost benefit analysis for different types of contracts are performed. The labour market information and reports are also studied and considered before awarding contracts. The local conditions in the project area are studied and monitored regularly. The company has established protocols for selecting designers, material suppliers, and manufacturers.	0.77

Continuation of Table 9-9

Construction Management Practices	Level	Verbal Description	Score
Model Development	D	A 4D Model has been developed for the project. The model is updated manually.	0.32
Regulatory Requirement	F	Initial investigations based on the type of permits, timeline to get the permit approved, the validity period of the permit, the authority issuing the permit, pre-inspection requirements, and fees have been conducted. Permit requirements are linked to schedules. A system is established to track the acquisition and validity period of each permit. The system is automatically updated based on continued updates of schedule and permit expiry dates.	0.85
Pre-construction Phase Management Practices Sub-Total Score			***7.52***
Crew Composition	E	Crew formation is addressed before the commencement of construction works. Experience and knowledge of employees, job requirements, and location of the project are considered while forming crew.The performance of the crew is assessed after completion of each task and corrective measures are taken accordingly.	0.62
Skills Assessment and Evaluation	D	Skills assessment is addressed before the beginning of construction work; and the previous experience, skill and knowledge of workers are considered during evaluation.	0.44
Employees Training	E	Training is provided to an employee when he/she begins working for the company and, if needed, extra training will be conducted on the job site. A worker is certified to work in or supervise specific trade.	0.60
Career Development	D	The organization has a formal career development plan for employees, but it only addresses short term career developments.	0.43
Non-Financial Incentive Programs	D	The organization has a formal recognition program that provides recognition on long term basis.	0.39
Financial Incentive Programs	D	The organization has a formal incentive program that provides incentives on long term basis.	0.40
Social Activities	D	The organization formally plans a social activity once or twice a year in which the project managers will attend, along with a yearly organization wide social activity.	0.40
Stability of Organizational Structure	E	The key professionals are named or defined in the contract. It is also stated that they cannot be changed without notice and prior approval.	0.65
Clear Delegation of Responsibility	E	The delegation of responsibility is formal, but differing between technical and administrative staff.	0.67
Retention Plan for Experienced Personnel	E	Incentives such as employee training and others are available. Employee training is a requirement for junior staff. The employer makes available a list of opportunities for the next project.	0.61
Exit Interviews	C	There is exit interview for key personnel only.	0.23
Human Resource Management Practices Sub-Total Score			***5.44***
Housekeeping	E	Major travel paths are organized and clean. Housekeeping occurs weekly.	0.71
Safety and Health Policy	F	There is health and safety policy at company and project levels. The policy is documented and publicized; it deals with the health and safety of workers, and it is periodically updated based on the organizational and industry feedback.The organization screens project particiapants for their health and safety programs and chooses those with records of good performance. Health and safety policy is integrated with procurement processes. Money is budgeted for the construction projects to address various health and safety issues.	0.95
Safety and Health Plan	F	Zero Accident Techniques are fully utilized on the project. The project has a very proactive approach towards safety.	0.92
Safe Work Method Statement	F	Safe Work Method Statements (SWMS's) are utilized daily on the project for all tasks and the project team prepares additional SWMS's as the task changes.	0.91
Hazards Analysis	F	Hazards are identified for all tasks (high-risk and low-risk) and incorporated into the project's task specific safety planning process.	0.92
Safety and Health Training	E	There is project specific induction regarding personal protective equipment, housekeeping and access to site, and others. Supervisors receive additional induction on safety meetings, first aid and medical treatment processes. Some employees should pass fitness for duty testing prior to starting construction of some tasks. The orientation addresses zero accidents philosophy and general project safety rules.	0.71
Toolbox Safety Meetings	F	The project conducts weekly meetings at a prearranged time, generally at the start of the day. Meetings address current job status, hazards posed by upcoming project activities, and corrective actions taken. It reviews recorded injuries and near misses, and reiterates job site safety rules and expectations. Time is set aside during the meeting for interactive discussion and allows worker feedback.The date of the meeting varies or can be conducted daily.	0.91
Health and Safety Practices Sub-Total Score			***6.03***
Total Construction Management Practices Score			**31.22**

The logistic regression models of the six categories of the construction management practices and productivity can also be used to estimate the probability of exceeding baseline productivity factors. The discussions on the application of the logistic regression models of the six categories of the construction management practices are made in the following sub-sections.

Application of the Logistic Regression Model of the Construction Materials Management Practices and Productivity

Consider the construction materials management practices score of a project indicated in Table 9-8. The total score of the materials management practices is 2 (Table 9-8), and the equivalent probability of exceeding PF=1.05 is 5% (Figure 9-8). This implies that the actual productivity of a project can be less than the planned productivity, and the project could be delayed. Thus, corrective actions should be taken. The action could be increasing the levels of implementations of the construction materials management practices that are more important to enhance productivity in multi-storey building construction projects.

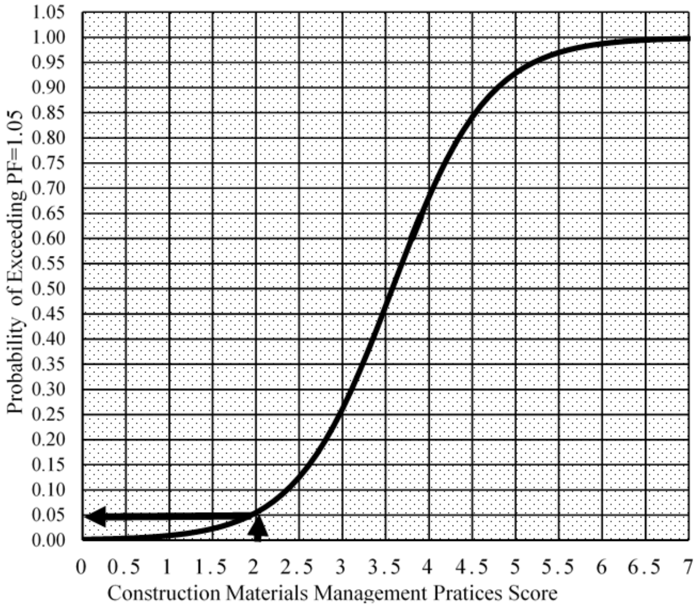


Figure 9-8 Application of the Sigmoid Graph of the Materials Management Practices

Application of the Logistic Regression Models of the Construction Equipment Management Practices and Productivity

To illustrate how the logistic regression model of the construction equipment management practices and productivity is used, the score of the example project in Table 9-8 is used. Accordingly, the total score of the construction equipment management practices for the project is 0.30 (Table 9-8), and the probability of exceeding PF=0.90 is approximately 43% (Figure 9-9). This implies that the actual productivity is less than the planned productivity and the possibility of occurrence of the project delay is high. However, the project manager can make other trials by increasing the level of implementation of the construction equipment management practices to maximise the chance of completing the project early.

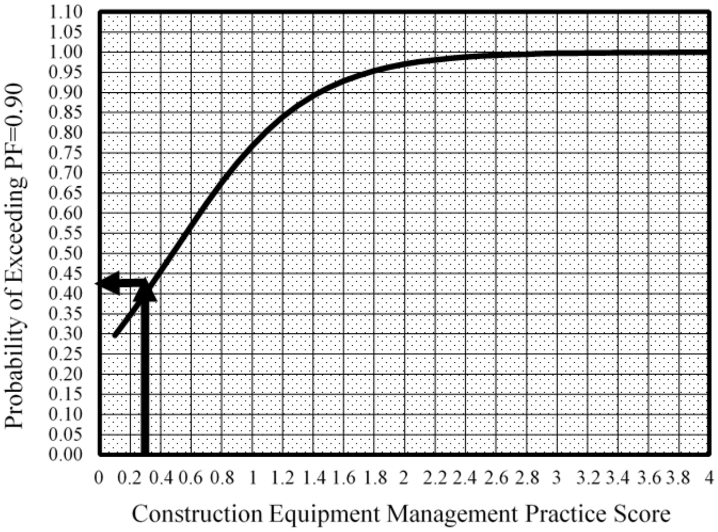


Figure 9-9 The Use of the Sigmoid Graph of the Construction Equipment Management Practices

Application of the Logistic Regression Models of the Management Practices Related to Construction Methods and Productivity

As shown in Table 9-8, based on the project manager's planned levels of the management practices related to construction methods, the total score for this category is 3.51. The sigmoid graph which is plotted using the logistic regression model of the management practices related to construction methods can be used to estimate the probability of exceeding PF= 0.90. Accordingly, the probability value is 0.40 (Figure 9-10). This implies that the actual productivity during the construction could be less than planned productivity and the risk level of a project delay will be higher. On the other hand, the project manager can increase the chance of completing a project on or before the contract date by increasing the level of implementation of the practices as shown in Table 9-9 above.

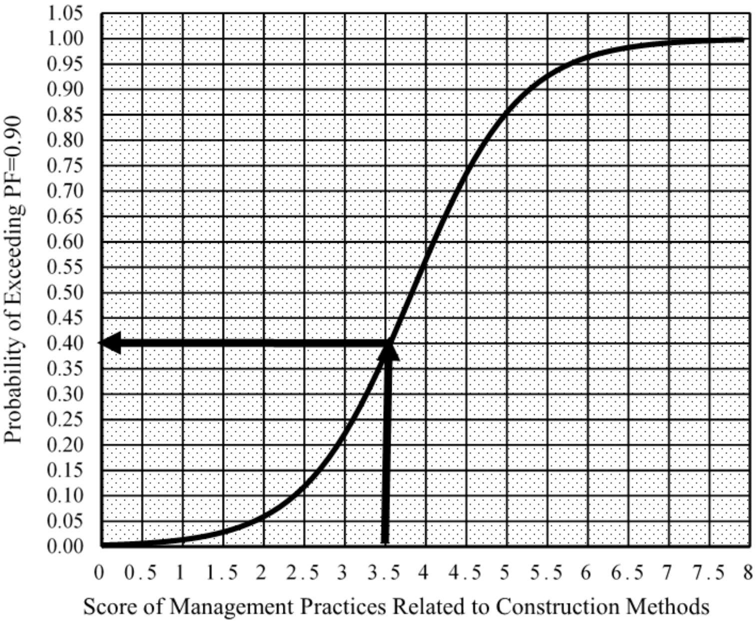


Figure 9-10 Application of the Probability Graph of Management Practices Related to Construction Methods

Application of the Logistic Regression Models of the Preconstruction Phase Management Practices and Productivity

For the project considered in Table 9-8, the total score of the pre-construction phase management practices is 4 and probability of exceeding PF=1.00 is 30% (Figure 9-11) which implies that with this score, there could be a high chance of incurring project delay. Thus, the project manager needs to increase the level of implementation of the preconstruction phase management practices, read the probability from the graph and plan appropriate practices before commencing the construction of the project.

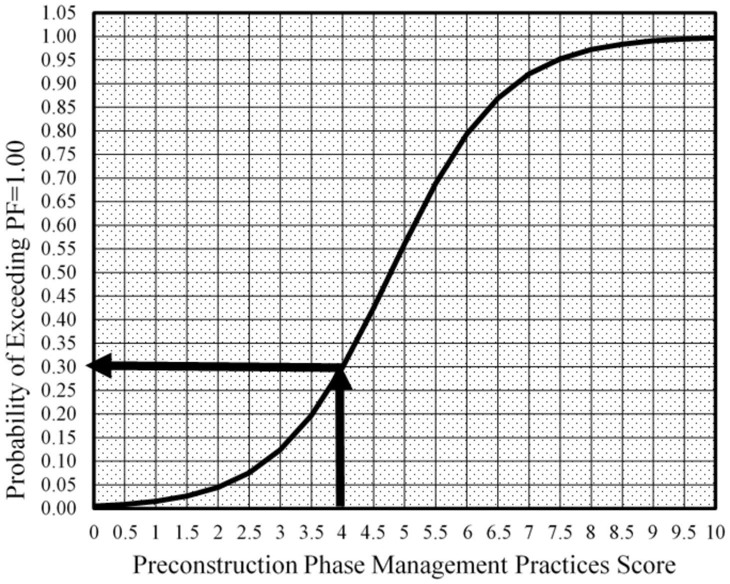


Figure 9-11 The Use of the Probability Plot of the Preconstruction Phase Management Practices

Application of the Logistic Regression Models of the Human Resource Management Practices and Productivity

The score of the human resource management (HRM) practices for the example project in Table 9-8 is 3.18, and the equivalent probability of exceeding PF=0.90 can be read from the probability graph of the HRM practices. Accordingly, the probability value is about 26% (Figure 9-12). This indicates that the actual productivity of the particular project can be less than the planned productivity and the chance of occurrence of the project delay is high.

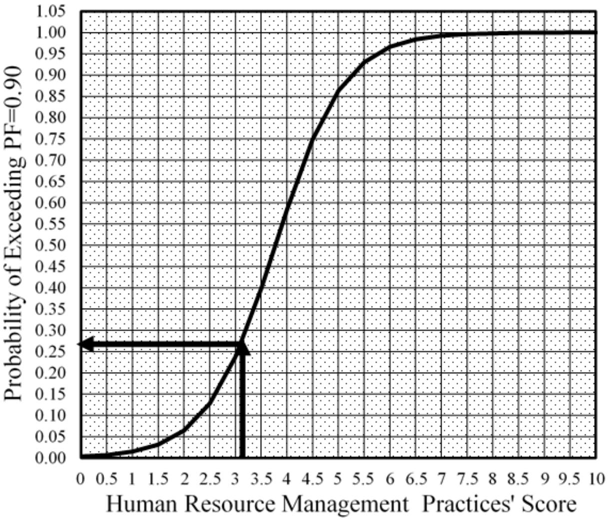


Figure 9-12 Application the Sigmoid Graph of the HRM Practices

Application of the Logistic Regression Models of the Safety and Health Practices and Productivity

For the example project considered in Table 9-8, the total safety and health practices score is 2.0, and the probability of exceeding PF=0.90 is 0.01% (Figure 9-13) which implies that the chance of occurrence of project delay is high. Thus, the project manager should take corrective actions prior to the commencement of the construction.

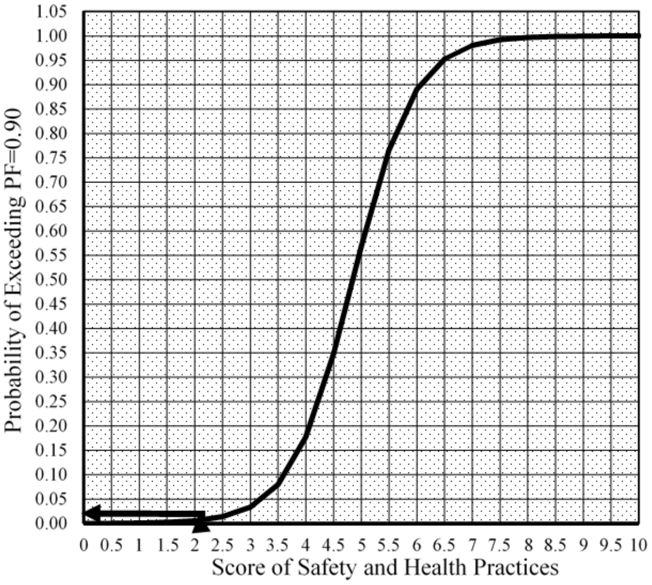


Figure 9-13 Application of the Probability Graph of Safety and Health Practices

9.4.2 The Application of the Construction Management Practices Scoring Tools and the Linear Regression Models during Project Planning Phase

The management practices' scoring tools and the linear regression model of productivity and the practices can be used to investigate the proportion of productivity factor explained by the construction management practices. In this research, it is found that the management practices can explain about 48% of the variation in productivity factor and the relationship between productivity and the management practices is statistically significant.

The productivity factor of a certain multi-storey building project can be determined based on a measured value of the management practices by using the linear regression model of productivity and the practices. For instance, the overall score of the project considered in Table 9-8 is 15.03, and the productivity factor of the specific project can be computed using Equation 9-1 (linear regression model of overall management practices).

$$PF_{ex} = 0.02CMP_{ex} + 0.58 \qquad \text{Equation 9-1}$$

In the equation, PF_{ex} is the productivity factor of the example project, and CMP_{ex} is the overall score of the construction management practices for the example project or 15.03.

By inserting the score of the project in Equation 9-1, the productivity factor of the particular project is found to **0.88**. This implies that the actual productivity of the project is 0.88 times the planned productivity and the project could be delayed. In other words, the actual completion time (duration) could be (1/0.88 =1.14) times the planned duration. For example, if the planned completion time of the project is 300 days, then the actual completion time could be 1.14×300 = 342 days. The expected project delay could be 342 - 300 = **42 days**. Thus, the project manager should make another trial, predict productivity factor, estimate the project delay and make the necessary decisions regarding the implementation levels of the management practices. Therefore, the linear regression model and the scoring tool can assist the project manager to plan appropriate management practices for the proposed project.

9.4.3 The Use of the Scoring Tools during Construction Phase

The scoring tools can be used to monitor the implementation of the management practices. Consider the six management practices which are planned by a contractor's project manager in Table 9-10. The project manager planned the practice material inspection process as "the materials inspection is made for all items delivered to the site. The inspection is conducted during manufacturing and onsite. Materials inspections are organised immediately upon delivery of materials, the materials are verified if they conform to the standards, and they are arranged for on-site tracking or level E" (Table 9-10). However, during the construction phase, the manager monitors the implementation of the particular practice and found that the implementation level is "materials inspection is made for all items delivered to the site. There is a lack of organisation of the inspection process and materials are not separated into stages of the receipt process nor does it record the location of the materials and mark the materials for tracking or Level D" (Table 9-10). Thus, since the implemented practice is different from the planned practice corrective action is required for the practice 'materials inspection process' (Table 9-10). If the corrective measures are not taken, the chance of achieving the planned productivity level would be low.

However, for the practice 'traffic control plan,' the manager planned to implement "the project has a traffic control plan and equipment for all times of the day including trained persons for traffic control. There is a trained traffic control supervisor. The project has an approved contingency plan to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours and flyovers or Level F," and while controlling the implementation of the practice, a similar result was found

(Table 9-10). Thus, corrective action is not required for this practice. For other management practices, by using a similar procedure, the project manager can take corrective measures after comparing the planned and implemented practices. Therefore, the scoring tools can be used to control the implementation of management practices.

Table 9-10 The Use the Scoring Tool to Monitor the Construction Management Practices

Construction Management Practices	**Planned Practices**		**Implemented Practices**		**Corrective Action**
	Level	*Verbal Description*	*Level*	*Verbal Description*	
Material Inspection Process	E	The materials inspection is made for all items delivered to the site. The inspection is conducted during manufacturing and onsite. Materials inspections are organized immediately upon delivery of materials, the materials are verified if they conform to the standards, and they are arranged for on-site tracking.	D	Materials inspection is made for all items delivered to the site. There is a lack of organization of the inspection process and materials are not separated into stages of the receipt process nor does it record the location of the materials and mark the materials for tracking.	Required
Construction Equipment Maintenance	E	Construction equipment maintenance record is linked to individual construction equipment, and maintenance is centrally scheduled and administered. A computer program is used to record and administer equipment maintenance information such as the required and accomplished maintenance logs and usage logs.	C	Construction equipment is logged in simplified spreadsheet and maintenance is carried out by operator request.	Required
Traffic Control Plan	F	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control. There is a trained traffic control supervisor. The project has an approved contingency plan to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours and flyovers.	F	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control. There is a trained traffic control supervisor. The project has an approved contingency plan to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours and flyovers.	Not required
Short Interval Plan	F	Short interval plan indicates the required materials, tools and equipment, labour, and project information required to complete each task, and activities in the project schedule are resource loaded. The short interval plan considers the effects of congestion. Alternate plans are prepared such as modified equipment schedules, shortened shifts, lengthened shifts, or added shifts in case the original plans did not work.	D	Short interval plan indicates the required materials, tools and equipment, labour, and project information required to complete each task, and activities in the project schedule are not resource loaded.	Required
Crew Composition	E	Crew formation is addressed before the commencement of construction works. Experience and knowledge of employees, job requirements, and location are considered. The performance of the crew is assessed after completion of each task and corrective measures are taken accordingly.	E	Crew formation is addressed before the commencement of construction works. Experience and knowledge of employees, job requirements, and location are considered. The performance of the crew is assessed after completion of each task and corrective measures are taken accordingly.	Not required
Housekeeping	E	Major travel paths are organized and clean. Housekeeping occurs weekly.	D	Housekeeping occurs on a bi-weekly basis.	Required

9.4.4 The Application of the Scoring Tools during the Project Closure Phase

The management practices scoring tools can also be used during the project closure phase. The effectiveness of the implemented practices can be evaluated, and lessons can be learned from the completed project. For instance, consider the project manager has planned and implemented the practices indicated in Table 9-9. The overall score is 31.22, and the equivalent productivity factor (PF) of the project using the linear regression model's equation (Equation 9-1) can be computed as 0.02 × 31.22 + 0.58 =

1.20. This implies that the actual project duration could be 1/1.20 or 0.83 times the planned duration. For instance, if the planned duration is 400 days, the expected actual duration would be 332 days (estimated at the start of the project). However, after the project is completed (during evaluation of project performance or project closure phase), the actual duration, for instance, is found to be 380 days. This shows that the implemented practices might not be associated with PF=1.20 and higher levels of the practices should be planned for the next project. Thus, lessons can be learnt from the completed project.

9.5 Summary

This chapter provided the discussions of the findings obtained to achieve Objective 1 or "to identify and prioritize the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia," Objective 2 or "to refine and validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects," and Objective 3 or "to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices."

The management practices and their relative importance in improving the productivity of the multi-storey building construction projects in the context of Victoria State, Australia have been discussed. The findings of this study were compared with the results of previous studies, and the possible reasons for the variations were explained. The relationships among the management practices in the six categories (construction materials management practices, construction equipment management practices, management practices related to construction methods, human resource management practices, pre-construction phase management practices, and safety and health practices) were described. The inter-relationships among the practices within their categories were also explained.

The applications of the scoring tools of the management practices and the logistic regression models during the project planning phase were discussed by using an example project. The productivity factor of the example project was predicted using the linear regression model, and the project delay associated with the planned practices was estimated. The application of the scoring tools to monitor the implementation of the planned management practices was explained by providing an example project. Finally, the uses of the scoring tools to evaluate if the implemented practices are associated with the predicted productivity factor were also discussed with the help of an example. The next chapter presents the summary and conclusions of the study.

CHAPTER TEN

10 SUMMARY AND CONCLUSION

10.1 Introduction

This chapter provides the summary of the key findings of the research. It also addresses the contributions of the study, the limitations, and the recommendations for future research. In Section 10.2, the summaries of the findings of the study are described. In this section, the objectives of the study are restated, and the main findings are explained; and the scoring tools of the construction management practices, the probability graphs and the linear regression model of the management practices and productivity are presented. Section 10.3 discusses the theoretical and practical contributions of the research. Finally, the limitations of the study and directions for future studies are described in Section 10.4.

10.2 Summary of Findings

This section summarizes the findings obtained to achieve the three objectives of the study which are (1) to identify and prioritize the management practices that have the potential to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia, (2) to refine and validate scoring tools for measuring, planning, monitoring and evaluating the management practices that could improve productivity in multi-storey building construction projects, and (3) to build and validate a tool that can be used to predict the probability of exceeding baseline productivity factor based on a score of the management practices.

10.2.1 The Prioritized Construction Management Practices Influencing Productivity in Multi-Storey Building Projects

Overall, 47 construction management practices that have the potential to improve productivity in multi-storey building projects in the context of Victoria State, Australia have been identified and prioritised. These comprise of six construction materials management practices, three construction equipment management practices, 10 management practices related to construction methods, 10 pre-construction phase management practices, 11 human resource management practices, and seven safety and health practices. Safety and Health practices are found to be the most important practices among the six main categories of the construction management practices, and all the seven health and safety practices are ranked with the top ten. The practices well-defined scope of works, safety and health policy, and safety and health plan are found to be the three most important management practices (Table 10-1).

Table 10-1 The Prioritized Construction Management Practices

Construction Management Practices	*RII*	*Overall Rank*
Well-Defined Scope of Work	0.96	1
Safety and Health Policy	0.95	2
Safety and Health Plan	0.92	3
Hazards Analysis	0.92	3
Long-Lead Materials Identification	0.92	5
Safe Work Method Statement	0.91	6
Toolbox Safety Meetings	0.91	7
Housekeeping	0.89	8
Safety and Health Training	0.89	8
Short Interval Plan	0.88	10
Buildability Review	0.88	10
Construction Work Packages	0.86	12
Traffic Control Plan	0.85	13
Project Start -up Plan	0.85	13
Regulatory Requirement	0.85	13
Procurement Plans for Materials	0.85	16
Clear Delegation of Responsibility	0.84	17
Project Completion Plan	0.83	18
Machinery Positioning Strategy	0.82	19
Dynamic Site Layout Plan	0.82	20
Stability of Organizational Structure	0.82	20
Construction Equipment Maintenance	0.79	22
Contract Types	0.77	23
Schedule Control	0.77	24
Crew Composition	0.77	24
Use of Software in Planning Work Packages	0.76	26
Retention Plan for Experienced Personnel	0.76	26
Utilities Alignment	0.76	28
Materials Delivery Schedule	0.75	29
Employees Training	0.75	29
Skill Assessment and Evaluation	0.74	31
Work Schedule Strategies	0.73	32
Site Security Plan	0.73	32
Career Development	0.71	34
Material Inspection Process	0.7	35
Procurement Plan for Construction Equipment	0.69	36
Financial Incentive Programs	0.67	37
Social Activities	0.67	37
Materials Status Database	0.66	39
Integrated Schedules	0.66	40
Non-Financial Incentive Programs	0.65	41
Innovations and New Technologies	0.64	42
Dedicated Planner	0.61	43
Construction Equipment Productivity Analysis	0.61	44
Exit Interviews	0.57	45
Materials Inspection Team	0.57	46
Model Development	0.54	47

Construction Management Practices	*RII*	*Rank within Category*
Construction Materials Management Practices (CMMP)		
Long-Lead Materials Identification	0.92	1
Procurement Plans for Materials	0.85	2
Materials Delivery Schedule	0.75	3
Material Inspection Process	0.70	4
Materials Status Database	0.66	5
Materials Inspection Team	0.57	6
Average weight of CMMP	***0.74***	
Construction Equipment Management Practices (CEMP)		
Construction Equipment Maintenance	0.79	1
Procurement Plan for Construction Equipment	0.61	2
Construction Equipment Productivity Analysis	0.79	3
Average weight of CEMP	***0.73***	
Management Practices Related to Construction Methods (MPRCM)		
Traffic Control Plan	0.851	1
Project start-up plan	0.851	1
Machinery Positioning Strategy	0.826	3
Project Completion Plan	0.821	4
Dynamic Site Layout Plan	0.815	5
Schedule Control	0.769	6
Work Schedule Strategies	0.733	7
Site Security Plan	0.733	7
Integrated Schedule	0.656	9
Innovations and New Technologies	0.636	10
Average weight of MPRCM	***0.77***	
Pre-Construction Phase Management Practices (PCPMP)		
Well-Defined Scope of Work	0.959	1
Short Interval Plan	0.877	2
Buildability Review	0.877	2
Construction Work Packages	0.856	4
Regulatory Requirement	0.851	5
Contract Types	0.774	6
Use of Software in Planning Work Packages	0.764	7
Utilities Alignment	0.759	8
Dedicated Planner	0.61	9
Model Development	0.538	10
Average weight of PCPMP	***0.79***	
Human Resource Management Practices (HRMP)		
Clear Delegation of Responsibility	0.836	1
Stability of Organizational Structure	0.815	2
Crew Composition	0.769	3
Retention Plan for Experienced Personnel	0.764	4
Employees Training	0.749	5
Skill Assessment and Evaluation	0.738	6
Career Development	0.708	7
Financial Incentive Programs	0.672	8
Social Activities	0.672	8
Non-Financial Incentive Programs	0.651	10
Exit Interviews	0.574	11
Average weight of HRMP	***0.72***	
Safety and Health Practices (SHP)		
Safety and Health Policy	0.949	1
Safety and Health Plan	0.923	2
Hazards Analysis	0.923	2
Safe Work Method Statement	0.913	4
Toolbox Safety Meetings	0.908	5
Housekeeping	0.887	6
Safety and Health Training	0.887	6
Average weight of SHP	***0.91***	

The findings of the correlation analyses revealed that all the 47 construction management practices are positively associated with productivity. The output of linear regression analysis also showed that there is a positive and statistically significant relationship between productivity and the management practices. The findings of Friedman test indicate that the practices ‘well-defined scope of work,’ ‘safety and health policy,’ ‘safety and health plan,’ ‘hazard analysis,’ ‘long-lead materials identification,’ ‘safe work method statement’ and ‘toolbox safety meetings’ are equally important to improve productivity in multi-storey building projects.

Long-lead materials identification, procurement plans for materials and materials delivery schedule are found to be the three most important practices in the construction materials management practices category (Table 10-1). The results of the study revealed that high levels of implementation of the construction materials management practices are associated with low project delays and high project costs. Annual turnover, company experience and company sizes are positively correlated with construction materials management practices, but the associations are not significant.

Construction equipment maintenance, construction equipment procurement plan, and construction equipment productivity analysis are found to be the three construction equipment management practices that positively influence productivity in multi-storey building projects (Table 10-1). The study revealed that high levels of implementation of the construction equipment management practices are associated with high productivity and low project delays. The levels of implementation of the construction equipment management practices increase with project costs and company size. Annual turnover and company experience are positively correlated with construction equipment management practices, but the associations are not statistically significant.

Traffic control plan, project start-up plan, machinery positioning strategy, project completion plan, and dynamic site layout plan are found to be the top five most important practices in the category of management practices related to construction methods (Table 10-1). The findings of Friedman and Wilcoxon tests indicated that there are no discernible differences among the top five practices. Hence, these practices should be implemented jointly to improve productivity in multi-storey building projects. The study revealed that high levels of implementation of the management practices related to construction methods are associated with low project delays and high productivity. The level of implementation of the management practices related to construction methods increases as project cost increases. Positive correlations among company's annual turnover, company size, company experience and the management practices related to construction methods are found. However, these relationships are not statistically significant.

Among the 10 pre-construction phase management practices, well-defined scope of work, short interval plan, buildability review, construction work packages, and regulatory requirement are found to be the top five most important practices (Table 10-1). The results of Friedman and Wilcoxon tests showed that short interval plan, buildability review, construction work packages, and regulatory requirement are equally important. Thus, these practices need to be implemented jointly to improve productivity in multi-storey building construction projects. The correlation analysis revealed that higher levels of implementation of the pre-construction phase management practices are associated with higher productivity, higher project costs and lower project delays. Annual turnover has a very weak correlation with the pre-construction phase management practices. Company experience and company size are positively correlated with pre-construction phase management practices, but the relationships are not statistically significant.

Clear delegation of responsibility, stability of organizational structure and crew composition are found to be the three most important human resource management (HRM) practices (Table 10-1). The study revealed that there is no significant difference among the three practices, and the author suggested that they should be implemented jointly to enhance productivity in multi-storey building projects. The correlation analysis indicated that project delay is negatively correlated with HRM practices which imply that the increment in the level of implementation of the HRM practices could decrease the occurrence of delays in multi-storey building projects. The relationship between company size and HRM practices is positive and significant. This indicates that the level of implementation of HRM increases with company size. The project cost is strongly associated with HRM practices. Company experience and project turnover are positively correlated with HRM practices, but the relationships are not statistically significant.

Safety and health policy, safety and health plan, and hazard analysis are the three most important practices in the safety and health category (Table 10-1). It has been found that the seven safety and health practices are equally important and the author suggested the joint implementation of the seven safety and health practices to enhance productivity in multi-storey building construction projects in the context of Victoria State, Australia. The results of correlation analysis revealed that the level of implementation of the safety and health practices increases with project costs. Project delay is negatively correlated with safety and health practices, but the degree of association is weak and insignificant. This indicates that increasing the level of implementation of safety and health practices might not reduce the possibility of occurrence of project delay. Company experience and company size are positively correlated with safety and health practices, and the relationships are statistically significant. The finding implies that experienced and large construction companies implement higher levels of safety and health practices. Annual turnover and safety and health practices are positively correlated, but the relationship is not significant.

10.2.2 The Scoring Tools of the Construction Management Practices

The scoring tool which can be used to measure, plan, monitor and evaluate the 47 management practices have been refined and validated. The reliability test for the scoring tools was also conducted and findings show that the tools are reliable. The validated scoring tools are presented in Table 10-2 below. The baseline scores against which the users of the scoring tools assess the adequacy of their practices have been fixed and validated. The baseline scores can be used as a benchmark to assess if the planned or implemented management practices on a certain multi-storey building project would be associated with high or low productivity. Thus, contractors’ project managers can use the scoring tools indicated in Table 10-2 to compute their projects’ scores and compare with the baseline scores. Accordingly, multi-storey building projects with the overall construction management practices scores less than 22.75 (baseline score for overall construction management practices) can be considered as less-productive projects, and projects with overall construction management practices scores exceeding 22.75 can be regarded as high-score projects, and they could have higher productivity.

Table 10-2 The Scoring Tools of the Construction Management Practices

	A. Construction Materials Management Practices Scoring Tools	
	A1. Procurement Plans for Materials	*Weights*
Level A	A procurement plan for materials is not applicable	0.00
Level B	There is no documented procurement plan for materials.	0.17
Level C	A procurement plan and schedule exists only for large materials and costly items.	0.34
Level D	Continuation of Level C, plus the plan includes all materials and consumables. Also, there is an established protocol for identifying reputation of potential vendors.	0.51
Level E	Continuation of Level D, plus the plan identifies necessary equipment and onsite resources to support delivery.	0.68
Level F	Continuation of Level E, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.	0.85
	A2. *Long lead Materials Identification*	
Level A	A separate procurement plan for long-lead materials is not applicable.	0.00
Level B	There is no documented procurement plan for long-lead materials.	0.18
Level C	A procurement plan and schedule exists for long-lead materials.	0.37
Level D	Continuation of Level C, plus there is an established protocol for identifying reputation of potential vendors of the long-lead materials.	0.55
Level E	Continuation of Level D, plus the plan identifies necessary equipment and onsite resources to support delivery of long-lead materials.	0.73
Level F	Continuation of Level E, plus the long-lead materials procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.	0.92
	A3. Materials Status Database	
Level A	Material status database is not applicable.	0.00
Level B	There is no formal paper-based system used to track materials status.	0.13
Level C	There is a formal paper-based system to track materials status.	0.26
Level D	Available software is used to track materials status, but it is not integrated with company's project control systems or used by other contractors.	0.40
Level E	Commercially available software is used to track materials status but it is only integrated internally with the company's project control systems.	0.53
Level F	Continuation of Level E, plus the software is used by all stakeholders in the materials supply chain system.	0.66
	A4. Materials Delivery Schedule	
Level A	Materials delivery schedule is not applicable.	0.00
Level B	There is no documented materials delivery schedule.	0.15
Level C	Materials delivery is planned early in the project and is integrated with a project schedule.	0.30
Level D	Continuation of Level C, plus the schedule is automatically updated on receipt of new information as the procurement proceeds.	0.45
Level E	Continuation of Level D, plus the schedule is automatically linked with procurement and overall project scheduling systems.	0.60
Level F	Continuation of Level E, plus materials delivery planning and management is completely integrated with other automated project processes including automated materials tracking throughout the supply chain.	0.75
	A5. Material Inspection Process	
Level A	The material inspection process is not applicable.	0.00
Level B	There is no materials inspection process.	0.14
Level C	Materials inspection is made for large items or costly items only.	0.28
Level D	Materials inspection is made for all items delivered to the site. There is a lack of organization of the inspection process and materials are not separated into stages of the receipt process. The locations of materials are not recorded.The materials are not marked for tracking.	0.42
Level E	The inspection is conducted during manufacturing and onsite. Materials inspections are organized immediately upon delivery of materials; the materials are verified if they conform to the standards, specifications, and drawings; and they are arranged for on-site tracking. However, there is no separation of materials into stages of receipt.	0.56
Level F	Continuation of Level E, plus the process includes separation of material into categorical stages of the receipt process (e.g. awaiting inspection, scrap, and/or awaiting for shipment).	0.70

Table 10-2 continued

	A6. Materials Inspection Team	*Weights*
Level A	Materials inspection team is not applicable.	0.00
Level B	There is no materials inspection team.	0.11
Level C	There is a designated person who conducts materials inspection but no training and qualification of the person is specified.	0.23
Level D	Continuations of Level C, plus inspections are performed by a project manager or another worker rather than a team.	0.34
Level E	Continuation of Level D, plus there is an inspection team who can inspect materials.	0.46
Level F	Continuation of Level E, plus the members of the inspection team are experts at inspection processes and procedures.The team can adequately inspect the materials and understand the material specifications and standards.	0.57
	B. Construction Equipment Management Practices Scoring Tools	
	B1. Procurement Plan for Construction Equipment	
Level A	A procurement plan for construction equipment is not applicable for this building project.	0.00
Level B	Construction equipment procurement plan is not prepared for this building project.	0.14
Level C	Construction equipment procurement strategies such as hiring or leasing are prepared for this building project.	0.28
Level D	Continuation of Level C and there is a procedure for identifying reputation of potential equipment suppliers	0.41
Level E	Continuation of Level D, plus the plan identifies necessary equipment and onsite resources to support delivery.	0.55
Level F	Continuation of Level E and construction equipment schedule is integrated with other project schedules.	0.69
	B2. Construction Equipment Productivity Analysis	
Level A	Construction equipment is not used in this building project.	0.00
Level B	Construction equipment is utilized but requirements and usage are not planned and tracked.	0.12
Level C	Construction equipment requirements are planned and tracked but they are not tied to a project schedule. The usage is tracked against budget only.	0.24
Level D	Continuation of Level C and regular meeting is conducted to assess the requirement of construction equipment.	0.37
Level E	Continuation of Level D, and the construction equipment resource curves are drawn and resources are leveled.	0.49
Level F	Continuation of Level E and equipment schedule is adjusted based on the audit report that shows equipment downtime and other information.	0.61
	B3. Construction Equipment Maintenance	
Level A	Construction equipment maintenance is not applicable for this building project.	0.00
Level B	Construction equipment maintenance is not planned for this building project.	0.16
Level C	Construction equipment is logged in simplified spreadsheet and maintenance is carried out by operator request.	0.32
Level D	Continuation of Level C and equipment maintenance record is linked to individual construction equipment, and maintenance is centrally scheduled and administered.	0.47
Level E	Continuation of Level D and a computer program is used to record and administer equipment maintenance information such as required and accomplished maintenance logs and usage logs.	0.63
Level F	Continuation of Level E and maintenance schedule is electronically updated and maintenance due notices are automatically issued to the concerned parties.	0.79
	C. Management Practices Related to Construction Methods Scoring Tools	
	C1. Integrated Schedule	
Level A	The use of an integrated schedule using critical path method (CPM) is not applicable.	0.00
Level B	The use of an integrated schedule using CPM has not been addressed.	0.13
Level C	Developing a schedule with no resources present and managing schedule status via duration or remaining duration but not linked to earned percent complete progress for associated deliverables per activity.	0.26
Level D	Developing a schedule with resources present but not linked to earned percent complete progress for associated deliverables per activity.	0.40
Level E	Continuation of Level D, plus resources are updated to reflect current work content or quantity adjustments.	0.53
Level F	Continuation of Level E, plus earned progress for the activity is based on measured or assessed work completed per deliverables per activity. Progress measurement is performed in application adapted specifically for each deliverable.	0.66

Table 10-2 continued

	C2. Work Schedule Strategies	*Weights*
Level A	The development of a work schedule strategy is not applicable	0.00
Level B	The development of a work schedule strategy has not been addressed	0.15
Level C	The strategy is based on a single work schedule be it either a straight time such as 36 hours per week schedule, overtime, or other work schedule strategies.	0.29
Level D	Strategy considers multiple work schedules considering critical and near critical activity sequences.	0.44
Level E	Continuation of Level D, plus strategy considers the potential impact on worker fatigue, supervision, safety, and absenteeism.	0.58
Level F	Continuation of Level E, plus each potential strategy's impact is analysed for manpower density and congestion at an area or sub-area level.	0.73
	C3. Schedule Control	
Level A	The development of a schedule compliance plan is not applicable.	0.00
Level B	The development of a schedule compliance plan has not been addressed.	0.15
Level C	There is a consistent follow-up to update schedules periodically, conduct critical path analysis, and prepare progress narrative as required. There is effective team participation in schedule updates.	0.31
Level D	Continuation of Level C, plus quantity reports are regularly performed. Upon request, or as the project requires, may include any of the following: change management analysis, risks assessment analysis, date variance analysis, communication with material suppliers to ensure material will arrive on site as per the plan.	0.46
Level E	The schedule is rigorously updated based on manual input of quantity reports, critical and near critical path is analysed, progress narrative is prepared and there is effective team participation in schedule updates. Quantity reports rigorously done by trained individual(s). Material suppliers routinely contacted to track the status of material delivery dates. Change management analysis, risks assessment analysis, date variance analysis may be conducted as a project requires.	0.62
Level F	Continuation of Level E, plus progress tracking using 3D imaging and other techniques.	0.77
	C4. Dynamic Site Layout Plan	
Level A	Site layout plan is not applicable for the project.	0.00
Level B	A site layout plan has not been addressed.	0.16
Level C	The project team examines the project schedule and assesses when Temporary Facilities (TF) will be brought in.	0.33
Level D	Continuation of Level C, plus analyses what sizes will be needed prior to the start of the project. No consideration is given to the addition and removal of TFs at different stages of the project. No analysis is done in regards to the layout of the project to optimize locations of the TFs to limit travel time.	0.49
Level E	Continuation of Level D, plus consideration is given to the addition and removal of TFs at different stages of the project.	0.65
Level F	Continuation of Level E, plus the team analyses the layout of the project including where the different parties will be working and place their TFs in the optimum location in order to limit travel time to and from TFs.	0.82
	C5. Traffic Control Plan	
Level A	Traffic control plans are not applicable for this project.	0.00
Level B	Traffic control plans have not been addressed in this project.	0.17
Level C	The project has some traffic control plans, and it is used on a reactive basis.	0.34
Level D	The project has a traffic control plan, traffic control equipment, and an arrangement for daylight traffic control only and has no trained traffic control persons.	0.51
Level E	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control.	0.68
Level F	Continuation of level E, plus a trained traffic control supervisor. The project has an approved contingency plan to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours and flyovers.	0.85
	C6. Site Security Plan	
Level A	Site security plan is not applicable for this project.	0.00
Level B	The site does not have security with regard to entry to the site, and the securing equipment is not available.	0.15
Level C	There is control during entry and exit from the site, but does not have any other formal security system throughout the site.	0.29
Level D	The site has established security procedures including visitor sign in and sign out procedure and security guards at every gate. The site has implemented security measures to ensure the preservation of company assets. Protocols have been identified for searching individuals and their personal property. Searching is conducted randomly.	0.44
Level E	Continuation of Level D, plus the site has ensured that material is not leaving the job site by instituting "lock-ups" for items that are prone to theft.	0.59
Level F	Continuation of Level E, plus the use of electronic security such as security cameras has been implemented.	0.73

Table 10-2 continued

	C7. Machinery Positioning Strategy	*Weights*
Level A	Machinery positioning strategy is not applicable.	0.00
Level B	There is no strategy for positioning of machinery at the project site.	0.16
Level C	Heavy rigging and lifting studies are accomplished on all critical lifts including evaluation of the machinery, rigging selection, and crane location.	0.33
Level D	Continuation of Level C, plus planning includes the use of 2D layout and studies to aid in locating machinery.	0.49
Level E	Continuation of Level D, plus some 3D modelling studies to aid in locating machinery.	0.65
Level F	Continuation of Level E, plus thorough use of 3D modeling/visualization to locate machinery.	0.82
	C8. Project Start-up Plan	
Level A	No start-up plan exists.	0.00
Level B	A partial start-up plan has been prepared; the plan has not been communicated to the concerned stakeholders.	0.17
Level C	A basic start-up plan has been developed with input from the project participants, but the plan has not been implemented.	0.34
Level D	Continuation of Level C, plus with considerations for interfaces among sub-contractors or project participants. A start-up plan that identifies the duties and responsibilities of each stakeholder has been developed.	0.51
Level E	Continuation of Level D, plus with consideration for cost analysis and detailed scheduling components. The plan is well communicated to all the stakeholders.	0.68
Level F	Continuation of Level E, plus with the plan being implemented on the project by incorporating feedbacks from the stakeholders or project participants.	0.85
	C9. Project Completion Plan	
Level A	The project completion requirement or handover procedure is not applicable.	0.00
Level B	The project completion requirement or handover procedure has not been identified.	0.17
Level C	The project has a handover procedure that defines the parameters of project completion and delineates the requirements for the handover.	0.33
Level D	The project has a formal handover process that defines the necessary documentation, parameters of completion and other issues to ensure proper handover of a project.	0.50
Level E	Continuation of Level D, plus the procedure has been reviewed and agreed by the stakeholders.	0.66
Level F	Continuation of Level E, plus the plan is approved by project management team and is reviewed for applicability during all phases of the handover process.	0.83
	C10. Innovations and New Technologies	
Level A	Innovation in new materials, equipment, information systems is not applicable.	0.00
Level B	Innovations and new technologies investigation is not addressed.	0.13
Level C	The project does not have a formal program for investigation of innovations and new technologies. Implementation of innovations and new systems will only occur after the industry-wide implementation.	0.25
Level D	The organization has an informal program for the investigation of innovations, and the company will investigate the feasibility of the new technologies on a regular basis.	0.38
Level E	Continuation of Level D, plus there is a formal program to investigate some new systems.	0.51
Level F	Continuation of Level E, plus the company investigates all the available new technologies.	0.64
	D. Pre-Construction Phase Management Practices Scoring Tools	
	D1. Short Interval Plan	
Level A	The use of short interval plan is not applicable to this building project.	0.00
Level B	Short interval plan is not prepared.	0.18
Level C	Activities in the project schedule are not resource loaded and short interval plan does not detail the required materials, tools and equipment, labour, and required project information.	0.35
Level D	Short interval plan indicates the required materials, tools and equipment, labour, and project information required to complete each task, and activities in the project schedule are not resource loaded.	0.53
Level E	Continuations of Level D, and activities in the project schedule are resource loaded. The short interval plan considers the effects of congestion.	0.70
Level F	Continuation of Level E, and alternate plans are prepared such as modified equipment schedules, shortened shifts, lengthened shifts, or added shifts in case the original plans did not work.	0.88
	D2. Well-Defined Scope of Work	
Level A	A well-defined scope of work is not applicable to this building project.	0.00
Level B	Working drawings are based on incomplete design, and execution is controlled with a milestone schedule.	0.19
Level C	Continuation of Level B, and design is complete but without buildability review; execution is controlled using a master schedule.	0.38
Level D	Continuation of Level C, plus the design is completed and buildability review has been performed.	0.58
Level E	Continuation of Level D, plus duration for the work package is estimated, material availability, testing and inspection requirements are defined, but budget and quantities are not included in the scope of work.	0.77
Level F	Continuation of Level E, and budget and quantities are included in the scope of work.	0.96

Table 10-2 continued

	D3. Use of Software in Planning Work Packages	*Weights*
Level A	Utilization of software in work packaging is not applicable.	0.00
Level B	This project uses a software system to generate and track work packages.The system is not integrated; and materials, drawing and other information are entered manually.	0.15
Level C	Continuation of Level B, and percent complete is entered manually by reviewing the status of the work package.	0.31
Level D	Continuation of Level C, and the project uses a software system which automatically includes the drawings and material delivery status. Schedule, percent complete, test and inspection status, and closure are entered manually by review of the work package.	0.46
Level E	Continuation of Level D, and the system is updated regularly, and it provides current design drawing information, updated status of materials, implementation schedule with durations and quantities, test and inspection status, and percent complete.	0.61
Level F	Continuation of Level E, plus the work package status is updated electronically.	0.76
	D4. Dedicated Planner	
Level A	Assigning dedicated planner is not applicable to this building project.	0.00
Level B	Hiring of the dedicated planner has not been addressed.	0.12
Level C	Single planner or multiple personnel who prepare initial project schedule and coordinate materials procurement process are assigned.	0.24
Level D	Continuation of Level C, plus the planner initiate and maintain communication regarding the delivery and inspection of materials and update the schedules as appropriate.	0.37
Level E	Continuation of Level D, plus continued update of schedule and onsite inspection to track consumption of materials as necessary.	0.48
Level F	Continuation of Level E, plus continued communication regarding consumption of materials and report their status.	0.61
	D5. Construction Work Packages	
Level A	Organizing information for each Construction Work Packages (CWP) is not applicable.	0.00
Level B	Basic information such as materials and equipment requirements are addressed.	0.17
Level C	Some information such as the scope of works, safety, quality of work, materials, personnel and equipment requirements is compiled, but the information is not complete.	0.34
Level D	All information required for execution of each CWP has been addressed. However, the information in each section displays no in-depth consideration.	0.51
Level E	Continuation of Level D, plus in-depth consideration for most of the sections are given.	0.69
Level F	Continuation of Level E, plus all sections have received in-depth consideration. The construction work package can be performed easily based on the information documented for each CWP.	0.86
	D6. Buildability Review	
Level A	Buildability review is not applicable to this building project.	0.00
Level B	Buildability review is not addressed	0.18
Level C	Some scheduling and coordination of the phases of construction have been performed by the contractor before conducting detailed buildability review.	0.35
Level D	Continuation of Level C, plus the contractor has prepared a detailed schedule for all phases of construction after conducting detailed buildability review.	0.53
Level E	Continuation of Level D, plus the owner is involved in buildability review process.	0.70
Level F	Continuation of Level E, plus all buildability reviews and schedules are completed before construction.	0.88
	D7. Utilities Alignment	
Level A	Utility alignment is not applicable to this project.	0.00
Level B	Utility alignment is not addressed in this project.	0.15
Level C	The project has a review process for working in areas surrounding utilities. The process includes listing the existing utilities, identifying their locations, and providing warning signs.	0.30
Level D	Continuation of Level C, plus necessary city council approvals have been obtained and utility adjustment plan is prepared.	0.46
Level E	Continuation of Level D, plus communication with businesses and local community have been made. Arrangements for temporary shutoffs and interruptions have been made.	0.61
Level F	Continuation of Level E, plus the physical markings described to mark the horizontal route of underground facilities have been protected, detours have been constructed, and all activities related to utilities alignments have been integrated with other project schedules.	0.76
	D8. Contract Types	
Level A	Contracting strategies are not applicable	0.00
Level B	Contract types are not addressed	0.16
Level C	The project has a review process for the contract types. It considers fee structure and financing options, but risks associated with different contract types are not considered.	0.31
Level D	Continuation of Level C, plus risks associated with different contract types are considered. Cost-benefit analyses for different types of contracts are performed.	0.47
Level E	Continuation of Level D, plus the labour market information and reports are studied and considered before awarding contracts.	0.62
Level F	Continuation of Level E, plus the local conditions in the project area are studied and monitored regularly.The company has established protocols for selecting designers, material suppliers, and manufacturers.	0.77

Table 10-2 continued

	D9. Model Development	*Weights*
Level A	Models are not required for this project.	0.00
Level B	Integration of the project's 3D and schedule information has not been addressed	0.11
Level C	A 4D Model has been developed for the project.	0.22
Level D	Continuation of Level C and the model is updated manually.	0.32
Level E	Continuation of Level D, plus the model is dynamic and includes material specifications, change order documentation, and other pertinent design and construction information.	0.43
Level F	Continuation of Level E, plus the model is automatically updated based on work progress.	0.54
	D10. Regulatory Requirements	
Level A	Regulatory requirements are not applicable.	0.00
Level B	Required permitting has not been addressed.	0.17
Level C	Initial investigations based on the type of permits; timeline to get the permits approved; the validity period of the permits; the authority issuing the permits; pre-inspection requirements; and fees have been conducted.	0.34
Level D	Continuation of level C, plus permit requirements are linked to project schedules.	0.51
Level E	Continuation of Level D, plus a system is established to track the acquisition and validity period of each permit.	0.68
Level F	Continuation of Level E, plus the system is automatically updated based on continued updates of the work schedule and the permit expiry dates.	0.85
	E. Human Resource Management Practices Scoring Tools	
	E1. Crew Composition	
Level A	Crew formation/composition is not applicable to this building project.	0.00
Level B	Crew composition is not addressed in this project.	0.15
Level C	Crew formation is addressed after the commencement of the construction of the project.	0.31
Level D	Crew formation is addressed before the commencement of the construction works. Experience and knowledge of employees, job requirements, and location of the project are considered while forming crew.	0.46
Level E	Continuation of Level D, plus the performance of the crew is assessed after completion of each task and corrective measures are taken accordingly.	0.62
Level F	Continuation of Level E, plus the crew formation and its performance is assessed regularly on daily, weekly, and monthly basis and necessary changes are made.	0.77
	E2. Skill Assessment and Evaluation	
Level A	Skills assessment is not applicable to this project.	0.00
Level B	Skills assessment is not addressed.	0.15
Level C	Skills assessment is addressed after the beginning of the construction of the project.	0.30
Level D	Skills assessment is addressed before the beginning of construction work; and previous experience, skill and knowledge of workers are considered during the assessment.	0.44
Level E	Continuation of Level D, plus the assessment is made after completion of each task and adjustments are made accordingly.	0.59
Level F	Continuation of Level E, plus the assessment is performed regularly on daily, weekly, and monthly basis, and necessary changes are made and monitored.	0.74
	E3. Employees Training	
Level A	Employees Training is not applicable to this building project.	0.00
Level B	Employees Training is not addressed.	0.15
Level C	Employees Training is addressed on the jobsite after the beginning of the project.	0.30
Level D	Training is provided to an employee when he/she begins working for the company and, if needed, extra training will be conducted on the job site.	0.45
Level E	Continuation of Level D, plus worker is certified to work in or supervise specific trade.	0.60
Level F	Continuation of Level E, plus a worker takes part in training regarding the new technologies that are introduced in that trade on annual or and bi-annual basis.	0.75
	E4. Career Development	
Level A	Career development is not applicable to this building project.	0.00
Level B	Career development is not addressed in this project.	0.14
Level C	The organization does not have a formal career development plan for employees, but the management discusses future plans with them informally.	0.28
Level D	The organization has a formal career development plan for employees, but it only addresses short term career developments.	0.43
Level E	Continuation of Level D, plus it addresses long term career developments.	0.57
Level F	Continuation of Level E, plus addresses the expected performance of the employee and how the performance will affect his/her career development.	0.71

Table 10-2 continued

	E5. Non-Financial Incentive Programs	*Weights*
Level A	Non-financial incentive/recognition programs are not applicable to this building project.	0.00
Level B	Non-financial incentive programs are not addressed in this project.	0.13
Level C	The organization has informal recognition programs and employees are recognized occasionally, but not in a formal manner.	0.26
Level D	The organization has a formal recognition program that provides recognition on long-term basis.	0.39
Level E	Continuation of Level D, plus it recognizes workers on a regular basis for performance, positive safety results and good safety behaviour.	0.52
Level F	Continuation of Level E, plus the rewards are given on both short and a long-term basis, and they are recognized by the upper management of the organization.	0.65
	E6. Financial Incentive Programs	
Level A	Financial incentive program is not applicable to this building project.	0.00
Level B	Financial incentive program is not addressed.	0.13
Level C	The organization has an informal incentive program that provides incentives occasionally, but not in a formal manner.	0.27
Level D	The organization has a formal incentive program that provides incentives on long-term basis.	0.40
Level E	Continuation of Level D, plus it provides a monetary bonus for employees based on their performances.	0.54
Level F	Continuation of Level E, plus the rewards are given on both a short and long-term basis, and they are recognized by the upper management of the organization.	0.67
	E7. Social Activities	
Level A	Social activities for employees are not applicable.	0.00
Level B	Social activities for the employees are not addressed.	0.13
Level C	The organization does not formally plan social activities for the employees, and there is only a yearly organization wide social activity.	0.27
Level D	The organization formally plans a social activity once or twice a year in which the project managers will attend, along with a yearly organization-wide social activity.	0.40
Level E	Continuation of Level D, plus several times throughout the year which the project managers will attend, along with a yearly organization-wide social activity.	0.54
Level F	Continuation of Level E, plus monthly which the project managers will attend and upper management including the president will attend on a quarterly basis, along with a yearly organization-wide social activity.	0.67
	E8. Stability of Organisational Structure	
Level A	Maintaining the Stability of the organizational structure is not important.	0.00
Level B	No plans to manage change of key people in a contract.	0.16
Level C	The key professionals are named or defined in the contract.	0.33
Level D	Continuation of Level C, plus the contract states that they cannot be changed without notice and prior approval.	0.49
Level E	Continuation of Level D, plus there are pre-approved designated successors.	0.65
Level F	Continuation of Level E, plus the contract specifies all professionals, along with possible successors and right of approval by the other party.	0.82
	E9. Clear Delegation of Responsibility	
Level A	Clear delegation of responsibility is not applicable to this building project.	0.00
Level B	There is a simple and centralized delegation of responsibility.	0.17
Level C	There is a simple and formal delegation of responsibility which is customized for each project.	0.33
Level D	Continuation of Level C, plus there is stable project environment.	0.50
Level E	Continuation of Level D, plus the delegation of responsibility vary based on the areas of expertises; for instance, preparation of separate documents for technical and administrative staff.	0.67
Level F	Continuation of Level E, plus there is a formal delegation of authority that is clearly defined for all parties involved in the construction. The plan is reviewed periodically and evolves when necessary.	0.84
	E10. Retention Plan for Experienced Personnel	
Level A	Retention plan for experienced personnel is not applicable to this building project.	0.00
Level B	A retention plan is not addressed.	0.15
Level C	Each project manager is responsible for retention of his workers.	0.31
Level D	Incentives such as employee training and others may be available, but it is not a requirement. Junior staffs have higher pay and preferred hiring status on the next project for the same employer.	0.46
Level E	Continuation of Level D, plus employee training is required for junior staff. The employer makes available a list of opportunities for the next project.	0.61
Level F	Continuation of Level E, plus testing and certification on the site lead to pay increases. Employer meets with individual worker and offers job at the new project site as required.	0.76
	E11. Exit Interviews	
Level A	Exit interview is not applicable.	0.00
Level B	Exit interview is not conducted.	0.12
Level C	There is exit interview for key personnel only.	0.23
Level D	Random exit interviews when there is time.	0.35
Level E	Formal exit interview for all personnel.	0.46
Level F	There are formal exit interviews for all personnel; feedback is obtained from the employees; lessons are learnt; and the management is committed to take corrective actions.	0.57

Table 10-2 continued

	F. Safety and Health Practices Scoring Tools	
	F1. Housekeeping	*Weights*
Level A	Housekeeping is not applicable to this building project	0.00
Level B	Regular housekeeping has not been addressed on the project.	0.18
Level C	Housekeeping occurs only after accidents occur.	0.36
Level D	Housekeeping occurs on a bi-weekly basis.	0.53
Level E	Major travel paths are organized and clean. Housekeeping occurs weekly.	0.71
Level F	All work areas are well organized and designated crews are regularly cleaning the site.	0.89
	F2. Health and Safety Policy	
Level A	Health and safety policy is not applicable to this project.	0.00
Level B	The company does not have a formal health and safety policy.	0.19
Level C	There is a health and safety policy at company and project levels. The policy is documented and publicized. It deals with the health and safety of workers.	0.38
Level D	Continuation of Level C, plus it is periodically updated based on the organizational and industry feedback.	0.57
Level E	Continuations of Level D, plus the organization screens project participants based on their health and safety programs and chooses those with records of good performance.	0.76
Level F	Continuation of Level E, plus health and safety policy is integrated with procurement processes. Money is budgeted for the project to address various health and safety issues.	0.95
	F3. Health and Safety Plan	
Level A	Health and safety plans are not applicable to this building project.	0.00
Level B	No health and safety targets have been examined and considered for the project.	0.19
Level C	Some techniques to reduce accidents on the project are utilized. The project has a reactive approach towards safety.	0.37
Level D	Most but not all accident reduction techniques are utilized on the project.	0.55
Level E	All potential accident reduction techniques are utilized on the project.	0.74
Level F	Zero accident techniques are fully utilized on the project. The project has a very proactive approach towards safety.	0.92
	F4. Safe Work Method Statement	
Level A	Task Safety Analysis or Safe Work Method Statement (SWMS) is not applicable to this building project.	0.00
Level B	No Task Safety Analysis or SWMS is utilized.	0.18
Level C	Task Safety Analysis is utilized only in high-risk areas of the project, and SWMS is prepared after the occurrence of the accidents.	0.37
Level D	SWMS is prepared and utilized for most tasks in this project.	0.55
Level E	Safe Work Method Statement (SWMS) is utilized daily on the project.	0.73
Level F	SWMS's are utilized daily on the project for all tasks and the project team prepares additional SWMS's as the task changes.	0.91
	F5. Hazards Analysis	
Level A	Hazard identification process is not applicable to this building project.	0.00
Level B	No hazard identification process is in place on this project.	0.19
Level C	Hazards are identified for a few tasks that are not covered in SWMS.	0.37
Level D	Hazards are identified for most tasks that are not covered in SWMS.	0.55
Level E	Hazards are identified for all tasks or for both high-risk and low-risk tasks.	0.74
Level F	Hazards are identified for all tasks (high-risk and low-risk) and incorporated into the project's task specific safety planning process.	0.92
	F6. Health and Safety Training	
Level A	Health and Safety training is not applicable to this building project.	0.00
Level B	The project does not have a project specific training program for new employee.	0.18
Level C	There is project specific induction regarding personal protective equipment, housekeeping and access to site, ladders and safe access to elevated platforms, fall protection, excavations and trenching, tools and equipment, electrical hazards and fire prevention. Supervisors receive additional induction about safety meetings, first aid and medical treatment processes, and alcohol and drugs in the workplace.	0.36
Level D	Continuation of Level C, plus some employees should pass fitness for duty testing prior to starting construction of some tasks. The induction addresses management commitment, general project safety rules, emergency procedures, hazard communication, housekeeping, injury/illness reporting, confined spaces, compressed gas cylinders, back injury prevention, hand/power tool safety and others.	0.53
Level E	Continuation of Level D, plus orientation addresses zero accidents philosophy.	0.71
Level F	Continuation of Level E, plus there is behavioural based training.	0.89
	F7. Toolbox Safety Meetings	
Level A	The project does not conduct safety meetings.	0.00
Level B	The project issues toolbox topics via handouts to employees on a periodic basis.	0.18
Level C	The project conducts a monthly meeting at or near breaks. Meetings reiterate job site safety rules.	0.36
Level D	The project conducts a weekly meeting at or near breaks. Meetings reiterate job site safety rules.	0.55
Level E	The project conducts weekly meetings at a prearranged time, generally at the start of the day. Meetings address current job status, hazards posed by upcoming project activities, and corrective actions taken. It reviews the recorded injuries and near misses, and reiterates job site safety rules and expectations. Time is set aside during the meeting for interactive discussion which allows worker feedback.	0.73
Level F	Continuation of Level E, plus the date of the meeting varies or the meeting can be conducted daily.	0.91

Multi-storey building projects with construction materials management practices scores less than 2.4 (baseline construction materials management practices score) are considered as low-score projects, and they could have an associated less productivity. On the other hand, projects having construction materials management practices scores greater than 2.4 are high-score projects, and the associated productivity could also be high. Projects with construction equipment management practices scores less than 0.93 (baseline construction materials equipment practices score) are considered as low-score projects, and their productivity could be low. Projects with a construction equipment management practices score exceeding 0.93 are regarded as high-score projects, and they could have higher productivity. Projects with management practices related to construction methods scores greater than 4.84 (baseline management practices related to construction methods score) can be considered as high-score projects, and the associated productivity could be high; and those with a score less than 4.84 are low-score projects, and their productivity could be low.

Projects having pre-construction phase management practice scores less than 4.52 (baseline pre-construction phase management practices score) are considered as low-score and less-productive projects. However, projects with a pre-construction phase management practices score exceeding 4.52 can be regarded as high-score projects and could have higher productivity. A human resource management practice score of 4.39 is used a baseline to divide projects into high-score and low-score. Accordingly, projects with HRM practices scores less than 4.39 are considered to have low productivity, and the implementation levels of the HRM practices should be increased to enhance productivity. On the other hand, multi-storey building projects with HRM scores exceeding 4.39 can be considered as high-score projects, and they could have higher productivity. Likewise, multi-storey building projects with safety and health practices scores less than 5.23 (baseline safety and health practices score) are considered as low-score projects, and projects having the safety and health practices scores exceeding 5.23 are high-score projects, and their productivity could be high.

10.2.3 The Probability-Based Regression Models, the Sigmoid Graphs, and the Linear Regression Model

Seven logistic regression models that can be used for predicting the probability of exceeding baseline productivity factors are built and validated (Equation 10-1 to

Equation 10-7). The reliability tests of the probability-based regression models were conducted, and acceptable results were found. By using the seven models, seven sigmoid graphs have been developed to determine the corresponding probabilities when the scores of the construction management practices are known. The first logistic regression model (Equation 10-1) predicts the probability of exceeding productivity factor of 0.90 when the overall score of the construction management practices is known. The overall score is determined by using the scoring tools presented in Table 10-2. The sigmoid graph of the overall construction management practices is shown in Figure 10-1.

Logistic Regression Model of the Overall Construction Management Practices and Productivity

$$\mathbf{P_i = \frac{e^{0.41CMP_i - 7.65}}{1+e^{0.41CMP_i - 7.65}}} \qquad \text{Equation 10-1}$$

P_i is the probability of exceeding productivity factor (PF) = 0.90 for an i^{th} project, CMP_i denotes the overall score of the construction management practices for an i^{th} project, and e is the mathematical constant (approximately = 2.72).

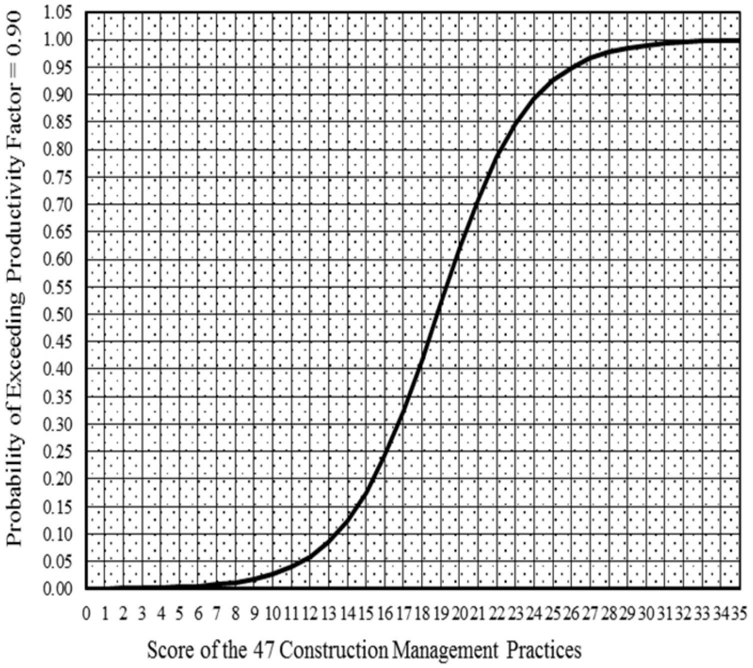


Figure 10-1 Probability Graph Plotted Using the Logistic Regression Model of the Overall Construction Management Practices and Productivity

Logistic Regression Model of the Construction Materials Management Practices and Productivity

The second logistic regression model is used to predict the probability of exceeding productivity factor of 1.05 when a score of construction materials management practices for a certain multi-storey building project is determined. The model is shown in Equation 10-2, and the associated sigmoid graph is indicated in Figure 10-2.

$$\mathbf{P_i}=\frac{e^{1.81MMP_i-6.46}}{1+e^{1.81MMP_i-6.46}} \qquad \text{Equation 10-2}$$

In Equation 10-2, P_i is the probability of exceeding productivity factor (PF) of 1.05 for an i^{th} project, MMP_i is the score of the construction materials management practices for an i^{th} project, and e denotes Euler's number which is approximately 2.72.

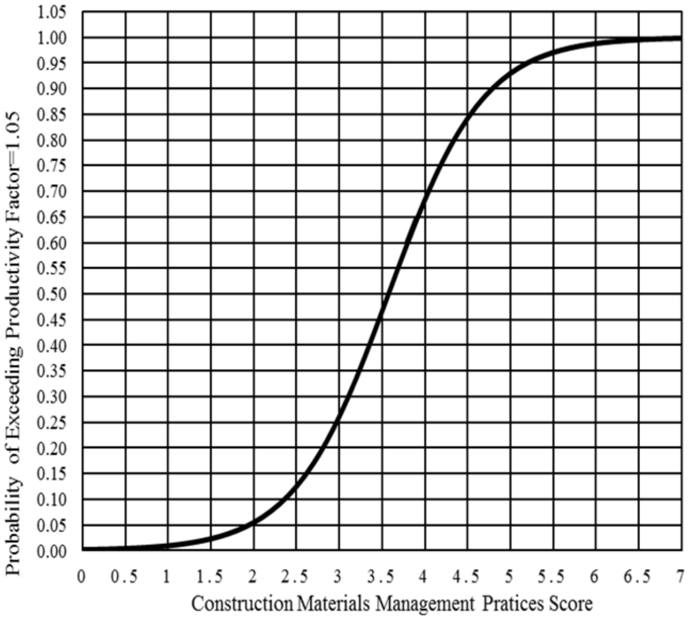


Figure 10-2 Probability Graph Plotted Using the Logistic Regression Model of the Construction Materials Management Practices and Productivity

Logistic Regression Model of the Construction Equipment Management Practices and Productivity

The third model predicts the probability of exceeding productivity factor of 0.90 given a score of construction equipment management practices. The model is presented in Equation 10-3, and the probability graph is shown in Figure 10-3.

$$\mathbf{P_i}=\frac{e^{2.29CEMP_i-0.98}}{1+e^{2.29CEMP_i-0.98}} \qquad \text{Equation 10-3}$$

Where P_i=probability of exceeding PF= 0.90 for an ith project, $CEMP_i$ = score of construction equipment management practice for an i^{th} project, and e= mathematical constant.

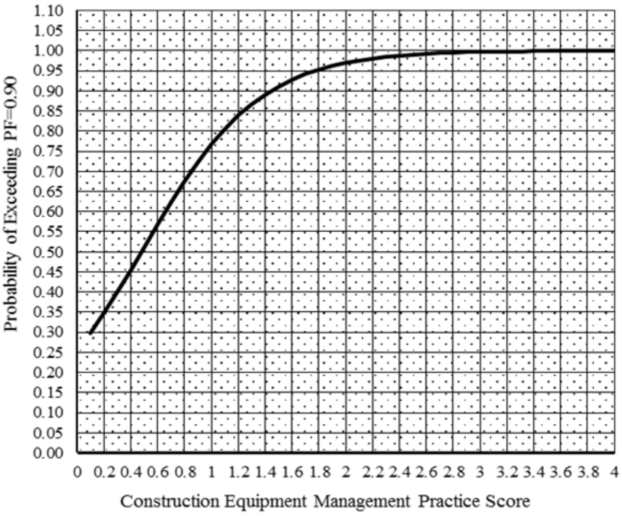


Figure 10-3 Probability Graph Plotted Using the Logistic Regression Model of the Construction Equipment Management Practices and Productivity

Logistic Regression Model of the Management Practices Related to Construction Methods and Productivity

The fourth model is used to predict the probability of exceeding productivity factor of 0.90 when a score of management practices related to construction methods is determined. The model is presented in Equation 10-4, and the sigmoid graph plotted by using the model's equation is shown in Figure 10-4.

$$\mathbf{P_i} = \frac{e^{1.51MPRCM_i - 5.79}}{1 + e^{1.51MPRCM_i - 5.79}} \qquad \text{Equation 10-4}$$

In the equation, P_i is the probability of exceeding PF=0.90 for an i^{th} project, $MPRCM_i$ represents a score of management practices related to construction methods for an i^{th} project, and e is Euler's number.

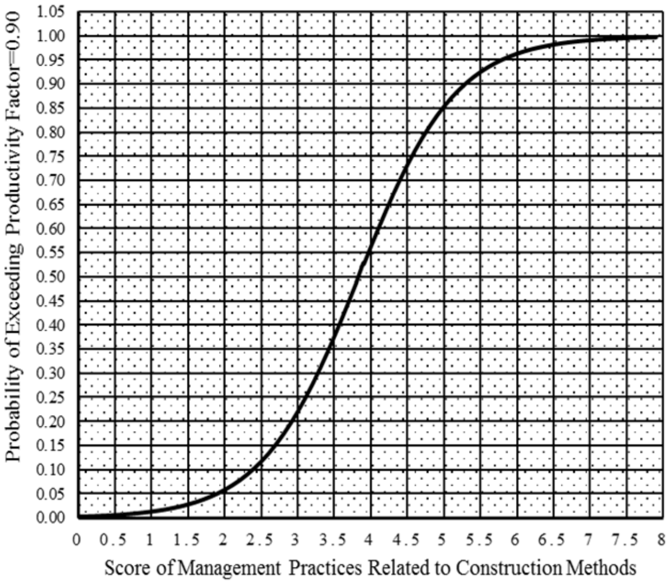


Figure 10-4 Probability Graph Plotted Using the Logistic Regression Model of the Management Practices Related to Construction Methods and Productivity

Logistic Regression Model of the Pre-Construction Phase Management Practices and Productivity

The fifth model (Equation 10-5) is developed to predict the probability of exceeding the productivity factor of 1.0 when a score of pre-construction phase management practices is known. The probability graph which is plotted by using the model is shown in Figure 10-5.

$$P_i = \frac{e^{1.10PCPMP_i - 5.26}}{1 + e^{1.10PCPMP_i - 5.26}} \qquad \text{Equation 10-5}$$

Where P_i = probability of exceeding PF=1.00 for an i^{th} project, $PCPMP_i$ = a score of pre-construction phase management practices of an i^{th} project, and e = mathematical constant which is approximately 2.72.

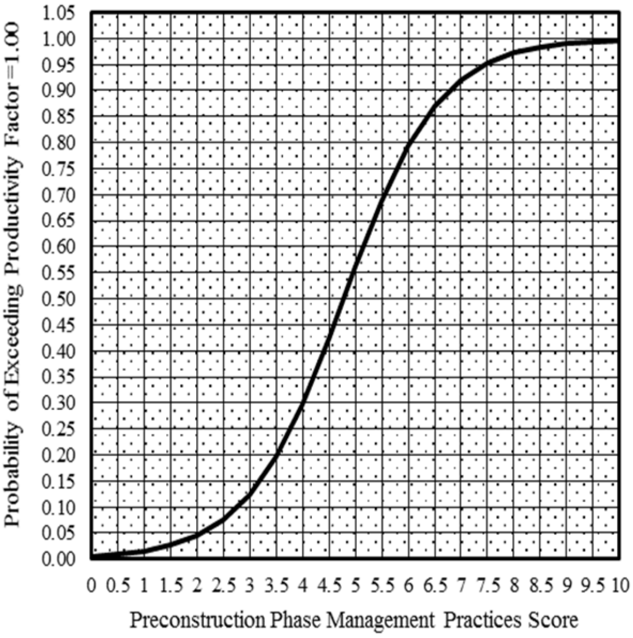


Figure 10-5 Probability Graph Plotted Using the Logistic Regression Model of the Pre-Construction Phase Management Practices and Productivity

Logistic Regression Model of the Human Resource Management Practices and Productivity

The six model predicts the probability of exceeding productivity factor of 0.90 given a score of human resource management practices. The model is represented by Equation 10-6, and the associated sigmoid graph is presented in Figure 10-6.

$$\mathbf{P_i=\frac{e^{1.5HRMP_i-5.68}}{1+e^{1.5HRMP_i-5.68}}} \quad \text{Equation 10-6}$$

P_i = probability of exceeding PF=0.9 for an ith project, HRMP$_i$ = a score of HRM practices for an ith project, and e= mathematical constant.

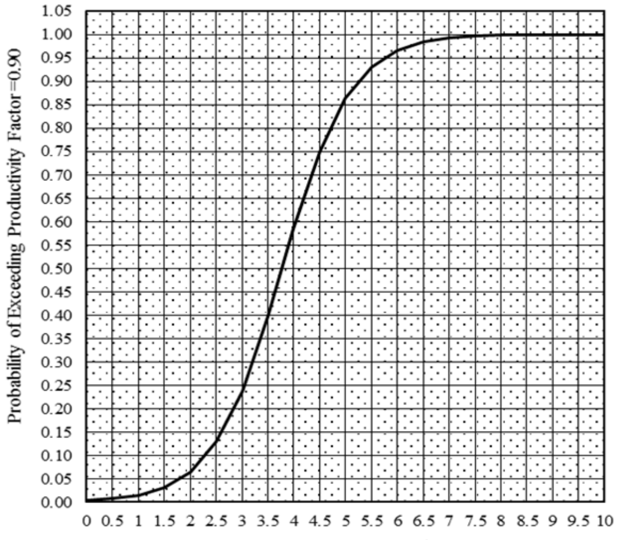


Figure 10-6 Probability Graph Plotted Using the Logistic Regression Model of the Human Resource Management Practices and Productivity

Logistic Regression Model of the Safety and Health Practices and Productivity

The seventh model (Equation 10-7) is used to predict the probability of exceeding productivity factor of 0.90 when a score of safety and health practices is determined. The probability graph plotted using Equation 10-7 is shown in Figure 10-7.

$$\mathbf{P_i = \frac{e^{1.81SHP_i 8.79}}{1+e^{1.81SHP_i -8.79}}} \qquad \text{Equation 10-7}$$

In the equation, P_i is the probability of exceeding productivity factor of 0.9 for an i^{th} project, SHP_i refers to a score of safety and health practices for an i^{th} project, and e = Euler's number.

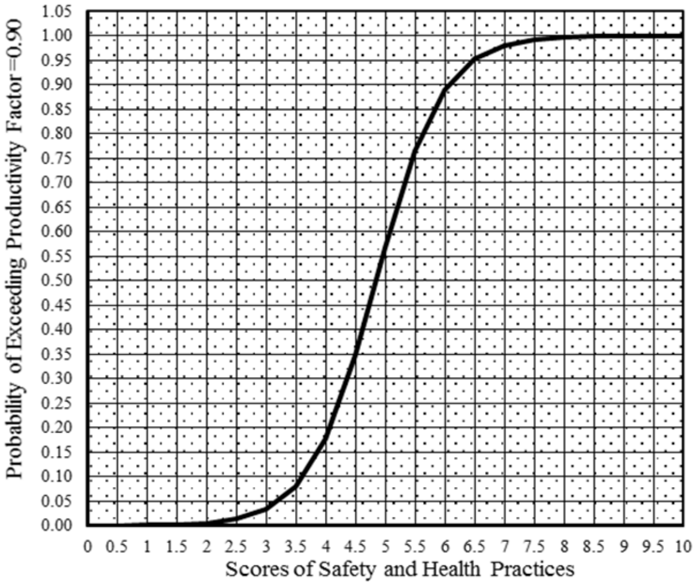


Figure 10-7 Probability Graph Plotted Using the Logistic Regression Model of the Safety and Health Practices and Productivity

Linear Regression Models of the Construction Management Practices and Productivity

The linear regression model which is used to predict the productivity factor of a multi-storey building project based on the overall score of the overall construction management practices is shown in Equation 10-8.

$$\mathbf{PF_i = 0.02CMP_i + 0.58} \qquad \text{Equation 10-8}$$

In the equation, PF_i refers to the productivity factor of an i^{th} project and CMP_i is the overall score of the construction management practices for an i^{th} project.

The linear regression models of the six categories of the construction management practices and productivity are presented in Equation 10-9 to Equation 10-14.

$\mathbf{PF_i = 0.09CMMP_i + 0.74}$ Equation 10-9: Linear Regression Model of Construction Materials Management Practices and Productivity.

$\mathbf{PF_i = 0.13CEMP_i + 0.84}$ Equation 10-10: Linear Regression Model of Construction Equipment Management Practices and Productivity.

$\mathbf{PF_i = 0.08MPRCM_i + 0.61}$ Equation 10-11: Linear Regression Model of Management Practices Related to Construction Methods and Productivity.

$\mathbf{PF_i = 0.06PCPM_i + 0.71}$ Equation 10-12: Linear Regression Model of Pre-Construction Phase Management Practices and Productivity.

$\mathbf{PF_i = 0.07HRMP_i + 0.64}$ Equation 10-13: Linear Regression Model of Human Resource Management Practices and Productivity.

$\mathbf{PF_i = 0.09SHP_i + 0.49}$ Equation 10-14: Linear Regression Model of Safety and Health Practices and Productivity.

Where PF_i = the productivity factor of an i^{th} project, $CMMP_i$ = a score of the construction materials management practices for an i^{th} project, $CEMP_i$ = a score of the construction equipment management practices for an i^{th} project, $MPRCM_i$ represents a score of the management practices related to construction methods for an i^{th} project, $PCPM_i$ is a score of the pre-construction phase management practices for an i^{th} project, $HRMP_i$ = a score of the human resource management practices for an i^{th} project and SHP_i is a score of the safety and health practices for an i^{th} project.

10.3 Implications of the Study

Improving the productivity of construction projects is essential for the economic growth of a country, for increasing the profit margins of contractors, and for reducing the project delays and the associated penalty such as liquidated damages. Over the last three decades, numerous researchers conducted studies which can help contractors to increase the productivity of their construction projects. Despite the presence of many studies on construction productivity, the construction industry is being blamed as the low productive industry as compared to other sectors. Thus, investigation of the techniques which could enhance construction productivity is essential. Most problems identified by previous researchers both in Australia and international context are related to the management of the construction projects. However, the adverse effect of these problems can be minimised by adopting management practices that are suitable to enhance productivity in specific project types such as building, industrial and infrastructure construction projects in a particular location or country. Furthermore, the practices should be measured, and their adequacy needs to be assessed so that corrective actions can be taken by the project managers. Moreover, the management practices should be planned, controlled, and evaluated; and the associated productivity level should be estimated based on the planned practices.

The finding of this study confirmed that not all construction management practices that are identified for enhancing productivity in infrastructure and industrial projects in North America are suitable for multi-storey building projects in Australia. Moreover, the priorities of the practices are different. For instance, site tools management strategy, tools tracking systems and on-site tools maintenance are among the three practices that are common to infrastructure and industrial projects (CII, 2013a, CII, 2013b). However, it is found that the tools management systems are not suitable for multi-storey building projects. Similarly, the scoring tools developed for engineering projects are not appropriate to measure construction management practices in multi-storey building projects as the type and the weights of the practices vary based on the types of projects. Furthermore, previous researchers did not integrate the management practices with productivity. The users of the existing tools are unable to predict the productivity of their project based on the scores of their construction management practices. Thus, this research is conducted to identify the construction management practices which are suitable to improve productivity in multi-storey building projects in the context of Victoria State Australia, to refine and validate the management practices scoring tools for multi-storey building projects, and to develop and validate the productivity prediction tools based on the measured values of the management practices. This section addresses the practical as well as the theoretical contributions of this study.

10.3.1 Practical Implications

This study has practical implications for contractors in Australia and other countries. Contractors involved in the delivery of multi-storey building projects in Victoria State, Australia can implement the identified construction management practices to improve productivity in their projects. Contractors in other countries can also implement the identified practices to enhance the productivity of their multi-storey building projects. However, as the practices could vary from country to country, validation is required to adapt to any local context. Contractors can focus on the implementation of the most important management practices identified in the study.

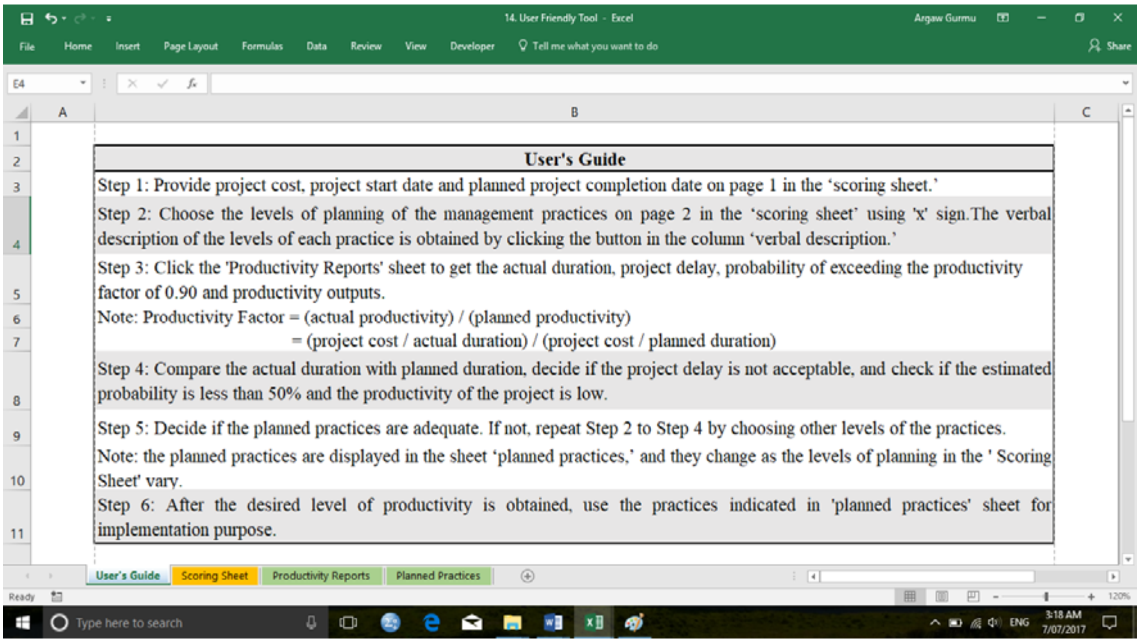
Contractors can use the scoring tools to assess the adequacy of their management practices. They can measure their practices using the scoring tools and compare with the baseline score developed in this research and take corrective actions. If the management practices score of a certain multi-storey building project is less than the baseline score, then the management practices of the particular project can be considered as inadequate, and the productivity of the project would be low. Thus, the project manager of a contractor should implement appropriate practices to potentially improve the productivity of the project.

The scoring tools can also be used as management practices' planning, monitoring, and evaluation tools during planning, construction and completion phases of a multi-storey building project respectively. During the project planning phase, the scoring tools and the logistic regression model or the linear regression model can be used to plan the management practices that could be implemented on a certain multi-storey building project. The logistic regression model can be used when the project manager wants to assess the expected productivity of a certain multi-storey building project with respect to a baseline productivity factor when a score of the management practices is known. Based on the predicted probability of exceeding the baseline productivity factor, the contractor's project manager can implement corrective actions to increase the chance of achieving a higher level of productivity as compared to the baseline. The linear regression model can be used when the project manager is interested in estimating the productivity factor of a certain multi-storey building construction project using the measured value of the construction management practices. Based on the predicted productivity factor, the project manager can make necessary decisions which could assist him/her to increase the productivity of a certain multi-storey building project. Similarly, by using the predicted productivity factor, the contractor's project manager can quantify the expected project delays in days or months.

During the construction phase, the scoring tools can be used to control the implementation of the management practices. The project manager of a certain multi-storey building project can use the tools to monitor if the implemented practices comply with the planned practices and take corrective actions if there is a deviation. During the project closure phase, the scoring tools can be used to evaluate if the practices which are implemented on a certain multi-storey building project are associated with the estimated productivity factor of the project. If the implemented practices are not associated with the desired level of productivity, lessons can be learnt from the completed project, and appropriate practices will be planned for future similar projects.

Finally, a user-friendly tool is developed by using Visual Basic Applications (VBA) in Microsoft Excel 2016 version so that the management practices scoring tools can be used easily. The tool comprises of four sheets: (1) User's Guide, (2) Scoring Sheet, (3) Productivity Reports and (4) Planned Practices. The 'User's Guide' sheet explains the procedures to be followed by the users. Table 10-3 shows the screenshot of the User's Guide sheet.

Table 10-3 The User's Guide Sheet



User's Guide

Step 1: Provide project cost, project start date and planned project completion date on page 1 in the 'scoring sheet.'

Step 2: Choose the levels of planning of the management practices on page 2 in the 'scoring sheet' using 'x' sign.The verbal description of the levels of each practice is obtained by clicking the button in the column 'verbal description.'

Step 3: Click the 'Productivity Reports' sheet to get the actual duration, project delay, probability of exceeding the productivity factor of 0.90 and productivity outputs.

Note: Productivity Factor = (actual productivity) / (planned productivity)
= (project cost / actual duration) / (project cost / planned duration)

Step 4: Compare the actual duration with planned duration, decide if the project delay is not acceptable, and check if the estimated probability is less than 50% and the productivity of the project is low.

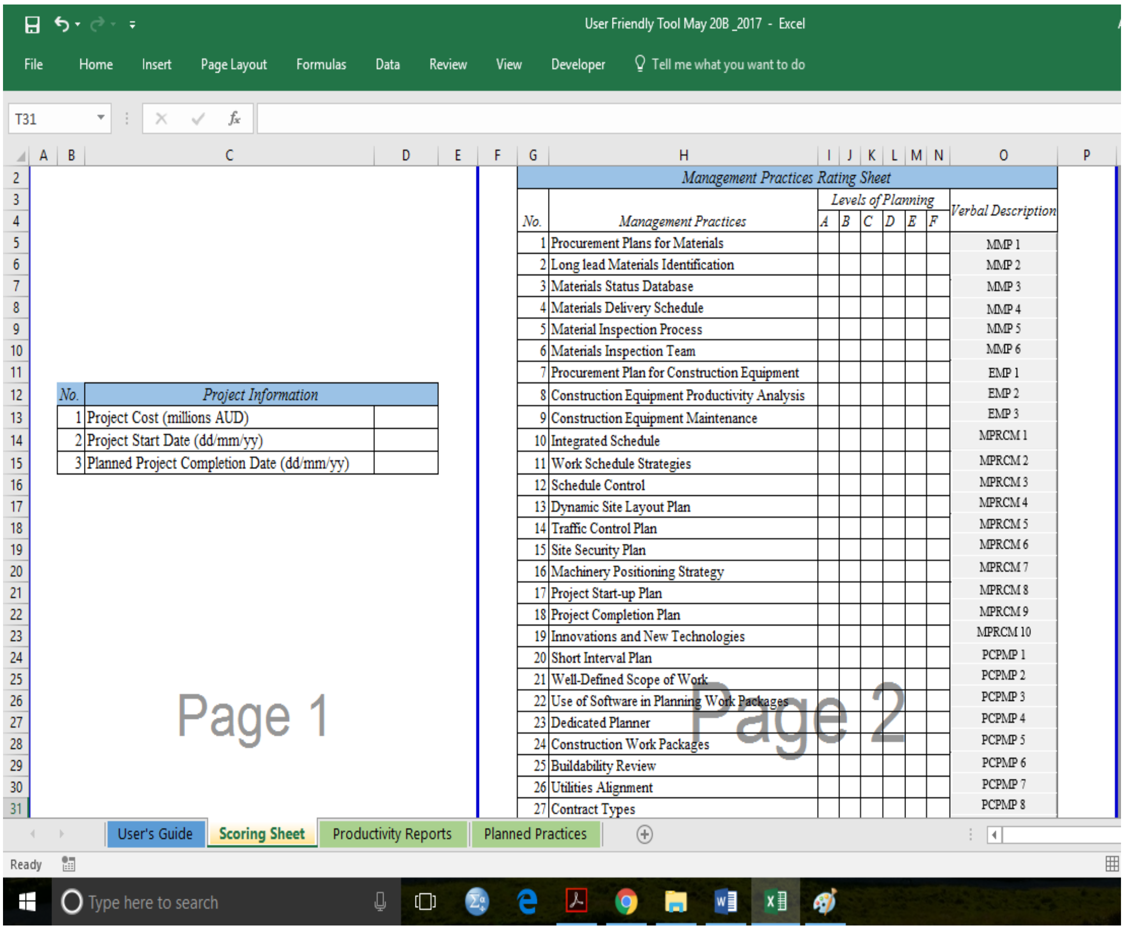
Step 5: Decide if the planned practices are adequate. If not, repeat Step 2 to Step 4 by choosing other levels of the practices.

Note: the planned practices are displayed in the sheet 'planned practices,' and they change as the levels of planning in the ' Scoring Sheet' vary.

Step 6: After the desired level of productivity is obtained, use the practices indicated in 'planned practices' sheet for implementation purpose.

In Page 1 of the 'Scoring Sheet,' users are requested to provide project cost, project start date and planned project completion date. In page 2 of the 'Scoring Sheet,' users choose the level of planning of each management practice. Table 10-4 presents the two pages of the 'Scoring Sheet' which do not contain the project details. Users can also view the detailed descriptions of each level of planning by clicking the command button under the column 'verbal descriptions.' For instance, the contractors' project managers can click the command button MMP 1 to read the message box which displays the description of the levels of the practice 'procurement plans for materials.'

Table 10-4 The Scoring Sheet of the User-Friendly Tool



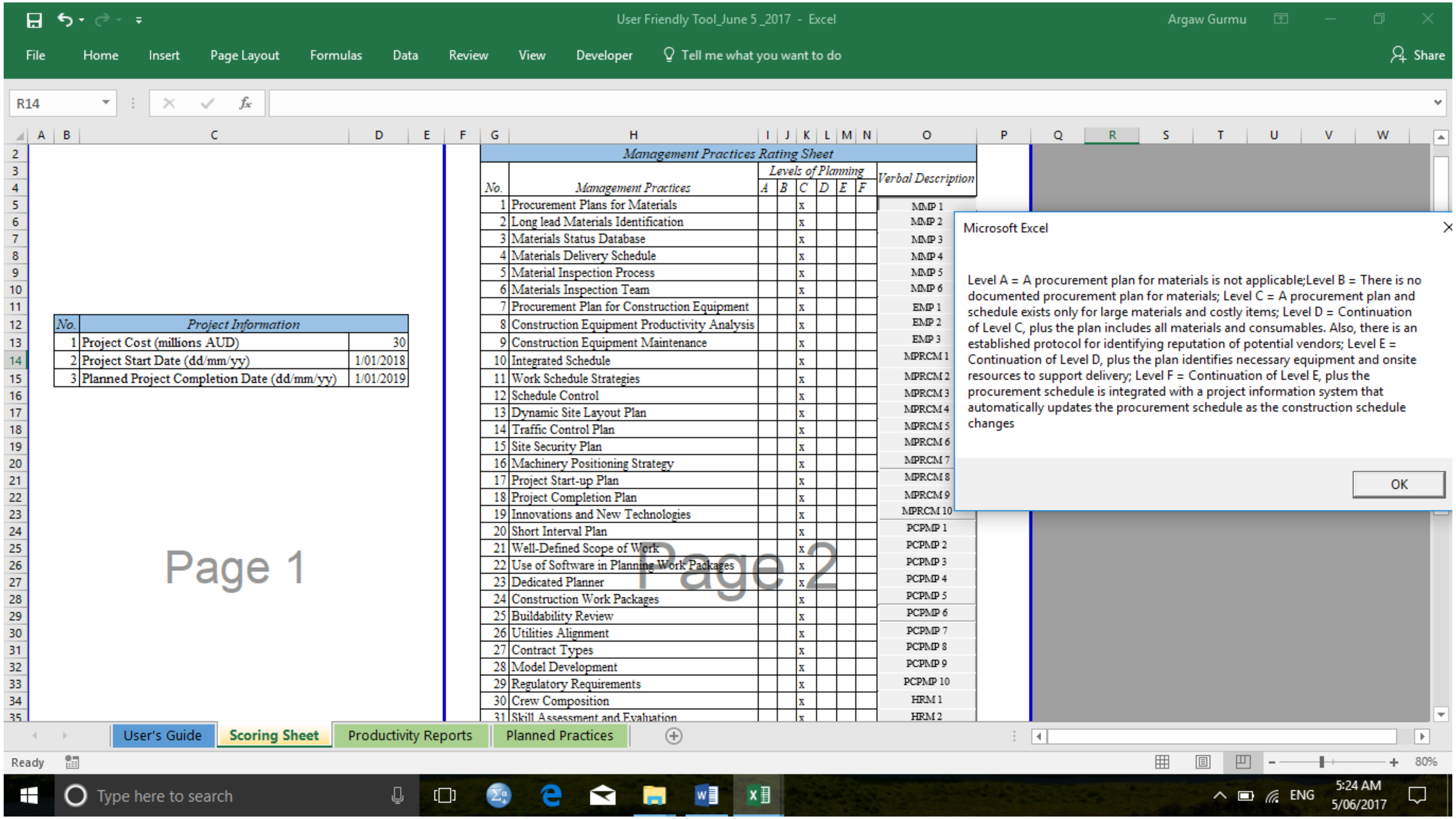
No.	Project Information	
1	Project Cost (millions AUD)	
2	Project Start Date (dd/mm/yy)	
3	Planned Project Completion Date (dd/mm/yy)	

Management Practices Rating Sheet

No.	Management Practices	Levels of Planning						Verbal Description
		A	B	C	D	E	F	
1	Procurement Plans for Materials							MMP 1
2	Long lead Materials Identification							MMP 2
3	Materials Status Database							MMP 3
4	Materials Delivery Schedule							MMP 4
5	Material Inspection Process							MMP 5
6	Materials Inspection Team							MMP 6
7	Procurement Plan for Construction Equipment							EMP 1
8	Construction Equipment Productivity Analysis							EMP 2
9	Construction Equipment Maintenance							EMP 3
10	Integrated Schedule							MPRCM 1
11	Work Schedule Strategies							MPRCM 2
12	Schedule Control							MPRCM 3
13	Dynamic Site Layout Plan							MPRCM 4
14	Traffic Control Plan							MPRCM 5
15	Site Security Plan							MPRCM 6
16	Machinery Positioning Strategy							MPRCM 7
17	Project Start-up Plan							MPRCM 8
18	Project Completion Plan							MPRCM 9
19	Innovations and New Technologies							MPRCM 10
20	Short Interval Plan							PCPMP 1
21	Well-Defined Scope of Work							PCPMP 2
22	Use of Software in Planning Work Packages							PCPMP 3
23	Dedicated Planner							PCPMP 4
24	Construction Work Packages							PCPMP 5
25	Buildability Review							PCPMP 6
26	Utilities Alignment							PCPMP 7
27	Contract Types							PCPMP 8

The project information and the management practices of an example multi-storey building project are provided in Table 10-5. After filling the forms on page 1 and page 2 of the 'Scoring Sheet,' the project managers of multi-storey building projects can open the sheet 'Productivity Reports' to get productivity related information which will help them to make necessary decision. The outputs in the 'Productivity Reports' sheet include the probability of exceeding the baseline productivity factor of 0.90, project delay, the expected productivity of the project and the actual completion date of the project which is predicted based on the levels of planning of the practices. Table 10-6 presents the outputs of the example project whose information is provided in the 'Scoring Sheet.'

Table 10-5 The Project Information and Management Practices for an Example Project



No.	Project Information	
1	Project Cost (millions AUD)	30
2	Project Start Date (dd/mm/yy)	1/01/2018
3	Planned Project Completion Date (dd/mm/yy)	1/01/2019

Management Practices Rating Sheet

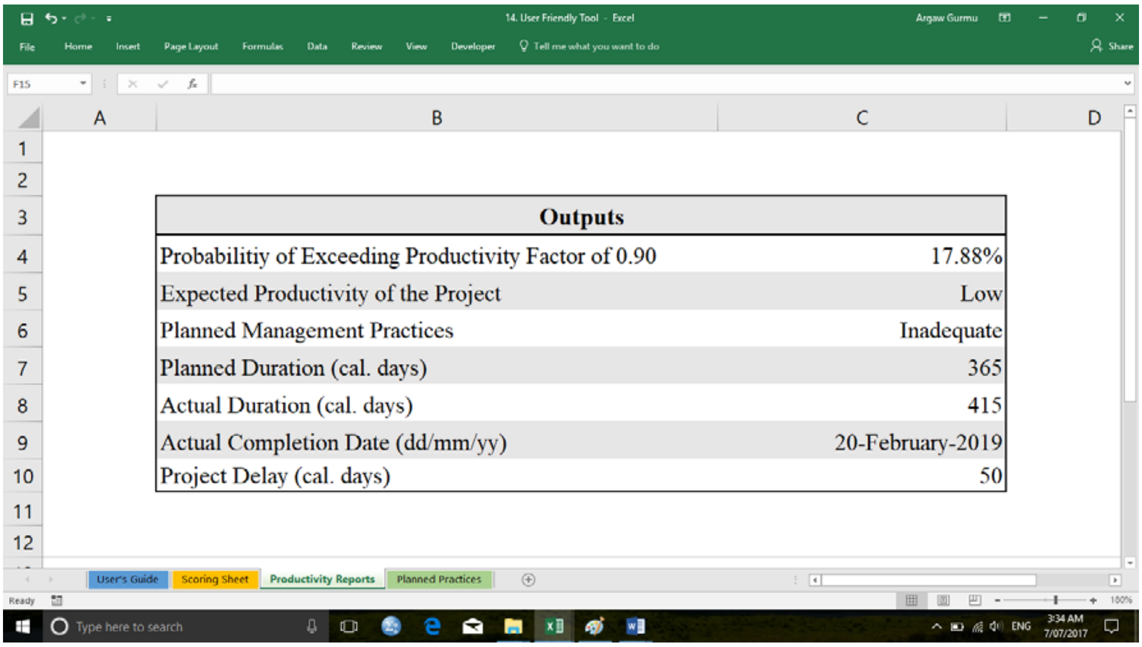
No.	*Management Practices*	*Levels of Planning*						*Verbal Description*
		A	*B*	*C*	*D*	*E*	*F*	
1	Procurement Plans for Materials			x				MMP 1
2	Long lead Materials Identification			x				MMP 2
3	Materials Status Database			x				MMP 3
4	Materials Delivery Schedule			x				MMP 4
5	Material Inspection Process			x				MMP 5
6	Materials Inspection Team			x				MMP 6
7	Procurement Plan for Construction Equipment			x				EMP 1
8	Construction Equipment Productivity Analysis			x				EMP 2
9	Construction Equipment Maintenance			x				EMP 3
10	Integrated Schedule			x				MPRCM 1
11	Work Schedule Strategies			x				MPRCM 2
12	Schedule Control			x				MPRCM 3
13	Dynamic Site Layout Plan			x				MPRCM 4
14	Traffic Control Plan			x				MPRCM 5
15	Site Security Plan			x				MPRCM 6
16	Machinery Positioning Strategy			x				MPRCM 7
17	Project Start-up Plan			x				MPRCM 8
18	Project Completion Plan			x				MPRCM 9
19	Innovations and New Technologies			x				MPRCM 10
20	Short Interval Plan			x				PCPMP 1
21	Well-Defined Scope of Work			x				PCPMP 2
22	Use of Software in Planning Work Packages			x				PCPMP 3
23	Dedicated Planner			x				PCPMP 4
24	Construction Work Packages			x				PCPMP 5
25	Buildability Review			x				PCPMP 6
26	Utilities Alignment			x				PCPMP 7
27	Contract Types			x				PCPMP 8
28	Model Development			x				PCPMP 9
29	Regulatory Requirements			x				PCPMP 10
30	Crew Composition			x				HRM 1
31	Skill Assessment and Evaluation			x				HRM 2

Microsoft Excel

Level A = A procurement plan for materials is not applicable;Level B = There is no documented procurement plan for materials; Level C = A procurement plan and schedule exists only for large materials and costly items; Level D = Continuation of Level C, plus the plan includes all materials and consumables. Also, there is an established protocol for identifying reputation of potential vendors; Level E = Continuation of Level D, plus the plan identifies necessary equipment and onsite resources to support delivery; Level F = Continuation of Level E, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes

OK

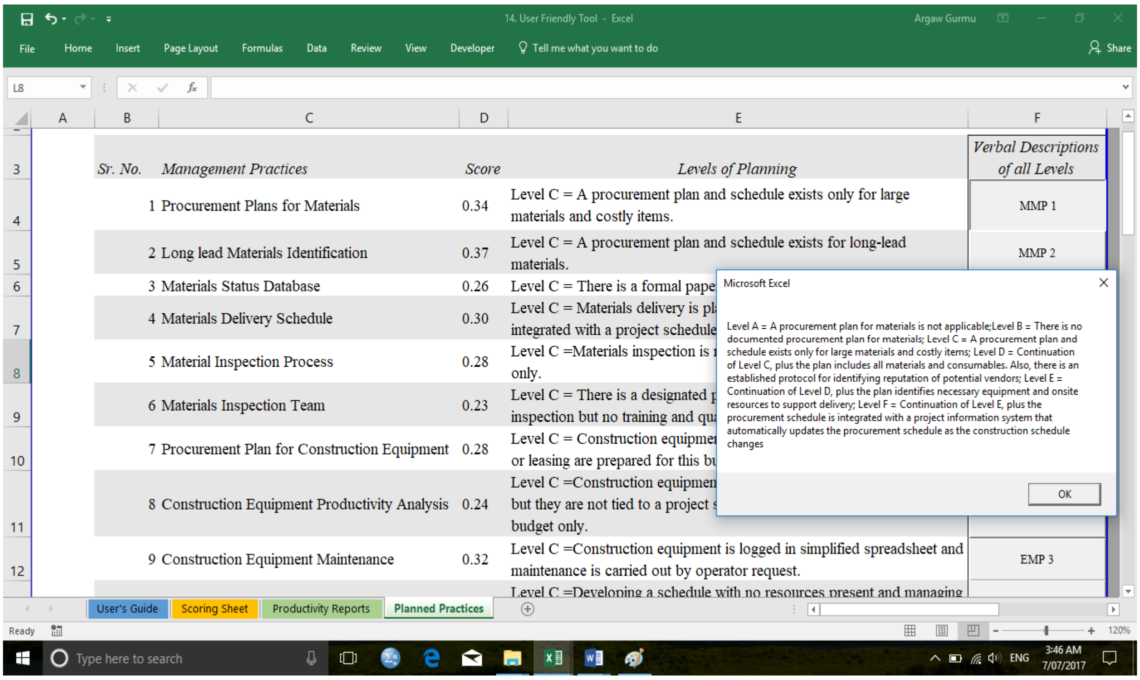
Table 10-6 Productivity Reports for the Example Project



Outputs	
Probabilitiy of Exceeding Productivity Factor of 0.90	17.88%
Expected Productivity of the Project	Low
Planned Management Practices	Inadequate
Planned Duration (cal. days)	365
Actual Duration (cal. days)	415
Actual Completion Date (dd/mm/yy)	20-February-2019
Project Delay (cal. days)	50

The ‘Planned Practices’ sheet shows the management practices scores and the verbal descriptions of the levels of planning which the user has chosen in the ‘Scoring Sheet.’ All the verbal descriptions of the 47 management practices can be viewed by clicking the command button of each practice under the ‘verbal description’ column (Table 10-7).

Table 10-7 The Management Practices Scores of the Example Project



Sr. No.	*Management Practices*	*Score*	*Levels of Planning*	*Verbal Descriptions of all Levels*
1	Procurement Plans for Materials	0.34	Level C = A procurement plan and schedule exists only for large materials and costly items.	MMP 1
2	Long lead Materials Identification	0.37	Level C = A procurement plan and schedule exists for long-lead materials.	MMP 2
3	Materials Status Database	0.26	Level C = There is a formal pape	
4	Materials Delivery Schedule	0.30	Level C = Materials delivery is pl integrated with a project schedule	
5	Material Inspection Process	0.28	Level C =Materials inspection is only.	
6	Materials Inspection Team	0.23	Level C = There is a designated p inspection but no training and qua	
7	Procurement Plan for Construction Equipment	0.28	Level C = Construction equipmen or leasing are prepared for this bu	
8	Construction Equipment Productivity Analysis	0.24	Level C =Construction equipmen but they are not tied to a project s budget only.	
9	Construction Equipment Maintenance	0.32	Level C =Construction equipment is logged in simplified spreadsheet and maintenance is carried out by operator request.	EMP 3
			Level C =Developing a schedule with no resources present and managing	

Microsoft Excel

Level A = A procurement plan for materials is not applicable;Level B = There is no documented procurement plan for materials; Level C = A procurement plan and schedule exists only for large materials and costly items; Level D = Continuation of Level C, plus the plan includes all materials and consumables. Also, there is an established protocol for identifying reputation of potential vendors; Level E = Continuation of Level D, plus the plan identifies necessary equipment and onsite resources to support delivery; Level F = Continuation of Level E, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes

OK

10.3.2 Theoretical Implications

This research contributes to the body of knowledge in construction management by identifying the management practices which are suitable to enhance labour productivity in multi-storey building construction projects. Researchers in other countries can use the independent variables (the construction management practices) identified in this study to investigate the relationship between productivity of multi-storey building projects and the construction management practices in other contexts. Moreover, they can also analyse the relative importance of the identified management practices in improving the productivity of multi-storey building construction projects in other countries and compare their findings with this study’s findings. It is also theoretically useful to understand which management practices that have the potential to enhance productivity in multi-storey building projects and engineering projects are similar and which are different and why. The findings should facilitate international comparisons as well as sectoral comparison and provide useful information to companies seeking construction works in Australia. After validation, researchers in other countries can use the scoring tools to measure the management practices and investigate the relationship between productivity and the practices. They can also develop productivity prediction models based on a score of the practices.

Besides the contribution to the body of knowledge in construction management, this research contributes to the growth accounting framework, which is based on neoclassical economic growth theory, by identifying independent variables or the construction management practices that can drive labour productivity in the context of multi-storey building construction projects. The neoclassical economic growth theory states that the two main sources of increasing the output per worker are the technological advancement and capital accumulation. The growth accounting framework suggested that the management practices could also be the source of growth in the labour productivity. However, the framework does not explain which management practices, in which sector, are suitable to enhance labour productivity. Thus, this research helps to increase the understanding of the construction management practices that have potential to improve productivity in the multi-storey building projects. The study identified 47 practices, prepared the measuring tools, and developed prediction models. It is found that the construction management practices can explain about 48% of the variance in the productivity factor, and the relationship between productivity and the practices is statistically significant. The remaining variance could be explained by other factors such as advance in technology and government regulations among others.

10.4 Study Limitations and Future Research Directions

This research developed models which can be used to predict the probability of exceeding baseline productivity factor when a score of the management practices is known. However, it did not identify the costs associated with each level of implementation of the construction management practices. Thus, future researchers can investigate the costs of implementation of the construction management practices and develop a model which integrates cost and the practices. Consequently, the contractors' project managers can make decisions regarding the implementation of the management practices on certain multi-storey building projects by considering the associated costs besides the estimated productivity levels.

This study focuses on the development and validation of the prediction models at the multi-storey building construction project level. Thus, activity level productivity could not be estimated using the models. Hence, future researchers can collect activity level productivity data, measure the management practices using the scoring tools prepared in this research, and develop as well as validate the productivity prediction models at activity levels. For instance, a model which can be used to predict the productivity of the concrete activity based on a score of the construction management practices can be built.

Due to the anonymity of the information related to construction productivity, the data such as floor areas, the number of storeys, and the layout of the project sites could not be obtained. Consequently, the associations among the floors areas, the number of storeys of the building projects and the construction management practices were not analysed. Thus, future studies can investigate these relationships by collecting the corresponding data. Furthermore, since some of the management practices identified in this research might not be suitable to enhance productivity in building projects with less than three storeys, it is recommended that future researchers need to identify which of the management practices are appropriate and which are not.

The other research direction is regarding the use of the management practices identified in this study in other countries. Since the practices might vary from country to country, validation is required prior to the implementation of the management practices that have the potential to improve productivity in multi-storey building construction projects in other contexts. Thus, future researchers can investigate context-specific management practices by using the findings of this study as a starting point. Moreover, as the weights of the practices could vary based on the local regulations, working culture, climate and other factors, future researchers can refine and validate the scoring tools and test the tools' reliability by using similar methodology adopted in this study.

Since the relative importance and the type of the management practices which could enhance productivity in multi-storey building projects and engineering projects might be different, future researchers in Australia should identify and prioritise the practices that are appropriate for increasing productivity in infrastructure and industrial construction projects in the context of Australia. The finding of this study can be used as a starting point for future investigations. It can also be used for comparison purpose.

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APPENDIX 1: QUESTIONNAIRE

PART -I

A. Relative Importance of the Construction Management Practices That Could Enhance Productivity in Multi-Storey Building Projects

A1: Please rate the following construction materials management practices based on their degree of importance in improving productivity in multi-storey building construction projects on the scale of 1 to 5.

No.	*Construction Materials Management Practices*	*Level of Importance*				
		Not important (1)	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
1	Procurement Plans for Materials					
2	Long-Lead Materials Identification					
3	Materials Status Database					
4	Materials Delivery Schedule					
5	Material Inspection Process					
6	Materials Inspection Team					

A2: Please rate the following construction equipment management practices based on their degree of importance in improving productivity in multi-storey building construction projects on the scale of 1 to 5.

No.	*Construction Equipment Management Practices*	*Level of Importance*				
		Not important (1)	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
1	Procurement Plan for Construction Equipment					
2	Construction Equipment Productivity Analysis					
3	Construction Equipment Maintenance					

A3: Please rate the following management practices related to construction methods based on their degree of importance in improving productivity in multi-storey building construction projects on the scale of 1 to 5.

No.	*Management Practices Related to Construction Methods*	*Level of Importance*				
		Not important (1)	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
1	Integrated Schedule					
2	Work Schedule Strategies					
3	Schedule Control					
4	Dynamic Site Lay Out Plan					
5	Traffic Control Plan					
6	Site Security Plan					
7	Machinery Positioning Strategy					
8	Project Start-Up Plan					
9	Project Completion Plan					
10	Innovations and New Technologies					

A4: Please rate the following pre-construction phase management practices based on their degree of importance in improving productivity in multi-storey building construction projects on the scale of 1 to 5.

No.	*Pre-construction Phase Management Practices*	*Level of Importance*				
		Not important (1)	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
1	Well-defined Scope of Work					
2	Short Interval Plan					
3	Buildability Review					

4	Construction Work Packages					
5	Regulatory requirement					
6	Contract Types					
7	Use of Software in planning Work Packages					
8	Utilities Alignment					
9	Dedicated Planner					
10	Model Development					

A5: Please rate the following human resource management practices based on their degree of importance in improving productivity in multi-storey building construction projects on the scale of 1 to 5.

No.	*Human Resource Management Practices*	*Level of Importance*				
		Not important (1)	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
1	Crew Composition					
2	Skill Assessment and Evaluation					
3	Employees Training					
4	Career Development					
5	Non-Financial Incentive Programs					
6	Financial Incentive Programs					
7	Social Activities					
8	Stability of Organizational Structure					
9	Clear Delegation of Responsibility					
10	Retention Plan for Experienced Personnel					
11	Exit Interviews					

A6: Please rate the following safety and health practices based on their degree of importance in improving productivity in multi-storey building construction projects on the scale of 1 to 5.

No.	*Safety and Health Practices*	*Level of Importance*				
		Not important (1)	*Slightly important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
1	Housekeeping					
2	Safety and Health Policy					
3	Safety and Health Plan					
4	Safe Work Method Statement					
5	Hazards Analysis					
6	Safety and Health Training					
7	Toolbox Safety Meetings					

PART-II

B. Project Characteristics

Project type (residential, commercial etc.) ________
Project value ________
Floor area ________
Project start date: ________
Planned completion date: ________
Actual completion date: ________

C. Validated Survey Instruments (adapted from CII (2013a) and CII (2013b))

C1: Validated Survey Instrument for Construction Materials Management Practices

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.

(√)	*1. Procurement Plan for Construction Equipment*	
	Level A	A procurement plan for materials and equipment is not applicable
	Level B	There is no documented procurement plan for materials.

	Level C	A procurement plan and schedule exists only for large materials and costly items.
	Level D	Continuation of Level C, plus plan includes all materials and consumables. Also, there is an established protocol for identifying reputation of potential vendors.
	Level E	Continuation of Level D, plus plan identifies necessary equipment and onsite resources to support delivery.
	Level F	Continuation of Level E, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule
(√)	*2. Long lead Materials Identification*	
	Level A	A separate procurement plan for long-lead materials is not applicable.
	Level B	There is no documented procurement plan for long-lead materials.
	Level C	A procurement plan and schedule exists for long-lead materials.
	Level D	Continuation of Level C, plus there is an established protocol for identifying reputation of potential vendors.
	Level E	Continuation of Level D, plus plan identifies necessary equipment and onsite resources to support delivery.
	Level F	Continuation of Level E, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.
(√)	*3. Materials Status Database*	
	Level A	Material status database is not applicable.
	Level B	There is no formal paper based system used to track materials status.
	Level C	There is a formal paper based system to track materials status.
	Level D	A proprietary internal materials status software tool is used, but it is not integrated with your company's project control systems or used by other contractors.
	Level E	An available software tool is used but it is only integrated internally with your company's project control systems.
	Level F	An available software tool is used by all stakeholders that are integrated with your supply chain and other project control systems.
(√)	*4. Materials Delivery Schedule*	
	Level A	Materials delivery schedule is not applicable.
	Level B	There is no documented materials delivery schedule.
	Level C	Materials delivery is planned early in the project and is integrated with a project schedule.
	Level D	Continuation of Level C plus the schedule is automatically updated on receipt of new information as procurement proceeds.
	Level E	Continuation of Level D plus the schedule is automatically linked with procurement, materials management, and overall project scheduling systems.
	Level F	Continuation of Level E plus materials delivery planning and management is completely integrated with other automated project processes including automated materials tracking throughout the supply chain.
(√)	*5. Material Inspection Process*	
	Level A	A material inspection process is not applicable.
	Level B	There is no materials inspection process.
	Level C	A materials inspection process is only utilized for large items or costly items on a project.
	Level D	A materials inspection process is utilized that includes all items delivered to the site. There is a lack of organization of the process and materials are not separated into stages of the receipt process nor does it record the location of the materials and mark the materials for tracking
	Level E	A materials inspection process is used at the supplier and onsite, and organizes materials receipt inspections immediately upon delivery of materials, verifies that materials conform to standards, and organizes materials for tracking.
	Level F	Continuation of Level E, plus the process includes separation of material into categorical stages of the receipt process (e.g. awaiting inspection, storage area restocking, scrap, and/or awaiting for shipment, verification if the materials conform to specifications, standards, drawings, etc., record of the location of materials and marked materials for tracking, and prioritization for quality).
(√)	*6. Materials Inspection Team*	
	Level A	Materials inspection team is not applicable.
	Level B	There is no materials inspection team.

	Level C	There is a designated materials inspection team but no training and qualifications of the individual's skill level is specified.
	Level D	Continuations of Level C, plus inspections are performed by project managers or workers rather than the team.
	Level E	Continuation of Level D, plus the inspection team can adequately inspect materials and understand the material specifications.
	Level F	Continuation of Level E, plus the members of the inspection team are experts at inspection processes and procedures, and knows how to inspect materials and understands the material specifications.

C2: Validated Survey Instrument for Construction Equipment Management Practices

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.		
(√		*1. Procurement Plan for Construction Equipment*
	Level A	A procurement plan for construction equipment is not applicable for this building project.
	Level B	Construction equipment procurement is not prepared for this building project.
	Level C	Construction equipment procurement strategies such as hiring or leasing are prepared for this building project.
	Level D	Continuation of Level C and there is a procedure for identifying reputation of potential equipment suppliers
	Level E	Continuation of Level D, plus plan identifies necessary equipment and onsite resources to support delivery.
	Level F	Continuation of Level E and construction equipment schedule is integrated with other project schedules.
(√)		*2. Construction Equipment Productivity Analysis*
	Level A	Construction equipment is not used on this building project.
	Level B	Construction equipment is utilized but requirements and usage are not planned and tracked.
	Level C	Construction equipment requirements are planned and tracked but they are not tied to a schedule. The usage is tracked against budget only.
	Level D	Continuations of Level C and regular meeting is conducted to assess the requirement of construction equipment.
	Level E	Continuation of Level D, and construction equipment resource curves are drawn and resources are leveled.
	Level F	Continuation of Level E and equipment schedule is adjusted based on the audit report that shows equipment downtime and other information.
(√)		*3. Construction Equipment Maintenance*
	Level A	Construction equipment maintenance is not applicable for this building project.
	Level B	Construction equipment maintenance is not planned for or this building project.
	Level C	Construction equipment is logged in simplified spreadsheet and maintenance is carried out by operator request.
	Level D	Continuation of Level C and equipment maintenance record is linked to individual construction equipment, and maintenance is centrally scheduled and administered.
	Level E	Continuation of Level D and a computer program is used to record and administer equipment maintenance information such as required and accomplished maintenance logs and usage logs.
	Level F	Continuation of Level E and maintenance schedule is electronically updated and maintenance due notices are automatically issued to concerned parties.

C3: Validated Survey Instrument for Management Practices Related to Construction Methods

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.		
(√)	*1.Integrated Schedule*	
	Level A	The use of an integrated schedule using CPM is not applicable.
	Level B	The use of an integrated schedule using CPM has not been addressed
	Level C	Developing a schedule with no resources present and managing schedule status via duration or remaining duration but no link to earned percent complete progress from associated deliverables per activity.

	Level D	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity.
	Level E	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity. Resources are updated to reflect current work content or quantity adjustments.
	Level F	Continuation of Level E and updated to include quantity adjustments. Earned progress for the activity is based on measured or assessed work completed per deliverables per activity. Progress measurement performed in application adapted specifically for each deliverable.
(√)	*2. Work Schedule Strategies*	
	Level A	The development of a work schedule strategy is not applicable
	Level B	The development of a work schedule strategy has not been addressed
	Level C	The strategy is based on a single work schedule be it either a straight time such as 36 hours per week schedule, overtime, or other work schedule strategies.
	Level D	Strategy considers multiple work schedules considering critical and near critical activity sequences.
	Level E	Continuation of Level D, plus strategies consider the potential impact on worker fatigue, supervision, safety, and absenteeism.
	Level F	Continuation of Level E, plus each potential strategy's impact is analysed for manpower density and congestion at an area or sub-area level.
(√)	*3. Schedule Control*	
	Level A	The development of a schedule compliance plan is not applicable
	Level B	The development of a schedule compliance plan has not been addressed
	Level C	Consistent follow-up to monitor the following tasks: schedule updated periodically, critical path analysis, and progress narrative prepared as required and effective team participation in schedule updates.
	Level D	Continuation of Level C, plus quantity reports are regularly performed. Upon request, or as the project requires, may include any of the following: change management analysis, risks assessment scenarios/analysis, date variance analysis to approved baseline or previous update period, start / finish percent achieved ratio analysis, communication with material suppliers to ensure material will arrive on site when planned.
	Level E	Continuation of Level D, plus monitor the following: schedule rigorously updated based on manual input of quantity reports, critical and near critical path analysis, progress narrative prepared and effective team participation in schedule updates. Quantity reports rigorously done by trained individual(s). Material suppliers routinely contacted to track the status of material delivery dates.
	Level F	Continuation of Level E, plus will consistently include all of the following, based on project requirements and observed schedule status conditions: change management analysis, risks assessment scenarios/analysis, date variance analysis to approved baseline or previous update period, start / finish percent achieved ratio analysis; also included progress tracking using 3D imaging and other techniques.
(√)	*4. Dynamic Site Layout Plan*	
	Level A	Site layout plan is not applicable for the project.
	Level B	A site layout plan has not been addressed.
	Level C	The project team examines the project schedule and assesses when Temporary Facilities (TF) will be brought in.
	Level D	Continuation of Level C, plus what sizes will be needed prior to the start of the project. No consideration is given to the addition and removal of TFs at different stages of the project. No analysis is done in regards to the layout of the project to optimize locations of the TFs to limit travel time.
	Level E	Continuation of Level D, plus consideration is given to the addition and removal of TFs at different stages of the project.
	Level F	Continuation of Level E, plus the team analyses the layout of the project including where the different parties will be working and place their TFs in the optimum location in order to limit travel time to and from TFs.
(√)	*5. Traffic Control Plan*	
	Level A	Traffic control plans are not applicable for the project.
	Level B	Traffic control plans have not been addressed for the project.
	Level C	The project has some traffic control plans and is used on a reactive basis.
	Level D	The project has a traffic control plan, equipment, and an arrangement for daylight traffic control only and has no trained traffic control persons.
	Level E	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control.

	Level F	Continuation of level E, plus a trained traffic control supervisor. It has an approved contingency plan in place to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours, flyovers, etc.
(√)	*6. Site Security Plan*	
	Level A	Site security plan is not applicable for the project.
	Level B	The site does not institute security in regards to entry to the site, securing commodities, or tools and equipment.
	Level C	The site controls entry and exit from the site, but does not have any other formal security throughout the site.
	Level D	The site has established security procedures including visitor sign in and sign out procedure and security guards at every gate. The site has implemented security measures to ensure the preservation of company assets. Protocols have been identified for searches of individuals and their personal property. Searches are conducted randomly.
	Level E	Continuation of Level D, plus the site has ensured that material is not leaving the job site by instituting "lock-ups" for items that are prone to theft.
	Level F	Continuation of Level E, plus the use of electronic security such as security cameras has been implemented.
(√)	*7.Machinery Positioning Strategy*	
	Level A	Machinery positioning strategy is not applicable.
	Level B	There is no strategy for positioning of machinery at the project site.
	Level C	Heavy rigging and lifting studies are accomplished on all critical lifts including evaluation of the machinery, rigging selection, and crane location.
	Level D	Continuation of Level C, plus planning includes the use of 2D layout and studies to aid in constructability for locating and utilizing machinery.
	Level E	Continuation of Level D, plus some 3D modelling studies to aid in constructability for locating and utilizing machinery.
	Level F	Continuation of Level E, plus planning includes the use of 3D layout studies and 3D modelling/visualization to aid in constructability for locating and utilizing machinery.
(√)	*8.Project Start-up Plan*	
	Level A	No start-up plan exists.
	Level B	A partial start-up plan has been prepared; the plan has not been communicated to the concerned stakeholders.
	Level C	A basic start-up plan has been developed with input from the project participants, but the plan has not been implemented.
	Level D	Continuation of Level C, plus with considerations for interfaces among sub-contractors or project participants. A start-up plan has been developed that identifies the duties and responsibilities of each stakeholder.
	Level E	Continuation of Level D, plus with consideration for cost analysis and detailed scheduling components. The plan is well communicated to all the stakeholders.
	Level F	Continuation of Level E, plus with the plan being implemented on the project by incorporating feedbacks from the stakeholders or project participants.
(√)	*9.Project Completion Plan*	
	Level A	The project completion requirement or handover procedure is not applicable.
	Level B	The project completion requirement or handover procedure has not been identified.
	Level C	The project has a handover procedure that defines the parameters of project completion and delineates the requirements for the handover.
	Level D	The project has a formal handover process that defines the necessary documentation, parameters of completion and other issues to assure proper handover of a project.
	Level E	Continuation of Level D, plus the procedure has been reviewed and agreed by the stakeholders.
	Level F	Continuation of Level E plus the plan is approved by project management team and is reviewed for applicability during all phases of the handover process.
(√)	*10.Innovations and New Technologies*	
	Level A	Innovation in new materials, equipment, information systems is not applicable.
	Level B	Innovations and new technologies investigation is not addressed.
	Level C	The project does not have a formal program for the investigation of innovations and new technologies. Implementation of innovations and new systems will only occur after the industry-wide implementation.
	Level D	The organization has an informal program for the investigation of innovations, and they will investigate the feasibility of the new technologies on a regular basis.
	Level E	Continuation of Level D, plus the program is formal to investigate new systems and they will investigate the feasibility of the new technologies on a regular basis.

	Level F	Continuation of Level E, plus they investigate all new technologies using a formal system of rating the new technology.

C4: Validated Survey Instrument for Pre-Construction Phase Management Practices

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.		
(√)	*1.Short Interval Plan*	
	Level A	The use of short interval plan is not applicable to this building project.
	Level B	Short interval plan is not prepared.
	Level C	Activities in the project schedule are not resource loaded and short interval plan does not detail the required materials, tools and equipment, labour, and required project information.
	Level D	Short interval plan indicates the required materials, tools and equipment, labour, and project information required to complete each task, and activities in the project schedule are not resource loaded.
	Level E	Continuations of Level D, and activities in the project schedule are resource loaded. The short interval plan considers the effects of congestion.
	Level F	Continuation of Level E , and alternate plans are prepared such as modified equipment schedules, shortened shifts, lengthened shifts, or added shifts in case the original plans did not work.
(√)	*2.Well-Defined Scope of Work*	
	Level A	A well-defined scope of work is not applicable to this building project.
	Level B	Working drawings are based on incomplete design, and execution is controlled with a milestone schedule.
	Level C	Continuation of Level B, and design is complete but without buildability review; execution is controlled with a master schedule.
	Level D	Continuation of Level C, plus design is completed and buildability review has been performed.
	Level E	Continuation of Level D, plus duration for the work package is defined, material availability, testing and inspection requirements are defined, but budget and quantities are not included in the scope of work.
	Level F	Continuation of Level E, and budget and quantities are included in the scope of work.
(√)	*3.Use of Software in Planning Work Packages*	
	Level A	Utilization of software in work packaging is not applicable.
	Level B	This project uses a software system to generate and track work packages. The system is not integrated. Materials, drawing and other information are entered manually.
	Level C	Continuation of Level B, and percent complete is entered by reviewing the package. Work package status is updated manually.
	Level D	Continuation of Level C, and the project uses a software system which automatically includes the drawings and material delivery status. Schedule, percent complete, test and inspection status, and closure are entered manually by review of the work package.
	Level E	Continuation of Level D, and the system is updated regularly and automatically, and provides current design drawing information, updated status of materials, implementation schedule with durations and quantities, test and inspection status, percent complete and closure.However ,work package status is updated to the master schedule manually.
	Level F	Continuation of Level E, and work package status is updated electronically.
(√)	*4.Dedicated Planner*	
	Level A	Assigning dedicated planner is not applicable to this building project.
	Level B	Hiring of dedicated planner has not been addressed.
	Level C	Dedication of single planner or multiple personnel who prepare initial plan and coordinate with procurement are assigned.
	Level D	Continuation of Level C, and the planner initiate and maintain communication regarding the delivery and inspection of materials and update the schedules as appropriate.
	Level E	Continuation of Level D, plus continued update of schedule, and onsite inspection to track consumption of materials as necessary.
	Level F	Continuation of Level E, plus continued communication regarding consumption of materials, and report their status.

(√)	*5.Construction Work Packages*	
	Level A	Organizing information for each Construction Work Packages (CWP) is not applicable.
	Level B	Information such as scope of works; safety , quality , materials , personnel and equipment requirements; and others that are required for the execution of each work package are compiled.
	Level C	Some information required for execution of CWP is complete.
	Level D	All information required for execution of each CWP have been addressed. The information in each section displays no in-depth consideration.
	Level E	Continuation of Level D, plus in-depth consideration for most of the sections are given.
	Level F	Continuation of Level E, plus all sections have received in-depth consideration. The construction work package can be performed easily based on the information documented for each CWP.
(√)	*6.Buildability Review*	
	Level A	Buildability review is not applicable to this building project.
	Level B	Buildability review is not addressed
	Level C	Some scheduling and coordination of the phases of construction has been performed by principal contractor before conducting detailed buildability review.
	Level D	Continuation of Level C, plus the principal contractor has prepared a detailed schedule for all phases of construction after conducting detailed buildability review.
	Level E	Continuation of Level D, plus the owner is involved in buildability review process.
	Level F	Continuation of Level E, plus all buildability reviews and schedules are completed before construction
(√)	*7.Utilities Alignment*	
	Level A	Utility alignment is not applicable to this project.
	Level B	Utility alignment is not addressed in this project.
	Level C	The project has a review process for working in areas surrounding utilities. The process includes list of utilities, locations, and warning signs.
	Level D	Continuation of Level C, plus necessary city council approvals have been obtained and utility adjustment plan is prepared.
	Level E	Continuation of Level D, plus communication with businesses and local community have been made. Arrangements for temporary shutoffs and interruptions have been made.
	Level F	Continuation of Level E, plus the physical markings described to mark the horizontal route of underground facilities have been protected, detours have been constructed, and the all activities related to utilities alignments have been integrated with other project schedules.
(√)	*8.Contract Types*	
	Level A	Contracting strategies are not applicable.
	Level B	Contract types are not addressed.
	Level C	The project has a review process for the contract types. It considers fee structure and financing options, but risks associated with different contract types are not considered.
	Level D	Continuation of Level C, plus risks associated with different contract types are also considered. Cost benefit analysis for different types of contracts are performed.
	Level E	Continuation of Level D, plus the labour market information and reports are also studied and considered before awarding contracts.
	Level F	Continuation of Level E, plus the local conditions in the project area are studied and monitored regularly. The company has established protocols for selecting sub-contractors, designers, material suppliers, and manufacturers.
(√)	*9.Model Development*	
	Level A	Models are not required for this project.
	Level B	Integration of the projects 3D and schedule information has not been addressed.
	Level C	A 4D Model has been established for the project.
	Level D	Continuation of Level C and the model is updated manually.
	Level E	Continuation of Level D, plus the model is dynamic and includes material specifications, change order documentation, and other pertinent design and construction information.
	Level F	Continuation of Level E, plus the model is automatically updated based on work progress.
(√)	*10.Regulatory Requirements*	

	Level A	Regulatory requirements are not applicable.
	Level B	Required permitting has not been addressed.
	Level C	Initial investigations based on the type of permits; timeline to get the permit approved; the validity period of the permit; the authority issuing the permit; pre-inspection requirements; and fees have been conducted.
	Level D	Continuation of level C, plus permit requirements are tied to schedules and milestones.
	Level E	Continuation of Level D, plus a system is established to track the acquisition and validity period of each permit.
	Level F	Continuation of Level E, plus the system is automatically updated based on continued updates to schedule and permit expiry dates.

C5: Validated Survey Instrument for Human Resource Management Practices

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.		
(√)	*1. Crew Composition*	
	Level A	Crew formation/composition is not applicable to this building project.
	Level B	Crew composition is not addressed in this project.
	Level C	Crew formation is addressed after the commencement of the construction of the building project.
	Level D	Crew formation is addressed before the commencement of construction works; experience and knowledge of employees, job requirements, and location are considered.
	Level E	Continuation of Level D, plus the performance of the crew is assessed after completion of each task and corrective measures are taken accordingly to improve productivity.
	Level F	Continuation of Level E, plus the crew formation and its performance is assessed regularly on daily, weekly, and monthly basis and necessary changes are made.
(√)	*2.Skill Assessment and Evaluation*	
	Level A	Skills assessment is not applicable to this project.
	Level B	Skills assessment is not addressed.
	Level C	Skills assessment is addressed after the beginning of the construction this project.
	Level D	Skills assessment is addressed before the beginning of construction work; previous experience, skill and knowledge of workers are considered.
	Level E	Continuation of Level D, plus the assessment is made again after completion of each task and adjustments are made accordingly to improve productivity.
	Level F	Continuation of Level E, plus the assessment is performed regularly on daily, weekly, and monthly basis, and necessary changes are made and monitored.
(√)	*3. Employees Training*	
	Level A	Employees Training is not applicable to this building project.
	Level B	Employees Training is not addressed.
	Level C	Employees Training is addressed on the jobsite after the beginning of the project.
	Level D	Employees Training is provided to an employee when he/she begins working for the company, and if needed extra training will occur on the job site.
	Level E	Continuation of Level D, plus worker is certified to work in or supervise specific trade. Before each project, new training in the trade will take place if necessary.
	Level F	Continuation of Level E, plus a worker takes part in training for new technologies that are introduced in that trade annually and bi-annually.
(√)	*4.Career Development*	
	Level A	Career development is not applicable to this building project.
	Level B	Career development is not addressed in this project.
	Level C	The organization does not have a formal career development plan for employees, but the management will discuss future plans with them.
	Level D	The organization has a formal career development plan for employees, but it only addresses short term career developments.
	Level E	Continuation of Level D, plus it addresses long term career developments and options.
	Level F	Continuation of Level E, plus addresses the expected performance of the employee and how the performance will affect his/her career development.
(√)	*5. Non-Financial Incentive Programs*	

	Level A	Non-financial incentive/recognition programs are not applicable to this building project.
	Level B	Non-financial incentive programs are not addressed in this project.
	Level C	The organization has an informal recognition programs that will recognize employees occasionally, but not in a formal manner.
	Level D	The organization has a formal recognition program that provides recognition on long term basis.
	Level E	Continuation of Level D, plus it recognizes workers on a regular basis for both positive safety results and good safety behaviour.
	Level F	Continuation of Level E, plus the rewards are given on both short and long term basis, and they are recognized by the upper management of the organization.
(√	*6. Financial Incentive Programs*	
	Level A	Financial incentive program is not applicable to this building project.
	Level B	Financial incentive program is not addressed.
	Level C	The organization has an informal incentive program that will recognize employees occasionally, but not in a formal manner.
	Level D	The organization has a formal incentive program that provides incentives on long term basis.
	Level E	Continuation of Level D, plus it provides a monetary bonus for employees based on their performances.
	Level F	Continuation of Level E, plus the rewards are given on both a short and long term basis, and they are recognized by the upper management of the organization.
(√)	*7.Social Activites*	
	Level A	Social activities for the employees are not applicable.
	Level B	Social activities for the employees are not addressed.
	Level C	The organization does not formally plan social activities for the employees, and there is only a yearly organization wide social activity.
	Level D	The organization formally plans a social activity once or twice a year in which the project managers will attend, along with a yearly organization wide social activity.
	Level E	Continuation of Level D, plus several times throughout the year which the project managers will attend, along with a yearly organization wide social activity.
	Level F	Continuation of Level F, plus monthly which the project managers will attend and upper management including the president will attend on a quarterly basis, along with a yearly organization wide social activity.
(√)	*8. Stability of Organisational Structure*	
	Level A	Maintaining the Stability of the Organizational Structure is not important.
	Level B	No plans to manage change of key people in contract.
	Level C	The key professionals are named or define in the contract.
	Level D	Continuation of Level C, plus state that they cannot be changed without notice and prior approval.
	Level E	Continuation of Level D, plus there are pre-approved designated successors.
	Level F	Continuation of Level E, plus the contract specifies all professionals of sub-contractor and principal contractor teams, along with possible successors and right of approval by the other party.
(√)	*9. Clear Delegation of Responsibility*	
	Level A	Clear Delegation of Responsibility is not applicable to this building project.
	Level B	There is simple and centralized delegation of responsibility.
	Level C	There is simple and very formal delegation of responsibility.
	Level D	There is stable project environment and more formal delegation of responsibility.
	Level E	The delegation of responsibility is formal, but differing between technical, administrative, etc.
	Level F	There is a formal delegation of authority that is clearly defined for all involved parties. The plan is reviewed periodically and evolves when necessary.
(√)	*10. Retention Plan for Experienced Personnel*	
	Level A	Retention Plan for Experienced Personnel is not applicable to this building project.
	Level B	A retention plan is not addressed.
	Level C	Each project manager is responsible for retention of his workers.

	Level D	Incentives such as employee training and others are available but it is not requirement. Junior staffs have higher pay and preferred hiring status on the next project for the same employer.
	Level E	Continuation of Level D, plus employee training is required for junior staff. The employer makes available a list of opportunities for the next project.
	Level F	Continuation of Level E, plus testing and certification on the site lead to pay increases. Employer meets with individual worker and offers job(s) at new project site(s) as per requirements.
(√)	*11. Exit Interviews*	
	Level A	Exit Interview is not applicable.
	Level B	No exit interview.
	Level C	There is exit interview for key personnel only.
	Level D	Random exit interviews when there is time.
	Level E	Formal exit interview for all personnel.
	Level F	Formal exit interview for all personnel and feedback to management about lessons learned and how to improve retention when applicable.

C6: Validated Survey Instrument for Safety and Health Practices

Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.		
(√)		*1. Housekeeping*
	Level A	Housekeeping is not applicable to this building project
	Level B	Regular housekeeping has not been addressed on the project.
	Level C	Housekeeping occurs only after incidents occur.
	Level D	Housekeeping occurs on a bi-weekly scheduled basis.
	Level E	Major travel paths are organized and clean. "Roll backs" are held weekly.
	Level F	All work areas are well organized and designated crews are regularly cleaning
(√)		*2.Safety and Health Policy*
	Level A	Health and safety policy for the organization is not applicable
	Level B	The company does not have a formal health and safety policy.
	Level C	There is health and safety policy at company level and at particular project . The policy is
	Level D	Continuation of Level C, plus it is periodically updated based on the organizational and industry feedback.
	Level E	Continuations of Level D, plus the organization screens sub-contractors for their health and safety programs and chooses those with records of good performance.
	Level F	Continuation of Level E, plus health and safety policy is integrated with procurement processes. Money is budgeted on the construction projects to address various health and safety issues.
(√)		*3. Safety and Health Plan*
	Level A	Health and safety plans are not applicable to this building project.
	Level B	No health and safety targets have been examined and considered for the project.
	Level C	Some techniques to reduce accidents on the project are utilized. The project has a reactive approach towards safety.
	Level D	Most but not accident reduction techniques are utilized on the project.
	Level E	All potential accident reduction techniques are utilized on the project.
	Level F	Zero Accident Techniques are fully utilized on the project. The project has a very proactive approach towards safety.
(√)		*4.Safe Work Method Statement*
	Level A	Task Safety Analysis or Safe Work Method Statement (SWMS) is not applicable to this building project.
	Level B	No Task Safety Analysis or SWMS is utilized.
	Level C	Limited Task Safety Analysis is utilized only on high risk areas of the project. The project has a reactive approach towards safety.
	Level D	SWMS is prepared and utilized for most tasks on this project.

	Level E	Safe Work Method Statement (SWMS) is utilized daily on the project.
	Level F	SWMS's are utilized daily on the projects on all tasks and some crews perform additional SWMS's as task changes.
(√)	*5. Hazards Analysis*	
	Level A	The process for hazard identification process is not applicable on this building project.
	Level B	No hazard identification process is in place on this project.
	Level C	Hazards are identified for a few tasks that not covered in SWMS.
	Level D	Hazards are identified for most tasks that are not covered in SWMS.
	Level E	Hazards are identified for all proposed scope of works.
	Level F	Hazards are identified for all proposed scope of work and incorporated into the project's task specific safety planning process.
(√)	*6. Health and Safety Training*	
	Level A	Health and Safety training is not applicable to this building project.
	Level B	The project does not have a project specific training program for new employee.
	Level C	There is project specific induction regarding personal protective equipment, housekeeping and access to site, ladders and safe access to elevated platforms, fall protection, excavations and trenching, tools and equipment, electrical hazards and fire prevention. Supervisors receive additional induction about conducting of safety meetings, first aid and medical treatment processes, consequences for violation of job site work rules and violence, alcohol and drugs in the workplace.
	Level D	Continuation of Level C, plus some employees should pass fitness for duty testing prior to starting construction of some tasks. The induction addresses management commitment, general project safety rules, emergency procedures, hazard communication, housekeeping, barricades, injury/illness reporting, lock-out and tag-out processes, confined spaces, compressed gas cylinders, back injury prevention, and hand/power tool safety.
	Level E	Continuation of Level D, plus orientation addresses zero accidents philosophy and general project safety rules.
	Level F	Continuation of Level E, plus workers trained on behavioural based training.
(√)	*7. Toolbox Safety Meetings*	
	Level A	The Project does not conduct safety meetings.
	Level B	The Project issues toolbox topics via handouts to employees on a periodic basis.
	Level C	The project conducts a monthly meeting at or near breaks. Meetings reiterate job site safety rules.
	Level D	The project conducts a weekly meeting at or near breaks. Meetings reiterate job site safety rules.
	Level E	The project conducts weekly meetings at a prearranged time, generally at the start of the day. Meetings address current job status and hazards presented by upcoming project activities, corrective actions, review recorded injuries and near misses, or reiterate job site safety rules and expectations. Time is set aside during the meeting for interactive discussion and allows worker feedback.
	Level F	Continuation of Level E, plus the day of the meeting vary on which they occur, or conduct them daily. Meetings address current job status and hazards presented by upcoming project activities, corrective actions, review recorded injuries and near misses, or reiterate job site safety rules and expectations.

Thank you very much for your time.

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APPENDIX 2: RAW DATA FOR DESCRIPTIVE DATA ANALYSIS

A1: Raw Data for Descriptive Analysis of Construction Materials Management Practices

Respondents' Code	*Procurement Plans for Materials*	*Long-Lead Materials Identification*	*Materials Status Database*	*Materials Delivery Schedule*	*Material Inspection Process*	*Materials Inspection Team*
R1	4.00	5.00	3.00	3.00	3.00	3.00
R2	5.00	5.00	4.00	5.00	4.00	4.00
R3	4.00	5.00	4.00	4.00	3.00	3.00
R4	4.00	5.00	4.00	4.00	5.00	4.00
R5	5.00	5.00	1.00	3.00	3.00	3.00
R6	4.00	4.00	3.00	3.00	2.00	2.00
R7	4.00	5.00	4.00	4.00	4.00	4.00
R8	4.00	5.00	4.00	4.00	3.00	2.00
R9	4.00	5.00	3.00	4.00	5.00	4.00
R10	5.00	4.00	4.00	5.00	4.00	4.00
R11	4.00	5.00	2.00	2.00	3.00	3.00
R12	3.00	4.00	3.00	3.00	3.00	3.00
R13	5.00	4.00	3.00	3.00	3.00	3.00
R14	5.00	5.00	5.00	5.00	3.00	2.00
R15	4.00	5.00	3.00	3.00	3.00	2.00
R16	5.00	5.00	4.00	4.00	3.00	2.00
R17	5.00	5.00	4.00	3.00	3.00	3.00
R18	4.00	4.00	3.00	3.00	3.00	3.00
R19	4.00	3.00	3.00	4.00	3.00	3.00
R20	3.00	4.00	2.00	3.00	4.00	1.00
R21	4.00	5.00	4.00	5.00	5.00	3.00
R22	4.00	4.00	2.00	4.00	3.00	2.00
R23	4.00	5.00	4.00	4.00	3.00	3.00
R24	4.00	5.00	4.00	4.00	5.00	2.00
R25	1.00	2.00	1.00	2.00	3.00	1.00
R26	3.00	4.00	2.00	3.00	2.00	1.00
R27	4.00	5.00	2.00	2.00	1.00	1.00
R28	5.00	5.00	5.00	5.00	5.00	4.00
R29	5.00	5.00	4.00	5.00	4.00	2.00
R30	5.00	5.00	4.00	5.00	4.00	4.00
R31	5.00	5.00	4.00	5.00	4.00	3.00
R32	5.00	4.00	3.00	4.00	4.00	3.00
R33	3.00	4.00	2.00	2.00	2.00	4.00
R34	5.00	5.00	3.00	4.00	4.00	4.00
R35	5.00	5.00	3.00	4.00	4.00	2.00
R36	5.00	5.00	4.00	4.00	3.00	3.00
R37	5.00	4.00	4.00	5.00	4.00	4.00
R38	4.00	5.00	4.00	3.00	4.00	3.00
R39	4.00	5.00	4.00	4.00	5.00	4.00

A2: Raw Data for Descriptive Analysis of Construction Equipment Management Practices

Respondents' Code	*Procurement Plans for Construction Machinery*	*Construction Machinery Productivity Analyses*	*Construction Machinery Maintenance*
R1	2.00	3.00	4.00
R2	4.00	5.00	4.00
R3	3.00	3.00	3.00
R4	5.00	5.00	5.00
R5	3.00	1.00	5.00
R6	3.00	4.00	3.00
R7	4.00	3.00	3.00
R8	4.00	3.00	4.00
R9	4.00	3.00	5.00
R10	3.00	4.00	5.00
R11	3.00	3.00	5.00
R12	3.00	3.00	3.00
R13	4.00	3.00	2.00
R14	2.00	2.00	2.00
R15	4.00	3.00	5.00
R16	3.00	4.00	5.00
R17	5.00	3.00	5.00
R18	2.00	2.00	2.00
R19	2.00	2.00	5.00
R20	3.00	3.00	4.00
R21	4.00	3.00	3.00
R22	3.00	3.00	4.00
R23	4.00	3.00	4.00
R24	4.00	5.00	5.00
R25	1.00	1.00	4.00
R26	3.00	2.00	4.00
R27	4.00	2.00	5.00
R28	4.00	4.00	5.00
R29	4.00	4.00	2.00
R30	5.00	4.00	4.00
R31	3.00	3.00	3.00
R32	4.00	2.00	5.00
R33	2.00	1.00	1.00
R34	5.00	3.00	3.00
R35	3.00	3.00	5.00
R36	4.00	3.00	5.00
R37	5.00	3.00	4.00
R38	3.00	3.00	5.00
R39	4.00	4.00	4.00

A3: Raw Data for Descriptive Analysis of the Management Practices Related to Construction Methods

Respondents' Code	*Integrated schedule*	*Works Schedule Strategies*	*Schedule control*	*Dynamic Site Layout Plan*	*Traffic Control Plan*	*Site Security Plan*	*Machinery Positioning Strategy*	*Project Start-up Plan*	*Project Completion Plan*	*Innovations and New Technologies*
R1	4.0	4.0	4.0	4.0	5.0	3.0	4.0	4.0	4.0	4.0
R2	4.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0
R3	3.0	4.0	5.0	4.0	4.0	4.0	4.0	5.0	5.0	3.0
R4	4.0	5.0	5.0	3.0	4.0	4.0	5.0	4.0	5.0	4.0
R5	1.0	4.0	3.0	4.0	4.0	3.0	2.0	5.0	5.0	1.0
R6	3.0	4.0	5.0	3.0	3.0	3.0	3.0	4.0	4.0	3.0
R7	4.0	4.0	4.0	5.0	5.0	4.0	5.0	4.0	3.0	3.0
R8	4.0	3.0	4.0	5.0	4.0	4.0	4.0	5.0	5.0	3.0
R9	4.0	4.0	4.0	3.0	5.0	4.0	5.0	2.0	5.0	3.0
R10	4.0	5.0	4.0	4.0	5.0	3.0	4.0	4.0	4.0	4.0
R11	4.0	4.0	4.0	5.0	5.0	3.0	5.0	5.0	3.0	2.0
R12	3.0	3.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0	4.0
R13	2.0	3.0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	2.0
R14	1.0	3.0	3.0	3.0	3.0	3.0	5.0	5.0	1.0	3.0
R15	3.0	4.0	4.0	4.0	5.0	5.0	5.0	4.0	4.0	3.0
R16	2.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	4.0
R17	4.0	4.0	4.0	5.0	5.0	3.0	5.0	5.0	5.0	3.0
R18	4.0	3.0	3.0	4.0	5.0	3.0	4.0	5.0	4.0	2.0
R19	3.0	4.0	5.0	3.0	5.0	3.0	5.0	3.0	4.0	3.0
R20	4.0	3.0	3.0	4.0	5.0	3.0	3.0	3.0	3.0	4.0
R21	4.0	4.0	4.0	5.0	4.0	4.0	5.0	5.0	4.0	5.0
R22	3.0	3.0	3.0	3.0	4.0	3.0	4.0	4.0	4.0	3.0
R23	4.0	4.0	4.0	4.0	3.0	4.0	4.0	4.0	5.0	3.0
R24	3.0	3.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0
R25	2.0	3.0	3.0	4.0	4.0	3.0	2.0	5.0	5.0	2.0
R26	3.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	2.0	3.0
R27	3.0	3.0	3.0	4.0	5.0	2.0	4.0	4.0	4.0	2.0
R28	4.0	4.0	4.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
R29	3.0	3.0	3.0	4.0	5.0	3.0	4.0	4.0	5.0	3.0
R30	4.0	4.0	5.0	4.0	4.0	4.0	5.0	5.0	4.0	3.0
R31	2.0	4.0	3.0	3.0	3.0	4.0	2.0	4.0	4.0	5.0
R32	3.0	2.0	2.0	5.0	4.0	4.0	5.0	4.0	3.0	3.0
R33	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	4.0
R34	3.0	3.0	4.0	4.0	3.0	2.0	2.0	4.0	4.0	3.0
R35	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	3.0	3.0
R36	4.0	4.0	4.0	4.0	4.0	5.0	3.0	5.0	5.0	4.0
R37	5.0	4.0	4.0	5.0	4.0	3.0	4.0	5.0	5.0	2.0
R38	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
R39	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0

A4: Raw Data for Descriptive Analysis of the Pre-Construction Phase Management Practices

Respondents' Code	*Short Interval Planning*	*Well Defined Scope of Work*	*Use of Software in Planning*	*Dedicated Planner*	*Construction Work Packages*	*Buildability Review*	*Utilities Alignment*	*Contract types*	*Model Development*	*Regulatory Requirements*
R1	5	5	3	3	4	4	3	4	3	5
R2	5	5	4	4	5	4	4	5	4	5
R3	4	4	4	4	4	5	3	4	3	4
R4	5	5	5	3	5	4	5	5	3	5
R5	5	5	5	1	5	4	2	3	1	3
R6	5	5	3	2	3	5	3	3	2	2
R7	4	4	3	3	4	4	4	5	3	4
R8	4	5	3	3	4	4	4	4	2	4
R9	5	5	4	4	5	5	4	4	2	5
R10	5	5	4	4	5	4	4	4	3	5
R11	4	5	5	1	4	4	3	3	1	5
R12	4	5	3	3	4	4	4	4	2	4
R13	5	5	3	3	5	5	4	5	2	5
R14	5	5	3	3	3	5	5	3	3	5
R15	4	5	4	3	4	5	3	4	4	4
R16	5	5	5	3	3	4	5	5	4	3
R17	5	5	5	5	5	5	5	4	3	5
R18	2	5	5	1	4	4	5	4	1	5
R19	5	5	4	3	4	4	3	4	3	3
R20	4	5	3	2	3	4	4	2	3	5
R21	5	5	5	3	5	5	4	5	2	5
R22	4	4	3	3	4	3	3	4	3	4
R23	4	5	4	5	4	4	4	4	4	4
R24	5	4	3	5	5	5	5	3	5	5
R25	3	5	5	3	4	4	3	3	3	4
R26	4	2	2	4	5	5	3	3	4	4
R27	5	5	3	4	4	4	4	4	2	5
R28	5	5	4	5	5	5	5	5	3	5
R29	5	4	2	1	5	4	3	4	1	4
R30	5	5	5	4	4	5	4	4	3	5
R31	3	5	4	2	5	4	3	4	2	3
R32	4	5	3	2	4	4	4	4	2	4
R33	4	5	2	3	4	3	3	3	1	2
R34	4	5	4	4	5	5	4	3	3	4
R35	4	5	4	2	4	5	4	4	2	4
R36	5	5	4	3	4	4	4	4	5	5
R37	4	5	5	3	5	5	4	5	3	5
R38	4	5	4	2	3	5	3	2	2	4
R39	4	5	5	3	5	5	4	4	3	4

A5: Raw Data for Descriptive Analysis of Human Resource Management Practices

Respondents' Code	*Crew Composition*	*Skill Assessment*	*Employee Training*	*Career Development*	*Non-Financial Incentive Program*	*Financial Incentive Program*	*Social Activities*	*Stability of Organizational Structure*	*Clear Delegation of Responsibility*	*Retention Plan for Experienced Personnel*	*Exit Interview*
R1	4	3	3	4	4	4	3	4	4	3	2
R2	5	5	5	5	4	5	4	5	5	5	4
R3	4	4	4	4	3	3	3	4	3	3	3
R4	5	4	4	4	3	3	4	3	5	5	5
R5	4	1	2	1	1	1	3	4	5	3	1
R6	2	2	1	2	3	4	3	5	5	4	2
R7	4	4	4	5	4	4	3	4	4	4	3
R8	4	4	4	4	4	1	3	4	4	3	3
R9	4	4	5	4	3	1	2	5	4	5	3
R10	4	4	3	3	4	5	4	4	5	4	5
R11	4	4	4	3	2	2	4	4	4	4	2
R12	5	4	4	4	4	4	3	4	5	4	4
R13	4	4	3	4	5	5	4	4	4	3	2
R14	4	4	3	1	2	4	2	5	4	3	1
R15	4	4	4	3	3	3	3	4	5	4	3
R16	5	5	4	4	4	2	2	3	4	5	4
R17	5	4	5	4	4	4	5	5	4	5	4
R18	3	3	4	4	1	4	3	5	4	4	4
R19	4	4	4	3	3	3	2	3	5	3	3
R20	3	4	4	4	3	3	4	4	4	3	3
R21	5	5	4	4	5	4	3	3	5	3	2
R22	4	4	4	4	3	3	4	4	3	4	1
R23	3	4	4	3	3	3	3	4	4	3	4
R24	5	5	5	4	3	4	5	5	5	4	4
R25	4	4	4	4	2	2	4	4	4	4	2
R26	3	4	4	4	4	4	3	3	2	2	3
R27	5	3	3	3	4	4	3	4	4	4	2
R28	5	5	5	4	4	4	3	4	5	4	4
R29	3	1	2	2	2	2	3	4	5	4	2
R30	4	4	4	4	5	3	4	5	5	5	2
R31	3	4	4	3	4	4	2	4	3	5	3
R32	2	3	3	3	3	4	2	3	3	2	2
R33	1	1	1	3	3	4	4	4	4	3	3
R34	3	3	3	3	3	3	3	2	3	4	3
R35	2	4	5	4	1	3	4	5	4	5	2
R36	4	4	5	5	3	4	5	5	5	4	4
R37	4	4	4	4	4	3	4	5	4	4	2
R38	5	3	4	3	3	3	3	4	3	4	3
R39	4	4	4	4	4	5	5	4	5	4	3

A6: Raw Data for Descriptive Analysis of the Safety and Health Practices

Respondents' Code	*House Keeping*	*Health and Safety Policy*	*Health and Safety Plans*	*Safe Work Method Statement*	*Hazards Analysis*	*Health and Safety Training*	*Toolbox Safety Meetings*
R1	4	5	5	5	5	4	5
R2	5	5	5	5	5	4	5
R3	3	5	5	5	5	5	4
R4	5	5	5	5	5	5	5
R5	5	5	5	5	4	3	3
R6	4	5	3	5	5	3	5
R7	4	5	5	5	5	5	5
R8	4	5	5	5	5	5	5
R9	4	4	5	5	5	5	4
R10	5	5	5	4	5	4	5
R11	5	5	4	5	5	5	5
R12	5	5	5	5	5	5	5
R13	4	5	5	4	3	3	5
R14	4	4	4	3	4	3	3
R15	5	5	5	4	5	5	4
R16	5	5	5	5	5	5	5
R17	5	4	4	5	5	4	5
R18	4	5	5	5	5	5	4
R19	3	5	5	5	5	5	5
R20	4	5	5	4	5	5	5
R21	4	5	5	5	5	5	4
R22	4	4	3	4	4	4	4
R23	4	4	4	4	4	4	4
R24	5	5	5	5	5	5	5
R25	5	5	5	5	5	5	5
R26	5	4	5	5	5	5	5
R27	4	5	5	5	5	5	5
R28	5	5	5	5	5	5	5
R29	5	5	5	4	4	4	4
R30	5	5	5	5	5	5	5
R31	5	5	5	5	5	5	5
R32	4	5	4	4	4	4	4
R33	4	3	3	3	3	3	3
R34	4	4	4	3	3	3	3
R35	5	5	4	5	5	5	5
R36	5	5	5	5	5	5	5
R37	4	4	4	3	3	5	5
R38	4	5	4	4	4	3	4
R39	5	5	5	5	5	5	5

APPENDIX 3: SCORES OF THE BUILDING PROJECTS

A1: Construction Materials Management Practices Scores

R	*PF*	*PPM*	*LLM*	*MSD*	*MDS*	*MIP*	*MIT*	*MMTS*
R1	1.00	0.51	0.55	0.13	0.30	0.28	0.11	1.88
R2	0.87	0.85	0.92	0.40	0.60	0.56	0.46	3.77
R3	1.02	0.68	0.73	0.53	0.30	0.56	0.11	2.91
R4	1.02	0.68	0.73	0.53	0.30	0.56	0.34	3.14
R5	1.01	0.34	0.73	0.40	0.30	0.28	0.23	2.28
R6	0.82	0.51	0.55	0.00	0.30	0.00	0.00	1.36
R7	0.78	0.85	0.92	0.26	0.45	0.56	0.46	3.49
R8	1.06	0.68	0.73	0.26	0.30	0.56	0.46	2.99
R9	1.14	0.51	0.73	0.53	0.45	0.42	0.34	2.98
R10	1.13	0.85	0.73	0.66	0.60	0.56	0.57	3.97
R11	0.59	0.34	0.37	0.13	0.30	0.28	0.11	1.53
R12	0.79	0.51	0.37	0.26	0.45	0.56	0.34	2.49
R13	1.07	0.51	0.37	0.13	0.30	0.42	0.11	1.84
R14	0.82	0.68	0.73	0.13	0.15	0.28	0.00	1.97
R15	0.88	0.34	0.37	0.26	0.30	0.56	0.34	2.17
R16	1.00	0.34	0.37	0.26	0.15	0.56	0.11	1.79
R17	0.67	0.85	0.18	0.13	0.45	0.42	0.34	2.37
R18	1.00	0.51	0.73	0.00	0.60	0.28	0.11	2.23
R19	1.08	0.51	0.37	0.00	0.30	0.28	0.00	1.45
R20	0.88	0.34	0.37	0.26	0.30	0.14	0.00	1.41
R21	0.96	0.68	0.73	0.26	0.45	0.42	0.11	2.66
R22	1.00	0.51	0.73	0.00	0.30	0.56	0.34	2.44
R23	0.89	0.68	0.37	0.53	0.30	0.56	0.23	2.66
R24	0.92	0.17	0.18	0.00	0.30	0.42	0.11	1.18
R25	0.96	0.17	0.18	0.00	0.45	0.28	0.00	1.08
R26	0.76	0.17	0.18	0.13	0.30	0.42	0.11	1.32
R27	1.08	0.51	0.55	0.13	0.45	0.28	0.00	1.92
R28	0.60	0.34	0.37	0.13	0.15	0.56	0.11	1.66
R29	0.92	0.51	0.37	0.26	0.30	0.56	0.34	2.34
R30	1.12	0.85	0.92	0.66	0.75	0.28	0.46	3.91
R31	0.91	0.34	0.92	0.26	0.60	0.42	0.23	2.77
R32	1.14	0.68	0.73	0.53	0.60	0.70	0.57	3.81
R33	0.90	0.17	0.55	0.26	0.45	0.14	0.00	1.57
R34	1.08	0.85	0.92	0.26	0.30	0.42	0.23	2.97
R35	1.06	0.34	0.37	0.00	0.30	0.56	0.11	1.68
R36	1.00	0.51	0.73	0.26	0.45	0.56	0.23	2.74
R37	1.08	0.85	0.92	0.66	0.60	0.56	0.34	3.92
R38	1.00	0.34	0.37	0.13	0.30	0.28	0.11	1.53
R39	1.10	0.85	0.92	0.53	0.30	0.56	0.46	3.61

Legend: R= Respondents, PF= Productivity Factor, MMTS= Materials Management Total Score, PPM=Procurement Plan for Materials, LLM= Long-lead Materials Identification, MSD=Materials Status Database, MDS= Materials Delivery Schedule, MIP=Materials Inspection Process MIT =Materials Inspection Team

A2: Construction Equipment Management Practices Scores

R	*PF*	*PPCE*	*CEPA*	*CEM*	*CEMP*
R1	1.00	0.14	0.12	0.32	0.58
R2	0.87	0.55	0.48	0.32	1.35
R3	1.02	0.28	0.24	0.32	0.83
R4	1.02	0.28	0.48	0.32	1.08
R5	1.01	0.14	0.12	0.32	0.58
R6	0.82	0.14	0.12	0.63	0.89
R7	0.78	0.55	0.48	0.63	1.67
R8	1.06	0.28	0.36	0.47	1.11
R9	1.14	0.55	0.36	0.32	1.23
R10	1.13	0.55	0.36	0.32	1.23
R11	0.59	0.14	0.12	0.32	0.58
R12	0.79	0.42	0.36	0.63	1.41
R13	1.07	0.42	0.24	0.32	0.97
R14	0.82	0.00	0.12	0.32	0.44
R15	0.88	0.28	0.12	0.32	0.71
R16	1.00	0.00	0.12	0.47	0.59
R17	0.67	0.00	0.24	0.47	0.72
R18	1.00	0.00	0.00	0.00	0.00
R19	1.08	0.00	0.24	0.32	0.56
R20	0.88	0.14	0.12	0.32	0.58
R21	0.96	0.14	0.12	0.32	0.58
R22	1.00	0.55	0.36	0.47	1.39
R23	0.89	0.42	0.48	0.47	1.37
R24	0.92	0.14	0.12	0.32	0.58
R25	0.96	0.28	0.24	0.16	0.68
R26	0.76	0.00	0.00	0.00	0.00
R27	1.08	0.55	0.36	0.63	1.55
R28	0.60	0.00	0.00	0.16	0.16
R29	0.92	0.55	0.61	0.32	1.47
R30	1.12	0.69	0.48	0.32	1.49
R31	0.91	0.28	0.36	0.32	0.96
R32	1.14	0.69	0.36	0.63	1.69
R33	0.90	0.14	0.12	0.16	0.42
R34	1.08	0.28	0.48	0.32	1.08
R35	1.06	0.00	0.12	0.47	0.59
R36	1.00	0.55	0.36	0.47	1.39
R37	1.08	0.69	0.61	0.79	2.09
R38	1.00	0.14	0.24	0.32	0.70
R39	1.10	0.55	0.12	0.47	1.15

Legend: R= Respondents, PF= Productivity Factor, R= respondents, CEMP= Total score of the Construction Equipment Management Practices, PPCE=Procurement Plans for Construction Equipment, CEPA=Construction Equipment Productivity Analysis, CEM=Construction Equipment Maintenance

A3: Project Scores of Management Practices Related to Construction Methods

R	*PF*	*IS*	*WSS*	*SC*	*DSLP*	*TCP*	*SSP*	*MPS*	*PSP*	*PCP*	*INT*	*CMTS*
R1	1.00	0.16	0.17	0.15	0.11	0.26	0.15	0.31	0.65	0.68	0.44	3.09
R2	0.87	0.49	0.84	0.61	0.57	0.66	0.59	0.62	0.82	0.85	0.73	6.77
R3	1.02	0.33	0.17	0.31	0.57	0.39	0.44	0.62	0.65	0.68	0.73	4.89
R4	1.02	0.49	0.84	0.76	0.57	0.39	0.44	0.46	0.33	0.68	0.59	5.55
R5	1.01	0.33	0.33	0.61	0.57	0.53	0.29	0.46	0.82	0.68	0.73	5.36
R6	0.82	0.16	0.50	0.61	0.23	0.66	0.73	0.31	0.65	0.85	0.73	5.44
R7	0.78	0.33	0.84	0.31	0.57	0.66	0.73	0.31	0.82	0.85	0.73	6.14
R8	1.06	0.65	0.84	0.31	0.57	0.66	0.73	0.46	0.82	0.68	0.44	6.16
R9	1.14	0.49	0.84	0.31	0.23	0.39	0.44	0.31	0.82	0.68	0.59	5.09
R10	1.13	0.33	0.67	0.61	0.57	0.53	0.44	0.62	0.82	0.85	0.29	5.72
R11	0.59	0.33	0.17	0.61	0.11	0.26	0.44	0.31	0.65	0.68	0.29	3.86
R12	0.79	0.49	0.50	0.61	0.34	0.39	0.29	0.46	0.65	0.51	0.59	4.85
R13	1.07	0.82	0.50	0.31	0.46	0.26	0.29	0.31	0.82	0.51	0.29	4.57
R14	0.82	0.33	0.84	0.76	0.57	0.26	0.44	0.31	0.16	0.34	0.29	4.31
R15	0.88	0.33	0.84	0.00	0.46	0.53	0.44	0.46	0.49	0.68	0.59	4.81
R16	1.00	0.16	0.67	0.00	0.00	0.66	0.73	0.31	0.65	0.85	0.29	4.33
R17	0.67	0.33	0.17	0.15	0.11	0.26	0.44	0.31	0.33	0.51	0.29	2.90
R18	1.00	0.33	0.67	0.00	0.00	0.53	0.44	0.31	0.82	0.68	0.29	4.06
R19	1.08	0.33	0.50	0.15	0.46	0.26	0.29	0.31	0.33	0.68	0.00	3.31
R20	0.88	0.33	0.17	0.15	0.46	0.66	0.44	0.31	0.82	0.34	0.29	3.96
R21	0.96	0.49	0.50	0.61	0.46	0.53	0.44	0.46	0.49	0.68	0.44	5.10
R22	1.00	0.82	0.67	0.61	0.34	0.26	0.44	0.46	0.82	0.85	0.59	5.86
R23	0.89	0.33	0.17	0.31	0.46	0.66	0.44	0.31	0.65	0.00	0.29	3.61
R24	0.92	0.16	0.17	0.15	0.11	0.13	0.15	0.31	0.65	0.51	0.29	2.64
R25	0.96	0.16	0.17	0.00	0.11	0.00	0.00	0.15	0.65	0.34	0.29	1.89
R26	0.76	0.16	0.33	0.15	0.11	0.00	0.29	0.31	0.49	0.34	0.59	2.78
R27	1.08	0.49	0.84	0.76	0.57	0.66	0.44	0.62	0.82	0.68	0.29	6.17
R28	0.60	0.00	0.17	0.00	0.00	0.26	0.44	0.31	0.33	0.34	0.29	2.14
R29	0.92	0.65	0.84	0.31	0.46	0.26	0.29	0.31	0.33	0.85	0.73	5.03
R30	1.12	0.33	0.84	0.61	0.00	0.39	0.44	0.31	0.82	0.85	0.73	5.31
R31	0.91	0.33	0.33	0.61	0.00	0.53	0.29	0.31	0.49	0.51	0.29	3.69
R32	1.14	0.49	0.50	0.15	0.46	0.53	0.44	0.62	0.82	0.85	0.73	5.58
R33	0.90	0.00	0.33	0.00	0.23	0.00	0.00	0.00	0.65	0.00	0.73	1.95
R34	1.08	0.49	0.33	0.15	0.46	0.66	0.44	0.31	0.82	0.85	0.73	5.24
R35	1.06	0.65	0.67	0.76	0.34	0.26	0.29	0.00	0.82	0.68	0.00	4.48
R36	1.00	0.82	0.84	0.76	0.46	0.39	0.44	0.31	0.82	0.68	0.44	5.95
R37	1.08	0.82	0.84	0.76	0.57	0.53	0.44	0.62	0.82	0.85	0.73	6.97
R38	1.00	0.49	0.67	0.31	0.46	0.53	0.44	0.46	0.82	0.68	0.73	5.58
R39	1.10	0.65	0.17	0.61	0.34	0.66	0.73	0.46	0.82	0.68	0.73	5.86

Legend: R=Respondents, PF= Productivity Factor, R=respondents, CMTS= Construction Methods Total Score, IS=Integrated Schedule, WSS= Work Schedule Strategies, SC=Schedule Control, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies

A4: Pre-Construction Phase Management Practices Scores

R	*PF*	*SIP*	*WSW*	*US*	*DP*	*CWP*	*BR*	*UA*	*CT*	*MD*	*RR*	*PPMP*
R1	1.00	0.70	0.58	0.31	0.24	0.69	0.35	0.76	0.00	0.22	0.34	4.18
R2	0.87	0.70	0.77	0.46	0.37	0.86	0.88	0.76	0.46	0.00	0.85	6.10
R3	1.02	0.35	0.58	0.31	0.24	0.69	0.53	0.76	0.62	0.32	0.51	4.90
R4	1.02	0.88	0.58	0.61	0.00	0.86	0.70	0.76	0.46	0.00	0.51	5.36
R5	1.01	0.35	0.58	0.15	0.00	0.86	0.88	0.46	0.46	0.00	0.34	4.07
R6	0.82	0.88	0.77	0.31	0.37	0.86	0.70	0.76	0.15	0.22	0.68	5.68
R7	0.78	0.53	0.58	0.46	0.37	0.86	0.53	0.76	0.77	0.00	0.85	5.69
R8	1.06	0.53	0.77	0.31	0.24	0.69	0.35	0.46	0.77	0.32	0.51	4.94
R9	1.14	0.88	0.58	0.31	0.37	0.86	0.53	0.76	0.46	0.22	0.51	5.46
R10	1.13	0.70	0.58	0.61	0.37	0.51	0.70	0.76	0.46	0.11	0.51	5.31
R11	0.59	0.35	0.38	0.31	0.12	0.51	0.70	0.61	0.15	0.00	0.51	3.65
R12	0.79	0.53	0.58	0.31	0.37	0.69	0.53	0.61	0.46	0.11	0.34	4.50
R13	1.07	0.35	0.77	0.31	0.24	0.69	0.53	0.76	0.31	0.11	0.34	4.40
R14	0.82	0.35	0.38	0.15	0.24	0.00	0.35	0.30	0.31	0.00	0.51	2.61
R15	0.88	0.35	0.96	0.31	0.00	0.69	0.88	0.30	0.77	0.43	0.34	5.03
R16	1.00	0.35	0.96	0.46	0.00	0.86	0.53	0.76	0.62	0.11	0.51	5.15
R17	0.67	0.35	0.19	0.61	0.37	0.34	0.53	0.30	0.15	0.11	0.34	3.30
R18	1.00	0.35	0.77	0.46	0.24	0.69	0.53	0.76	0.00	0.22	0.51	4.52
R19	1.08	0.35	0.38	0.31	0.00	0.69	0.53	0.30	0.00	0.11	0.34	3.00
R20	0.88	0.35	0.38	0.15	0.00	0.00	0.35	0.76	0.15	0.11	0.51	2.77
R21	0.96	0.35	0.58	0.15	0.12	0.00	0.35	0.76	0.46	0.00	0.68	3.46
R22	1.00	0.70	0.58	0.31	0.00	0.86	0.88	0.76	0.46	0.11	0.68	5.33
R23	0.89	0.70	0.19	0.46	0.37	0.69	0.35	0.76	0.31	0.11	0.68	4.61
R24	0.92	0.35	0.58	0.31	0.00	0.34	0.53	0.76	0.31	0.00	0.68	3.85
R25	0.96	0.35	0.58	0.15	0.00	0.86	0.00	0.15	0.15	0.22	0.34	2.80
R26	0.76	0.53	0.77	0.31	0.12	0.86	0.35	0.30	0.31	0.11	0.34	3.99
R27	1.08	0.70	0.77	0.31	0.37	0.69	0.70	0.76	0.77	0.11	0.68	5.85
R28	0.60	0.18	0.19	0.15	0.00	0.34	0.18	0.00	0.15	0.00	0.00	1.19
R29	0.92	0.88	0.58	0.31	0.37	0.86	0.70	0.30	0.31	0.11	0.85	5.25
R30	1.12	0.53	0.58	0.76	0.61	0.69	0.35	0.61	0.31	0.22	0.85	5.50
R31	0.91	0.35	0.58	0.31	0.37	0.51	0.53	0.61	0.31	0.32	0.51	4.39
R32	1.14	0.70	0.96	0.61	0.61	0.86	0.88	0.76	0.77	0.11	0.85	7.11
R33	0.90	0.35	0.58	0.15	0.37	0.00	0.00	0.00	0.00	0.00	0.34	1.79
R34	1.08	0.70	0.96	0.61	0.37	0.69	0.70	0.76	0.77	0.11	0.34	6.01
R35	1.06	0.35	0.77	0.31	0.00	0.00	0.18	0.00	0.00	0.11	0.34	2.05
R36	1.00	0.53	0.77	0.15	0.00	0.34	0.53	0.76	0.46	0.22	0.34	4.09
R37	1.08	0.88	0.96	0.76	0.00	0.86	0.88	0.76	0.77	0.00	0.85	6.72
R38	1.00	0.53	0.58	0.31	0.24	0.69	0.88	0.76	0.46	0.32	0.51	5.27
R39	1.10	0.70	0.96	0.76	0.37	0.86	0.70	0.61	0.46	0.43	0.68	6.53

Legend: Respondents, PF= Productivity Factor, R=Respondents PPMP= Preconstruction Phase Management Practices Total Score, SIP= Short Interval Plan, WSW=Well-defined Scope of Work, US= Use of Software in Planning Work Packages, DP= Dedicated Planner, CWP= Construction Work Package, BR= Buildability Review, UA= Utilities Alignment, CT= Contract Types, MD= Model Development, RR=Regulatory Requirement.

A5: Human Resource Management Practices Scores

R	*PF*	*CC*	*SA*	*ET*	*CD*	*NFIP*	*FIP*	*SoA*	*SOS*	*CDR*	*RPEP*	*EI*	*HRM*
R1	1.00	0.46	0.44	0.45	0.28	0.39	0.40	0.27	0.16	0.17	0.15	0.11	3.30
R2	0.87	0.77	0.59	0.75	0.57	0.26	0.67	0.40	0.49	0.84	0.61	0.57	6.52
R3	1.02	0.31	0.44	0.45	0.57	0.26	0.54	0.54	0.33	0.17	0.31	0.57	4.47
R4	1.02	0.77	0.74	0.75	0.71	0.26	0.54	0.54	0.49	0.84	0.76	0.57	6.96
R5	1.01	0.46	0.00	0.45	0.71	0.26	0.27	0.67	0.33	0.33	0.61	0.57	4.67
R6	0.82	0.77	0.74	0.15	0.71	0.65	0.67	0.54	0.16	0.50	0.61	0.23	5.73
R7	0.78	0.77	0.74	0.45	0.71	0.65	0.67	0.54	0.33	0.84	0.31	0.57	6.57
R8	1.06	0.46	0.74	0.45	0.42	0.52	0.13	0.40	0.65	0.84	0.31	0.57	5.50
R9	1.14	0.77	0.74	0.45	0.57	0.26	0.40	0.40	0.49	0.84	0.31	0.23	5.45
R10	1.13	0.77	0.44	0.45	0.42	0.65	0.67	0.54	0.33	0.67	0.61	0.57	6.13
R11	0.59	0.46	0.44	0.45	0.28	0.13	0.13	0.40	0.33	0.17	0.61	0.11	3.52
R12	0.79	0.46	0.44	0.45	0.42	0.39	0.40	0.54	0.49	0.50	0.61	0.34	5.06
R13	1.07	0.62	0.59	0.45	0.42	0.26	0.40	0.54	0.82	0.50	0.31	0.46	5.36
R14	0.82	0.46	0.30	0.30	0.28	0.26	0.00	0.13	0.33	0.84	0.76	0.57	4.23
R15	0.88	0.77	0.44	0.45	0.28	0.26	0.27	0.40	0.33	0.84	0.00	0.46	4.50
R16	1.00	0.46	0.44	0.45	0.00	0.00	0.00	0.40	0.16	0.67	0.00	0.00	2.59
R17	0.67	0.15	0.15	0.45	0.14	0.13	0.13	0.13	0.33	0.17	0.15	0.11	2.05
R18	1.00	0.62	0.74	0.45	0.57	0.00	0.54	0.40	0.33	0.67	0.00	0.00	4.30
R19	1.08	0.62	0.44	0.75	0.57	0.00	0.27	0.40	0.33	0.50	0.15	0.46	4.49
R20	0.88	0.46	0.30	0.45	0.28	0.39	0.00	0.40	0.33	0.17	0.15	0.46	3.39
R21	0.96	0.46	0.44	0.45	0.71	0.26	0.54	0.40	0.49	0.50	0.61	0.46	5.32
R22	1.00	0.77	0.74	0.75	0.71	0.39	0.40	0.54	0.82	0.67	0.61	0.34	6.74
R23	0.89	0.77	0.74	0.75	0.42	0.39	0.40	0.54	0.33	0.17	0.31	0.46	5.27
R24	0.92	0.31	0.44	0.45	0.28	0.00	0.00	0.40	0.16	0.17	0.15	0.11	2.48
R25	0.96	0.46	0.15	0.30	0.28	0.00	0.00	0.40	0.16	0.17	0.00	0.11	2.04
R26	0.76	0.46	0.44	0.45	0.57	0.39	0.27	0.54	0.16	0.33	0.15	0.11	3.88
R27	1.08	0.77	0.44	0.75	0.71	0.65	0.67	0.54	0.49	0.84	0.76	0.57	7.19
R28	0.60	0.31	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.92
R29	0.92	0.77	0.44	0.75	0.28	0.13	0.00	0.40	0.65	0.84	0.31	0.46	5.03
R30	1.12	0.46	0.44	0.45	0.28	0.00	0.00	0.40	0.33	0.84	0.61	0.00	3.81
R31	0.91	0.46	0.44	0.45	0.28	0.39	0.27	0.40	0.33	0.33	0.61	0.00	3.97
R32	1.14	0.46	0.59	0.45	0.57	0.39	0.54	0.54	0.49	0.50	0.15	0.46	5.14
R33	0.90	0.00	0.30	0.30	0.28	0.39	0.40	0.40	0.00	0.33	0.00	0.23	2.64
R34	1.08	0.46	0.44	0.30	0.57	0.39	0.27	0.67	0.49	0.33	0.15	0.46	4.54
R35	1.06	0.31	0.30	0.30	0.00	0.00	0.27	0.54	0.65	0.67	0.76	0.34	4.14
R36	1.00	0.46	0.44	0.45	0.42	0.13	0.40	0.40	0.82	0.84	0.76	0.46	5.59
R37	1.08	0.46	0.59	0.45	0.71	0.26	0.27	0.54	0.82	0.84	0.76	0.57	6.27
R38	1.00	0.46	0.44	0.45	0.28	0.39	0.40	0.54	0.49	0.67	0.31	0.46	4.89
R39	1.10	0.77	0.59	0.75	0.00	0.65	0.67	0.54	0.65	0.17	0.61	0.34	5.74

Legend: R= Respondents, PF= Productivity Factor, R=Respondents, HRM= Human Resource Management Practices Total Score, CC= Crew Composition, SA=Skill Assessment and Evaluation, ET= Employee Training, CD = Career Development, NFIP= Non-Financial Incentive Programs, FIP= Financial Incentive Programs, SoA= Social Activities, SOS= Stability of Organizational Structure, CDR= Clear Delegation of Responsibility, RPEP=Retention Plan for Experienced Personnel, EI= Exit Interviews

A6: Safety and Health Practices Scores

R	*PF*	*HK*	*SHPo*	*SHP*	*SWMS*	*HA*	*SHT*	*TSM*	*SHP*
R1	1.00	0.18	0.76	0.55	0.91	0.92	0.71	0.91	4.94
R2	0.87	0.89	0.95	0.55	0.91	0.92	0.35	0.73	5.31
R3	1.02	0.71	0.95	0.92	0.73	0.92	0.89	0.91	6.03
R4	1.02	0.89	0.76	0.55	0.55	0.92	0.71	0.91	5.29
R5	1.01	0.89	0.38	0.37	0.91	0.92	0.35	0.73	4.55
R6	0.82	0.89	0.95	0.92	0.91	0.92	0.89	0.91	6.39
R7	0.78	0.89	0.95	0.92	0.91	0.92	0.89	0.91	6.39
R8	1.06	0.89	0.76	0.92	0.91	0.92	0.35	0.73	5.49
R9	1.14	0.89	0.95	0.92	0.91	0.92	0.71	0.73	6.03
R10	1.13	0.71	0.57	0.74	0.91	0.92	0.71	0.73	5.29
R11	0.59	0.71	0.57	0.55	0.91	0.37	0.35	0.54	4.01
R12	0.79	0.89	0.95	0.74	0.73	0.92	0.89	0.91	6.02
R13	1.07	0.89	0.95	0.92	0.91	0.74	0.71	0.91	6.03
R14	0.82	0.35	0.19	0.37	0.55	0.37	0.18	0.73	2.73
R15	0.88	0.89	0.76	0.74	0.91	0.92	0.71	0.73	5.66
R16	1.00	0.89	0.76	0.92	0.91	0.92	0.35	0.73	5.49
R17	0.67	0.89	0.76	0.55	0.91	0.92	0.18	0.91	5.12
R18	1.00	0.89	0.57	0.92	0.91	0.92	0.71	0.73	5.65
R19	1.08	0.89	0.95	0.92	0.91	0.92	0.35	0.73	5.68
R20	0.88	0.53	0.38	0.74	0.91	0.92	0.35	0.54	4.39
R21	0.96	0.89	0.95	0.92	0.91	0.92	0.71	0.73	6.03
R22	1.00	0.89	0.95	0.00	0.91	0.92	0.89	0.73	5.29
R23	0.89	0.89	0.95	0.92	0.73	0.92	0.89	0.91	6.21
R24	0.92	0.53	0.76	0.55	0.73	0.92	0.35	0.18	4.03
R25	0.96	0.53	0.76	0.92	0.37	0.74	0.53	0.91	4.76
R26	0.76	0.35	0.57	0.74	0.73	0.74	0.35	0.91	4.39
R27	1.08	0.89	0.95	0.92	0.91	0.92	0.71	0.73	6.03
R28	0.60	0.89	0.38	0.74	0.73	0.37	0.35	0.54	4.00
R29	0.92	0.89	0.95	0.92	0.91	0.92	0.89	0.73	6.21
R30	1.12	0.89	0.95	0.92	0.91	0.92	0.71	0.54	5.85
R31	0.91	0.53	0.95	0.92	0.91	0.92	0.71	0.91	5.86
R32	1.14	0.89	0.95	0.92	0.91	0.92	0.71	0.73	6.03
R33	0.90	0.89	0.76	0.92	0.91	0.55	0.53	0.91	5.48
R34	1.08	0.89	0.95	0.92	0.91	0.92	0.53	0.73	5.85
R35	1.06	0.89	0.76	0.55	0.91	0.92	0.53	0.73	5.29
R36	1.00	0.89	0.95	0.92	0.91	0.92	0.89	0.73	6.21
R37	1.08	0.89	0.95	0.92	0.91	0.92	0.71	0.91	6.21
R38	1.00	0.53	0.76	0.74	0.91	0.92	0.53	0.73	5.12
R39	1.10	0.89	0.95	0.92	0.91	0.92	0.89	0.91	6.39

Legend: R= Respondents, PF= Productivity Factor, R=Respondents SHP= Safety and Health Practices Total Score, HK= Housekeeping, SHPo = Safety and Health Policy, SHP= Safety and Health Plan, SWMS = Safe Work Method Statement, HA= Hazard Analysis, SHT= Safety and Health Training, and TSM= Toolbox Safety Meeting.

APPENDIX 4: CORRELATION ANALYSIS RESULTS

Part -I

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	r	1.00																			
	p																				
2	r	0.73	1.00																		
	p	0.00																			
3	r	0.45	0.39	1.00																	
	p	0.00	0.01																		
4	r	0.45	0.29	0.26	1.00																
	p	0.00	0.08	0.10																	
5	r	0.43	0.49	0.42	0.42	1.00															
	p	0.01	0.00	0.01	0.01																
6	r	0.26	0.25	0.38	0.27	0.47	1.00														
	p	0.12	0.13	0.02	0.10	0.00															
7	r	0.23	0.28	0.33	0.32	0.31	0.33	1.00													
	p	0.17	0.08	0.04	0.05	0.06	0.04														
8	r	0.46	0.36	0.62	0.39	0.56	0.46	0.47	1.00												
	p	0.00	0.02	0.00	0.02	0.00	0.00	0.00													
9	r	0.42	0.29	0.64	0.31	0.61	0.47	0.33	0.76	1.00											
	p	0.01	0.07	0.00	0.06	0.00	0.00	0.04	0.00												
10	r	0.36	0.22	0.35	0.39	0.23	0.27	0.54	0.48	0.44	1.00										
	p	0.02	0.17	0.03	0.01	0.17	0.09	0.00	0.00	0.00											
11	r	0.45	0.56	0.46	0.24	0.50	0.32	0.40	0.38	0.46	0.41	1.00									
	p	0.00	0.00	0.00	0.15	0.00	0.05	0.01	0.02	0.00	0.01										
12	r	0.50	0.45	0.40	0.44	0.53	0.50	0.23	0.42	0.54	0.24	0.64	1.00								
	p	0.00	0.00	0.01	0.00	0.00	0.00	0.16	0.01	0.00	0.14	0.00									
13	r	0.43	0.31	0.49	0.24	0.28	0.50	0.22	0.30	0.39	0.31	0.53	0.56	1.00							
	p	0.01	0.05	0.00	0.14	0.08	0.00	0.18	0.06	0.01	0.06	0.00	0.00								
14	r	0.13	-0.03	0.21	0.36	0.24	0.19	0.23	0.04	0.19	-0.04	0.34	0.42	0.34	1.00						
15	r	0.19	0.31	0.43	0.08	0.32	0.15	0.21	0.47	0.42	0.40	0.37	0.20	0.44	0.03	1.00					
	p	0.26	0.06	0.01	0.63	0.05	0.35	0.20	0.00	0.01	0.01	0.02	0.22	0.01	0.87						
16	r	0.31	0.37	0.48	0.32	0.51	0.43	0.31	0.47	0.54	0.32	0.61	0.50	0.64	0.40	0.69	1.00				
	p	0.06	0.02	0.00	0.04	0.00	0.01	0.06	0.00	0.00	0.05	0.00	0.00	0.00	0.01	0.00					
17	r	0.31	0.22	0.47	0.51	0.47	0.49	0.29	0.31	0.53	0.54	0.50	0.53	0.61	0.53	0.44	0.66	1.00			
	p	0.05	0.17	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00				
18	r	0.28	0.17	0.32	0.26	0.45	0.34	0.28	0.37	0.48	0.53	0.59	0.44	0.52	0.43	0.41	0.59	0.77	1.00		
	p	0.08	0.30	0.05	0.11	0.00	0.03	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00			
19	r	0.47	0.45	0.34	0.31	0.41	0.15	0.24	0.46	0.33	0.41	0.43	0.21	0.18	0.11	0.41	0.35	0.42	0.42	1.00	
	p	0.00	0.00	0.03	0.05	0.01	0.37	0.13	0.00	0.04	0.01	0.01	0.21	0.26	0.51	0.01	0.03	0.01	0.01		
20	r	0.34	0.29	0.38	0.30	0.54	0.52	0.40	0.44	0.57	0.51	0.49	0.39	0.40	0.23	0.27	0.48	0.65	0.63	0.43	1.00
	p	0.04	0.07	0.02	0.06	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.16	0.10	0.00	0.00	0.00	0.01	

Part -II

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	r	0.38	0.27	0.29	0.46	0.48	0.35	0.27	0.48	0.34	0.26	0.11	0.31	0.15	0.16	0.31	0.25	0.30	0.07	0.29	0.32
	p	0.02	0.10	0.08	0.00	0.00	0.03	0.09	0.00	0.04	0.10	0.49	0.05	0.37	0.34	0.06	0.13	0.06	0.68	0.07	0.05
22	r	0.38	0.42	0.32	0.27	0.54	0.25	0.49	0.49	0.45	0.28	0.66	0.37	0.43	0.32	0.40	0.63	0.40	0.48	0.36	0.51
	p	0.02	0.01	0.05	0.10	0.00	0.12	0.00	0.00	0.00	0.08	0.00	0.02	0.01	0.04	0.01	0.00	0.01	0.00	0.02	0.00
23	r	0.29	0.20	0.11	0.17	0.20	0.38	0.47	0.08	0.14	0.25	0.50	0.35	0.36	0.47	0.00	0.38	0.44	0.40	0.21	0.42
	p	0.07	0.22	0.51	0.29	0.21	0.02	0.00	0.64	0.40	0.12	0.00	0.03	0.02	0.00	0.98	0.02	0.01	0.01	0.21	0.01
24	r	0.24	0.25	0.31	0.21	0.50	0.53	0.29	0.51	0.55	0.40	0.18	0.22	0.23	0.05	0.27	0.38	0.42	0.35	0.22	0.59
	p	0.14	0.13	0.06	0.21	0.00	0.00	0.08	0.00	0.00	0.01	0.28	0.18	0.15	0.74	0.10	0.02	0.01	0.03	0.18	0.00
25	r	0.38	0.32	0.67	0.29	0.62	0.45	0.25	0.60	0.67	0.22	0.26	0.31	0.24	0.12	0.25	0.43	0.43	0.34	0.34	0.47
	p	0.02	0.05	0.00	0.07	0.00	0.00	0.13	0.00	0.00	0.18	0.10	0.06	0.14	0.46	0.12	0.01	0.01	0.03	0.03	0.00
26	r	0.52	0.40	0.42	0.47	0.43	0.18	0.51	0.37	0.46	0.48	0.36	0.36	0.26	0.20	0.11	0.16	0.39	0.32	0.32	0.46
	p	0.00	0.01	0.01	0.00	0.01	0.26	0.00	0.02	0.00	0.00	0.02	0.02	0.12	0.22	0.49	0.34	0.01	0.05	0.05	0.00
27	r	0.56	0.50	0.71	0.36	0.49	0.47	0.28	0.68	0.61	0.51	0.42	0.47	0.54	0.13	0.55	0.54	0.57	0.49	0.47	0.38
	p	0.00	0.00	0.00	0.02	0.00	0.00	0.09	0.00	0.00	0.00	0.01	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.02
28	r	0.19	0.11	0.02	0.18	0.05	0.06	0.18	0.05	-0.03	0.19	-0.03	0.03	0.00	0.06	-0.01	0.09	0.14	-0.02	0.04	0.11
	p	0.25	0.50	0.90	0.27	0.75	0.70	0.27	0.77	0.87	0.24	0.87	0.85	0.99	0.71	0.94	0.58	0.41	0.92	0.83	0.52
29	r	0.44	0.47	0.40	0.27	0.53	0.37	0.25	0.30	0.52	0.23	0.47	0.45	0.36	0.32	0.21	0.38	0.57	0.47	0.41	0.52
	p	0.00	0.00	0.01	0.10	0.00	0.02	0.13	0.06	0.00	0.15	0.00	0.00	0.03	0.04	0.20	0.02	0.00	0.00	0.01	0.00
30	r	0.43	0.38	0.31	0.19	0.41	0.16	0.18	0.20	0.51	0.40	0.33	0.27	0.18	0.09	0.17	0.33	0.49	0.38	0.21	0.61
	p	0.01	0.02	0.05	0.25	0.01	0.34	0.26	0.22	0.00	0.01	0.04	0.09	0.26	0.58	0.30	0.04	0.00	0.02	0.21	0.00
31	r	0.41	0.52	0.32	0.29	0.40	0.26	0.46	0.34	0.49	0.47	0.41	0.40	0.21	0.12	0.39	0.43	0.45	0.37	0.32	0.58
	p	0.01	0.00	0.05	0.07	0.01	0.11	0.00	0.03	0.00	0.00	0.01	0.01	0.21	0.46	0.02	0.01	0.00	0.02	0.04	0.00
32	r	0.22	0.15	0.47	0.07	0.23	0.06	0.35	0.35	0.54	0.41	0.29	0.13	0.27	0.11	0.30	0.37	0.42	0.43	0.23	0.41
	p	0.17	0.37	0.00	0.66	0.16	0.69	0.03	0.03	0.00	0.01	0.07	0.44	0.09	0.52	0.06	0.02	0.01	0.01	0.17	0.01
33	r	0.29	0.18	0.47	0.25	0.37	0.36	0.31	0.47	0.55	0.38	0.33	0.42	0.16	0.29	0.02	0.12	0.33	0.36	0.22	0.45
	p	0.08	0.28	0.00	0.13	0.02	0.03	0.06	0.00	0.00	0.02	0.04	0.01	0.33	0.08	0.88	0.46	0.04	0.03	0.19	0.00
34	r	0.50	0.29	0.39	0.30	0.11	0.37	0.31	0.44	0.35	0.40	0.27	0.33	0.25	0.09	0.04	0.22	0.35	0.20	0.37	0.50
	p	0.00	0.07	0.01	0.06	0.52	0.02	0.06	0.01	0.03	0.01	0.09	0.04	0.12	0.57	0.81	0.18	0.03	0.22	0.02	0.00
35	r	0.41	0.32	0.49	0.35	0.32	0.34	0.57	0.39	0.48	0.38	0.41	0.44	0.23	0.37	0.18	0.24	0.38	0.18	0.28	0.46
	p	0.01	0.05	0.00	0.03	0.05	0.04	0.00	0.01	0.00	0.02	0.01	0.00	0.15	0.02	0.27	0.15	0.02	0.27	0.08	0.00
36	r	0.34	0.09	0.39	0.47	0.31	0.40	0.29	0.64	0.48	0.48	0.19	0.23	0.25	0.03	0.22	0.21	0.36	0.30	0.36	0.42
	p	0.03	0.60	0.01	0.00	0.05	0.01	0.08	0.00	0.00	0.00	0.26	0.15	0.12	0.84	0.17	0.19	0.03	0.07	0.02	0.01
37	r	0.23	0.21	0.42	0.47	0.37	0.20	0.12	0.34	0.39	0.47	0.43	0.37	0.24	0.17	0.45	0.45	0.56	0.53	0.46	0.43
	p	0.16	0.20	0.01	0.00	0.02	0.22	0.48	0.04	0.01	0.00	0.01	0.02	0.13	0.29	0.00	0.00	0.00	0.00	0.00	0.01
38	r	0.24	0.34	0.28	0.24	0.51	0.23	0.10	0.23	0.32	0.21	0.31	0.41	0.22	0.25	0.26	0.36	0.41	0.47	0.27	0.40
	p	0.14	0.03	0.09	0.14	0.00	0.17	0.54	0.17	0.04	0.20	0.05	0.01	0.17	0.12	0.11	0.02	0.01	0.00	0.10	0.01
39	r	0.17	0.19	0.36	0.21	0.26	0.11	-0.05	0.19	0.26	0.16	0.37	0.45	0.25	0.17	0.14	0.21	0.38	0.38	0.46	0.39
	p	0.29	0.24	0.02	0.19	0.11	0.52	0.77	0.26	0.11	0.33	0.02	0.00	0.13	0.30	0.40	0.19	0.02	0.02	0.00	0.02
40	r	0.38	0.26	0.60	0.24	0.25	0.27	0.15	0.50	0.51	0.51	0.47	0.36	0.40	0.01	0.28	0.23	0.37	0.45	0.31	0.32

Part -III

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
41	r	0.32	0.35	0.14	0.22	0.38	0.24	0.18	0.17	0.26	0.19	0.36	0.26	0.23	0.17	0.37	0.37	0.30	0.32	0.42	0.23
	p	0.05	0.03	0.38	0.18	0.02	0.15	0.28	0.29	0.11	0.25	0.02	0.11	0.16	0.31	0.02	0.02	0.06	0.05	0.01	0.17
42	r	0.27	0.16	0.23	0.21	0.41	0.38	0.41	0.23	0.34	0.45	0.45	0.39	0.27	0.37	0.30	0.32	0.66	0.64	0.50	0.49
	p	0.09	0.33	0.16	0.19	0.01	0.02	0.01	0.16	0.04	0.00	0.00	0.01	0.10	0.02	0.06	0.05	0.00	0.00	0.00	0.00
43	r	0.33	0.18	-0.08	0.17	0.16	0.17	0.17	-0.01	0.09	0.20	0.19	0.24	0.25	0.32	0.04	0.00	0.34	0.28	0.14	0.15
	p	0.04	0.28	0.62	0.30	0.34	0.31	0.31	0.97	0.57	0.22	0.25	0.14	0.12	0.05	0.82	1.00	0.04	0.09	0.39	0.35
44	r	0.38	0.26	0.09	0.50	0.55	0.18	0.10	0.18	0.17	-0.10	0.17	0.33	0.08	0.30	-0.10	0.23	0.21	0.10	0.27	0.15
	p	0.02	0.11	0.57	0.00	0.00	0.29	0.55	0.26	0.30	0.55	0.29	0.04	0.61	0.07	0.56	0.16	0.20	0.53	0.10	0.35
45	r	0.57	0.30	0.42	0.34	0.54	0.23	0.35	0.52	0.57	0.36	0.40	0.34	0.32	0.28	0.29	0.45	0.34	0.42	0.50	0.43
	p	0.00	0.07	0.01	0.03	0.00	0.16	0.03	0.00	0.00	0.02	0.01	0.04	0.05	0.09	0.07	0.00	0.03	0.01	0.00	0.01
46	r	-0.02	-0.12	-0.01	-0.17	-0.18	0.22	0.20	0.19	0.11	0.22	0.17	0.06	0.11	0.13	0.09	0.03	0.10	0.16	0.19	0.24
	p	0.89	0.48	0.95	0.29	0.28	0.18	0.22	0.25	0.49	0.18	0.29	0.73	0.51	0.42	0.57	0.84	0.55	0.34	0.25	0.14
47	r	0.23	0.14	0.23	0.21	0.32	0.38	0.24	0.19	0.43	0.47	0.31	0.34	0.29	0.27	0.35	0.32	0.63	0.41	0.39	0.52

Part -IV

		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	r	0.31	0.29	0.16	0.25	0.24	0.03	0.28	-0.11	0.14	0.29	0.39	0.21	0.28	-0.07	0.26	0.21	0.42	0.39	0.11	0.15
	p	0.05	0.07	0.34	0.12	0.15	0.87	0.08	0.50	0.38	0.07	0.01	0.19	0.08	0.68	0.11	0.20	0.01	0.01	0.51	0.37
42	r	0.29	0.33	0.44	0.34	0.27	0.37	0.37	0.21	0.45	0.36	0.47	0.38	0.38	0.21	0.43	0.31	0.50	0.23	0.28	0.16
	p	0.07	0.04	0.01	0.03	0.10	0.02	0.02	0.19	0.00	0.02	0.00	0.02	0.02	0.20	0.01	0.05	0.00	0.15	0.08	0.34
43	r	0.34	0.16	0.36	0.18	-0.14	0.17	0.21	0.37	0.23	0.15	0.31	0.00	0.15	0.11	0.19	0.10	0.10	0.11	-0.17	-0.03
	p	0.03	0.32	0.02	0.27	0.41	0.31	0.20	0.02	0.16	0.36	0.06	0.99	0.37	0.51	0.25	0.55	0.53	0.49	0.29	0.85
44	r	0.35	0.20	0.22	0.02	0.37	0.20	0.12	0.19	0.19	0.20	0.11	0.14	0.06	0.18	0.21	0.04	0.33	0.27	0.06	0.02
	p	0.03	0.22	0.17	0.88	0.02	0.23	0.48	0.25	0.25	0.23	0.50	0.40	0.70	0.27	0.19	0.82	0.04	0.10	0.72	0.89
45	r	0.27	0.44	0.16	0.23	0.41	0.49	0.40	0.33	0.39	0.31	0.30	0.46	0.28	0.19	0.33	0.28	0.36	0.27	0.20	0.24
	p	0.10	0.00	0.34	0.15	0.01	0.00	0.01	0.04	0.01	0.06	0.06	0.00	0.08	0.25	0.04	0.08	0.02	0.09	0.23	0.14
46	r	0.12	0.18	0.23	0.32	-0.07	0.00	0.01	0.17	-0.11	0.11	0.17	0.04	0.19	0.38	0.40	0.30	-0.01	-0.15	0.05	0.08
	p	0.47	0.26	0.15	0.05	0.69	1.00	0.96	0.30	0.52	0.52	0.29	0.83	0.25	0.02	0.01	0.06	0.95	0.35	0.78	0.65
47	r	0.22	0.22	0.33	0.32	0.23	0.40	0.27	0.35	0.36	0.49	0.51	0.29	0.33	0.36	0.58	0.41	0.37	0.19	0.29	0.13

Part -V

		41	42	43	44	45	46	47
41	r	1.00						
	p							
42	r	0.46	1.00					
	p	0.00						
43	r	0.33	0.57	1.00				
	p	0.04	0.00					
44	r	0.36	0.25	0.22	1.00			
	p	0.02	0.12	0.18				
45	r	0.31	0.45	0.14	0.40	1.00		
	p	0.05	0.00	0.38	0.01			
46	r	0.00	0.30	0.24	-0.20	-0.02	1.00	

	p	0.98	0.06	0.15	0.22	0.92		
47	r	0.30	0.66	0.42	0.09	0.40	0.40	1.00

Part -VI

		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
21	r	1.00																			
	p																				
22	r	0.73	1.00																		
	p	0.00																			
23	r	0.45	0.39	1.00																	
	p	0.00	0.01																		
24	r	0.45	0.29	0.26	1.00																
	p	0.00	0.08	0.10																	
25	r	0.43	0.49	0.42	0.42	1.00															
	p	0.01	0.00	0.01	0.01																
26	r	0.26	0.25	0.38	0.27	0.47	1.00														
	p	0.12	0.13	0.02	0.10	0.00															
27	r	0.23	0.28	0.33	0.32	0.31	0.33	1.00													
	p	0.17	0.08	0.04	0.05	0.06	0.04														
28	r	0.46	0.36	0.62	0.39	0.56	0.46	0.47	1.00												
	p	0.00	0.02	0.00	0.02	0.00	0.00	0.00													
29	r	0.42	0.29	0.64	0.31	0.61	0.47	0.33	0.76	1.00											
	p	0.01	0.07	0.00	0.06	0.00	0.00	0.04	0.00												
30	r	0.36	0.22	0.35	0.39	0.23	0.27	0.54	0.48	0.44	1.00										
	p	0.02	0.17	0.03	0.01	0.17	0.09	0.00	0.00	0.00											
31	r	0.45	0.56	0.46	0.24	0.50	0.32	0.40	0.38	0.46	0.41	1.00									
	p	0.00	0.00	0.00	0.15	0.00	0.05	0.01	0.02	0.00	0.01										
32	r	0.50	0.45	0.40	0.44	0.53	0.50	0.23	0.42	0.54	0.24	0.64	1.00								
	p	0.00	0.00	0.01	0.00	0.00	0.00	0.16	0.01	0.00	0.14	0.00									
33	r	0.43	0.31	0.49	0.24	0.28	0.50	0.22	0.30	0.39	0.31	0.53	0.56	1.00							
	p	0.01	0.05	0.00	0.14	0.08	0.00	0.18	0.06	0.01	0.06	0.00	0.00								
34	r	0.13	-0.03	0.21	0.36	0.24	0.19	0.23	0.04	0.19	-0.04	0.34	0.42	0.34	1.00						
	r	0.19	0.31	0.43	0.08	0.32	0.15	0.21	0.47	0.42	0.40	0.37	0.20	0.44	0.03	1.00					
35	p	0.26	0.06	0.01	0.63	0.05	0.35	0.20	0.00	0.01	0.01	0.02	0.22	0.01	0.87						
	r	0.31	0.37	0.48	0.32	0.51	0.43	0.31	0.47	0.54	0.32	0.61	0.50	0.64	0.40	0.69	1.00				
36	p	0.06	0.02	0.00	0.04	0.00	0.01	0.06	0.00	0.00	0.05	0.00	0.00	0.00	0.01	0.00					
	r	0.31	0.22	0.47	0.51	0.47	0.49	0.29	0.31	0.53	0.54	0.50	0.53	0.61	0.53	0.44	0.66	1.00			
37	p	0.05	0.17	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00				
	r	0.28	0.17	0.32	0.26	0.45	0.34	0.28	0.37	0.48	0.53	0.59	0.44	0.52	0.43	0.41	0.59	0.77	1.00		
38	p	0.08	0.30	0.05	0.11	0.00	0.03	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00			
	r	0.47	0.45	0.34	0.31	0.41	0.15	0.24	0.46	0.33	0.41	0.43	0.21	0.18	0.11	0.41	0.35	0.42	0.42	1.00	
39	p	0.00	0.00	0.03	0.05	0.01	0.37	0.13	0.00	0.04	0.01	0.01	0.21	0.26	0.51	0.01	0.03	0.01	0.01		
	r	0.34	0.29	0.38	0.30	0.54	0.52	0.40	0.44	0.57	0.51	0.49	0.39	0.40	0.23	0.27	0.48	0.65	0.63	0.43	1.00
40	p	0.04	0.07	0.02	0.06	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.16	0.10	0.00	0.00	0.00	0.01	

Legend 1= Integrated Schedule; 2=Work Schedule Strategies; 3=Schedule Control; 4= Dynamic Site Layout Plan; 5=Traffic Control Plan; 6=Site Security Plan; 7=Machinery Positioning Strategy; 8=Project start-up plan; 9=Project Completion Plan;10=Innovations and New Technologies; 11= Procurement Plans for Materials;12=Long -Lead Materials Identification; 13=Materials Status Database; 14=Materials Delivery Schedule; 15= Material Inspection Process; 16=Materials Inspection Team; 17=Procurement Plans for Construction Equipment; 18= Construction Equipment Productivity Analysis; 19=Construction Equipment Maintenance; 20=Short Interval Plan; 21=Well Defined Scope of Work; 22=Use of Software in Planning Work Packages;23=Dedicated Planner; 24=Construction Work Packages;25=Buildability Review; 26=Utilities Alignment; 27=Contract Types; 28=Model Development; 29=Regulatory Requirement; 30= Crew Composition; 31=Skill Assessmen;32=Employees Training;33=Career Development;34=Non-Financial Incentive Programs; 35=Financial Incentive Programs;36=Social Activities; 37= Stability of Organization Structure; 38=Clear Delegation of Responsibility;39=Retention Plan for Experienced Personnel; 40=Exit interviews; 41=Housekeeping;42=Health and Safety Policy;43=Health and Safety Plan;44=Safe work Method Statement;45=Hazards Analysis;46= Health and Safety Training; 47=Toolbox Safety Meetings.

APPENDIX 5: RAW DATA FOR LOGISTIC REGRESSION ANALYSES

A1: Raw Data for Logistic Regression Analysis of Construction Materials Management Practices and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Construction Materials Management Practices*
Validation Dataset^{11} Model Building Dataset^{12} Model Building Dataset^{13}	1	R7	0.0083	0.78	3.49
	2	R34	0.0160	1.08	2.97
	3	R11	0.0363	0.59	1.53
	4	R32	0.0561	1.14	3.81
	5	R25	0.1277	0.96	1.08
	6	R24	0.1442	0.92	1.18
	7	R2	0.1600	0.88	3.77
	8	R16	0.2287	1.00	1.79
	9	R4	0.2297	1.02	3.14
	10	R13	0.2753	1.07	1.84
	11	R3	0.2984	1.02	2.91
	12	R23	0.3212	0.89	2.66
	13	R6	0.3592	0.82	1.36
Model Building Dataset^{21} Validation Dataset^{22} Model Building Dataset^{23}	1	R33	0.4091	0.90	1.57
	2	R18	0.4116	1.00	2.23
	3	R14	0.4137	0.82	1.97
	4	R12	0.4265	0.79	2.49
	5	R39	0.4361	1.10	3.61
	6	R26	0.4496	0.76	1.32
	7	R38	0.4546	1.00	1.53
	8	R30	0.4590	1.12	3.91
	9	R9	0.6022	1.14	2.98
	10	R27	0.6119	1.08	1.92
	11	R37	0.6255	1.08	3.92
	12	R29	0.6372	0.92	2.34
	13	R35	0.7068	1.06	1.68
Model Building Dataset^{31} Model Building Dataset^{32} Validation Dataset^{33}	1	R8	0.7331	1.06	2.99
	2	R31	0.7343	0.91	2.77
	3	R19	0.7451	1.08	1.45
	4	R5	0.7493	1.01	2.28
	5	R10	0.8059	1.13	3.97
	6	R28	0.8183	0.60	1.66
	7	R20	0.8200	0.88	1.41
	8	R1	0.8350	1.00	1.88
	9	R15	0.8588	0.88	2.17
	10	R36	0.8672	1.00	2.74
	11	R17	0.9209	0.67	2.37
	12	R22	0.9288	1.00	2.44
	13	R21	0.9911	0.96	2.66

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Construction Materials Management Practices Scores*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	3.49
	2	R34	0.0160	1.08	2.97
	3	R11	0.0363	0.59	1.53
	4	R32	0.0561	1.14	3.81
	5	R25	0.1277	0.96	1.08
	6	R24	0.1442	0.92	1.18
	7	R2	0.1600	0.88	3.77
	8	R16	0.2287	1.00	1.79
	9	R4	0.2297	1.02	3.14
	10	R13	0.2753	1.07	1.84
	1	R3	0.2984	1.02	2.91
MBD^{24} VD^{25} MBD^{26} MBD^{27}	2	R23	0.3212	0.89	2.66
	3	R6	0.3592	0.82	1.36
	4	R33	0.4091	0.90	1.57
	5	R18	0.4116	1.00	2.23
	6	R14	0.4137	0.82	1.97
	7	R12	0.4265	0.79	2.49
	8	R39	0.4361	1.10	3.61
	9	R26	0.4496	0.76	1.32
	10	R38	0.4546	1.00	1.53
	1	R30	0.4590	1.12	3.91
MBD^{34} MBD^{35} VD^{36} MBD^{37}	2	R9	0.6022	1.14	2.98
	3	R27	0.6119	1.08	1.92
	4	R37	0.6255	1.08	3.92
	5	R29	0.6372	0.92	2.34
	6	R35	0.7068	1.06	1.68
	7	R8	0.7331	1.06	2.99
	8	R31	0.7343	0.91	2.77
	9	R19	0.7451	1.08	1.45
	10	R5	0.7493	1.01	2.28
MBD44 MBD45 VD46 MBD47	1	R10	0.8059	1.13	3.97
	2	R28	0.8183	0.60	1.66
	3	R20	0.8200	0.88	1.41
	4	R1	0.8350	1.00	1.88
	5	R15	0.8588	0.88	2.17
	6	R36	0.8672	1.00	2.74
	7	R17	0.9209	0.67	2.37
	8	R22	0.9288	1.00	2.44
	9	R21	0.9911	0.96	2.66

Legend: MBD= Model Building Dataset; VD=Validation Dataset

A2: Raw Data for Logistic Regression Analysis of Construction Equipment Management Practices and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Construction Equipment Management Practices*
Validation Dataset^{11} Model Building Dataset ^{12} Model Building Dataset ^{13}	1	R7	0.0083	0.78	1.67
	2	R34	0.0160	1.08	1.08
	3	R11	0.0363	0.59	0.58
	4	R32	0.0561	1.14	1.69
	5	R25	0.1277	0.96	0.68
	6	R24	0.1442	0.92	0.58
	7	R2	0.1600	0.88	1.35
	8	R16	0.2287	1.00	0.59
	9	R4	0.2297	1.02	1.08
	10	R13	0.2753	1.07	0.97
	11	R3	0.2984	1.02	0.83
	12	R23	0.3212	0.89	1.37
	13	R6	0.3592	0.82	0.89
Model Building Dataset^{21} Validation Dataset ^{22} Model Building Dataset ^{23}	1	R33	0.4091	0.90	0.42
	2	R18	0.4116	1.00	0.00
	3	R14	0.4137	0.82	0.44
	4	R12	0.4265	0.79	1.41
	5	R39	0.4361	1.10	1.15
	6	R26	0.4496	0.76	0.00
	7	R38	0.4546	1.00	0.70
	8	R30	0.4590	1.12	1.49
	9	R9	0.6022	1.14	1.23
	10	R27	0.6119	1.08	1.55
	11	R37	0.6255	1.08	2.09
	12	R29	0.6372	0.92	1.47
	13	R35	0.7068	1.06	0.59
Model Building Dataset^{31} Model Building Dataset ^{32} Validation Dataset ^{33}	1	R8	0.7331	1.06	1.11
	2	R31	0.7343	0.91	0.96
	3	R19	0.7451	1.08	0.56
	4	R5	0.7493	1.01	0.58
	5	R10	0.8059	1.13	1.23
	6	R28	0.8183	0.60	0.16
	7	R20	0.8200	0.88	0.58
	8	R1	0.8350	1.00	0.58
	9	R15	0.8588	0.88	0.71
	10	R36	0.8672	1.00	1.39
	11	R17	0.9209	0.67	0.72
	12	R22	0.9288	1.00	1.39
	13	R21	0.9911	0.96	0.58

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Construction Equipment Management Practices Scores*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	1.67
	2	R34	0.0160	1.08	1.08
	3	R11	0.0363	0.59	0.58
	4	R32	0.0561	1.14	1.69
	5	R25	0.1277	0.96	0.68
	6	R24	0.1442	0.92	0.58
	7	R2	0.1600	0.88	1.35
	8	R16	0.2287	1.00	0.59
	9	R4	0.2297	1.02	1.08
	10	R13	0.2753	1.07	0.97
MBD^{24} VD^{25} MBD^{26} MBD^{27}	1	R3	0.2984	1.02	0.83
	2	R23	0.3212	0.89	1.37
	3	R6	0.3592	0.82	0.89
	4	R33	0.4091	0.90	0.42
	5	R18	0.4116	1.00	0.00
	6	R14	0.4137	0.82	0.44
	7	R12	0.4265	0.79	1.41
	8	R39	0.4361	1.10	1.15
	9	R26	0.4496	0.76	0.00
	10	R38	0.4546	1.00	0.70
MBD^{34} MBD^{35} VD^{36} MBD^{37}	1	R30	0.4590	1.12	1.49
	2	R9	0.6022	1.14	1.23
	3	R27	0.6119	1.08	1.55
	4	R37	0.6255	1.08	2.09
	5	R29	0.6372	0.92	1.47
	6	R35	0.7068	1.06	0.59
	7	R8	0.7331	1.06	1.11
	8	R31	0.7343	0.91	0.96
	9	R19	0.7451	1.08	0.56
	10	R5	0.7493	1.01	0.58
MBD44 MBD45 VD46 MBD47	1	R10	0.8059	1.13	1.23
	2	R28	0.8183	0.60	0.16
	3	R20	0.8200	0.88	0.58
	4	R1	0.8350	1.00	0.58
	5	R15	0.8588	0.88	0.71
	6	R36	0.8672	1.00	1.39
	7	R17	0.9209	0.67	0.72
	8	R22	0.9288	1.00	1.39
	9	R21	0.9911	0.96	0.58

Legend: MBD= Model Building Dataset; VD=Validation Dataset

A3: Raw Data for Logistic Regression Analysis of Management Practices Related to Construction Methods and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Management Practices Related to Construction Methods Score*
Validation Dataset^{11} Model Building Dataset ^{12} Model Building Dataset ^{13}	1	R7	0.0083	0.78	6.78
	2	R34	0.0160	1.08	6.32
	3	R11	0.0363	0.59	3.76
	4	R32	0.0561	1.14	6.82
	5	R25	0.1277	0.96	2.19
	6	R24	0.1442	0.92	3.96
	7	R2	0.1600	0.88	6.80
	8	R16	0.2287	1.00	5.42
	9	R4	0.2297	1.02	5.40
	10	R13	0.2753	1.07	4.15
	11	R3	0.2984	1.02	6.32
	12	R23	0.3212	0.89	4.36
	13	R6	0.3592	0.82	5.69
Model Building Dataset^{21} Validation Dataset ^{22} Model Building Dataset ^{23}	1	R33	0.4091	0.90	2.55
	2	R18	0.4116	1.00	4.98
	3	R14	0.4137	0.82	3.06
	4	R12	0.4265	0.79	4.91
	5	R39	0.4361	1.10	6.46
	6	R26	0.4496	0.76	3.78
	7	R38	0.4546	1.00	5.58
	8	R30	0.4590	1.12	4.96
	9	R9	0.6022	1.14	4.93
	10	R27	0.6119	1.08	5.84
	11	R37	0.6255	1.08	6.24
	12	R29	0.6372	0.92	4.82
	13	R35	0.7068	1.06	3.15
Model Building Dataset^{31} Model Building Dataset ^{32} Validation Dataset ^{33}	1	R8	0.7331	1.06	6.30
	2	R31	0.7343	0.91	3.88
	3	R19	0.7451	1.08	3.62
	4	R5	0.7493	1.01	5.77
	5	R10	0.8059	1.13	5.79
	6	R28	0.8183	0.60	2.14
	7	R20	0.8200	0.88	4.07
	8	R1	0.8350	1.00	4.37
	9	R15	0.8588	0.88	4.77
	10	R36	0.8672	1.00	4.96
	11	R17	0.9209	0.67	3.60
	12	R22	0.9288	1.00	5.97
	13	R21	0.9911	0.96	4.20

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Management Practices Related to Construction Methods Score*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	6.78
	2	R34	0.0160	1.08	6.32
	3	R11	0.0363	0.59	3.76
	4	R32	0.0561	1.14	6.82
	5	R25	0.1277	0.96	2.19
	6	R24	0.1442	0.92	3.96
	7	R2	0.1600	0.88	6.80
	8	R16	0.2287	1.00	5.42
	9	R4	0.2297	1.02	5.40
	10	R13	0.2753	1.07	4.15
MBD^{24} VD^{25} MBD^{26} MBD^{27}	1	R3	0.2984	1.02	6.32
	2	R23	0.3212	0.89	4.36
	3	R6	0.3592	0.82	5.69
	4	R33	0.4091	0.90	2.55
	5	R18	0.4116	1.00	4.98
	6	R14	0.4137	0.82	3.06
	7	R12	0.4265	0.79	4.91
	8	R39	0.4361	1.10	6.46
	9	R26	0.4496	0.76	3.78
	10	R38	0.4546	1.00	5.58
MBD^{34} MBD^{35} VD^{36} MBD^{37}	1	R30	0.4590	1.12	4.96
	2	R9	0.6022	1.14	4.93
	3	R27	0.6119	1.08	5.84
	4	R37	0.6255	1.08	6.24
	5	R29	0.6372	0.92	4.82
	6	R35	0.7068	1.06	3.15
	7	R8	0.7331	1.06	6.30
	8	R31	0.7343	0.91	3.88
	9	R19	0.7451	1.08	3.62
	10	R5	0.7493	1.01	5.77
MBD44 MBD45 VD46 MBD47	1	R10	0.8059	1.13	5.79
	2	R28	0.8183	0.60	2.14
	3	R20	0.8200	0.88	4.07
	4	R1	0.8350	1.00	4.37
	5	R15	0.8588	0.88	4.77
	6	R36	0.8672	1.00	4.96
	7	R17	0.9209	0.67	3.60
	8	R22	0.9288	1.00	5.97
	9	R21	0.9911	0.96	4.20

Legend: MBD= Model Building Dataset; VD=Validation Dataset

A4: Raw Data for Logistic Regression Models for Pre-Construction Phase Management Practices and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Preconstruction Phase Management Practices Scores*
Validation Dataset^{11} Model Building Dataset^{12} Model Building Dataset^{13}	1	R7	0.0083	0.78	5.69
	2	R34	0.0160	1.08	6.01
	3	R11	0.0363	0.59	3.65
	4	R32	0.0561	1.14	7.11
	5	R25	0.1277	0.96	2.80
	6	R24	0.1442	0.92	3.85
	7	R2	0.1600	0.88	6.10
	8	R16	0.2287	1.00	5.15
	9	R4	0.2297	1.02	5.36
	10	R13	0.2753	1.07	4.40
	11	R3	0.2984	1.02	4.90
	12	R23	0.3212	0.89	4.61
	13	R6	0.3592	0.82	5.68
Model Building Dataset^{21} Validation Dataset^{22} Model Building Dataset^{23}	1	R33	0.4091	0.90	1.79
	2	R18	0.4116	1.00	4.52
	3	R14	0.4137	0.82	2.61
	4	R12	0.4265	0.79	4.50
	5	R39	0.4361	1.10	6.53
	6	R26	0.4496	0.76	3.99
	7	R38	0.4546	1.00	5.27
	8	R30	0.4590	1.12	5.50
	9	R9	0.6022	1.14	5.46
	10	R27	0.6119	1.08	5.85
	11	R37	0.6255	1.08	6.72
	12	R29	0.6372	0.92	5.25
	13	R35	0.7068	1.06	2.05
Model Building Dataset^{31} Model Building Dataset^{32} Validation Dataset^{33}	1	R8	0.7331	1.06	4.94
	2	R31	0.7343	0.91	4.39
	3	R19	0.7451	1.08	3.00
	4	R5	0.7493	1.01	4.07
	5	R10	0.8059	1.13	5.31
	6	R28	0.8183	0.60	1.19
	7	R20	0.8200	0.88	2.77
	8	R1	0.8350	1.00	4.18
	9	R15	0.8588	0.88	5.03
	10	R36	0.8672	1.00	4.09
	11	R17	0.9209	0.67	3.30
	12	R22	0.9288	1.00	5.33
	13	R21	0.9911	0.96	3.46

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Preconstruction Phase Management Practices Scores*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	6.57
	2	R34	0.0160	1.08	4.54
	3	R11	0.0363	0.59	3.52
	4	R32	0.0561	1.14	5.14
	5	R25	0.1277	0.96	2.04
	6	R24	0.1442	0.92	2.48
	7	R2	0.1600	0.88	6.52
	8	R16	0.2287	1.00	2.59
	9	R4	0.2297	1.02	6.96
	10	R13	0.2753	1.07	5.36
MBD^{24} VD^{25} MBD^{26} MBD^{27}	1	R3	0.2984	1.02	4.47
	2	R23	0.3212	0.89	5.27
	3	R6	0.3592	0.82	5.73
	4	R33	0.4091	0.90	2.64
	5	R18	0.4116	1.00	4.30
	6	R14	0.4137	0.82	4.23
	7	R12	0.4265	0.79	5.06
	8	R39	0.4361	1.10	5.74
	9	R26	0.4496	0.76	3.88
	10	R38	0.4546	1.00	4.89
MBD^{34} MBD^{35} VD^{36} MBD^{37}	1	R30	0.4590	1.12	3.81
	2	R9	0.6022	1.14	5.45
	3	R27	0.6119	1.08	7.19
	4	R37	0.6255	1.08	6.27
	5	R29	0.6372	0.92	5.03
	6	R35	0.7068	1.06	4.14
	7	R8	0.7331	1.06	5.50
	8	R31	0.7343	0.91	3.97
	9	R19	0.7451	1.08	4.49
	10	R5	0.7493	1.01	4.67
MBD44 MBD45 VD46 MBD47	1	R10	0.8059	1.13	6.13
	2	R28	0.8183	0.60	0.92
	3	R20	0.8200	0.88	3.39
	4	R1	0.8350	1.00	3.30
	5	R15	0.8588	0.88	4.50
	6	R36	0.8672	1.00	5.59
	7	R17	0.9209	0.67	2.05
	8	R22	0.9288	1.00	6.74
	9	R21	0.9911	0.96	5.32

Legend: MBD= Model Building Dataset; VD=Validation Dataset

A5: Raw Data for Logistic Regression Analysis of Human Resource Management Practices and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Human Resource Management Practices Scores*
Validation Dataset^{11} Model Building Dataset ^{12} Model Building Dataset ^{13}	1	R7	0.0083	0.78	6.57
	2	R34	0.0160	1.08	4.54
	3	R11	0.0363	0.59	3.52
	4	R32	0.0561	1.14	5.14
	5	R25	0.1277	0.96	2.04
	6	R24	0.1442	0.92	2.48
	7	R2	0.1600	0.88	6.52
	8	R16	0.2287	1.00	2.59
	9	R4	0.2297	1.02	6.96
	10	R13	0.2753	1.07	5.36
	11	R3	0.2984	1.02	4.47
	12	R23	0.3212	0.89	5.27
	13	R6	0.3592	0.82	5.73
Model Building Dataset^{21} Validation Dataset ^{22} Model Building Dataset ^{23}	1	R33	0.4091	0.90	2.64
	2	R18	0.4116	1.00	4.30
	3	R14	0.4137	0.82	4.23
	4	R12	0.4265	0.79	5.06
	5	R39	0.4361	1.10	5.74
	6	R26	0.4496	0.76	3.88
	7	R38	0.4546	1.00	4.89
	8	R30	0.4590	1.12	3.81
	9	R9	0.6022	1.14	5.45
	10	R27	0.6119	1.08	7.19
	11	R37	0.6255	1.08	6.27
	12	R29	0.6372	0.92	5.03
	13	R35	0.7068	1.06	4.14
Model Building Dataset^{31} Model Building Dataset ^{32} Validation Dataset ^{33}	1	R8	0.7331	1.06	5.50
	2	R31	0.7343	0.91	3.97
	3	R19	0.7451	1.08	4.49
	4	R5	0.7493	1.01	4.67
	5	R10	0.8059	1.13	6.13
	6	R28	0.8183	0.60	0.92
	7	R20	0.8200	0.88	3.39
	8	R1	0.8350	1.00	3.30
	9	R15	0.8588	0.88	4.50
	10	R36	0.8672	1.00	5.59
	11	R17	0.9209	0.67	2.05
	12	R22	0.9288	1.00	6.74
	13	R21	0.9911	0.96	5.32

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Human Resource Management Practices Scores*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	6.57
	2	R34	0.0160	1.08	4.54
	3	R11	0.0363	0.59	3.52
	4	R32	0.0561	1.14	5.14
	5	R25	0.1277	0.96	2.04
	6	R24	0.1442	0.92	2.48
	7	R2	0.1600	0.88	6.52
	8	R16	0.2287	1.00	2.59
	9	R4	0.2297	1.02	6.96
	10	R13	0.2753	1.07	5.36
MBD^{24} VD^{25} MBD^{26} MBD^{27}	1	R3	0.2984	1.02	4.47
	2	R23	0.3212	0.89	5.27
	3	R6	0.3592	0.82	5.73
	4	R33	0.4091	0.90	2.64
	5	R18	0.4116	1.00	4.30
	6	R14	0.4137	0.82	4.23
	7	R12	0.4265	0.79	5.06
	8	R39	0.4361	1.10	5.74
	9	R26	0.4496	0.76	3.88
	10	R38	0.4546	1.00	4.89
MBD^{34} MBD^{35} VD^{36} MBD^{37}	1	R30	0.4590	1.12	3.81
	2	R9	0.6022	1.14	5.45
	3	R27	0.6119	1.08	7.19
	4	R37	0.6255	1.08	6.27
	5	R29	0.6372	0.92	5.03
	6	R35	0.7068	1.06	4.14
	7	R8	0.7331	1.06	5.50
	8	R31	0.7343	0.91	3.97
	9	R19	0.7451	1.08	4.49
	10	R5	0.7493	1.01	4.67
MBD44 MBD45 VD46 MBD47	1	R10	0.8059	1.13	6.57
	2	R28	0.8183	0.60	4.54
	3	R20	0.8200	0.88	3.52
	4	R1	0.8350	1.00	5.14
	5	R15	0.8588	0.88	2.04
	6	R36	0.8672	1.00	2.48
	7	R17	0.9209	0.67	6.52
	8	R22	0.9288	1.00	2.59
	9	R21	0.9911	0.96	6.96

Legend: MBD= Model Building Dataset; VD=Validation Dataset

A6: Raw Data for Logistic Regression Analysis of Safety and Health Practices and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Safety and Health Practices Scores*
Validation Dataset^{11} Model Building Dataset ^{12} Model Building Dataset ^{13}	1	R7	0.0083	0.78	6.39
	2	R34	0.0160	1.08	5.85
	3	R11	0.0363	0.59	4.01
	4	R32	0.0561	1.14	6.03
	5	R25	0.1277	0.96	4.76
	6	R24	0.1442	0.92	4.03
	7	R2	0.1600	0.88	5.31
	8	R16	0.2287	1.00	5.49
	9	R4	0.2297	1.02	5.29
	10	R13	0.2753	1.07	6.03
	11	R3	0.2984	1.02	6.03
	12	R23	0.3212	0.89	6.21
	13	R6	0.3592	0.82	6.39
Model Building Dataset^{21} Validation Dataset ^{22} Model Building Dataset ^{23}	1	R33	0.4091	0.90	5.48
	2	R18	0.4116	1.00	5.65
	3	R14	0.4137	0.82	2.73
	4	R12	0.4265	0.79	6.02
	5	R39	0.4361	1.10	6.39
	6	R26	0.4496	0.76	4.39
	7	R38	0.4546	1.00	5.12
	8	R30	0.4590	1.12	5.85
	9	R9	0.6022	1.14	6.03
	10	R27	0.6119	1.08	6.03
	11	R37	0.6255	1.08	6.21
	12	R29	0.6372	0.92	6.21
	13	R35	0.7068	1.06	5.29
Model Building Dataset^{31} Model Building Dataset ^{32} Validation Dataset ^{33}	1	R8	0.7331	1.06	5.49
	2	R31	0.7343	0.91	5.86
	3	R19	0.7451	1.08	5.68
	4	R5	0.7493	1.01	4.55
	5	R10	0.8059	1.13	5.29
	6	R28	0.8183	0.60	4.00
	7	R20	0.8200	0.88	4.39
	8	R1	0.8350	1.00	4.94
	9	R15	0.8588	0.88	5.66
	10	R36	0.8672	1.00	6.21
	11	R17	0.9209	0.67	5.12
	12	R22	0.9288	1.00	5.29
	13	R21	0.9911	0.96	6.03

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Safety and Health Practices Scores*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	6.39
	2	R34	0.0160	1.08	5.85
	3	R11	0.0363	0.59	4.01
	4	R32	0.0561	1.14	6.03
	5	R25	0.1277	0.96	4.76
	6	R24	0.1442	0.92	4.03
	7	R2	0.1600	0.88	5.31
	8	R16	0.2287	1.00	5.49
	9	R4	0.2297	1.02	5.29
	10	R13	0.2753	1.07	6.03
MBD^{24} VD^{25} MBD^{26} MBD^{27}	1	R3	0.2984	1.02	6.03
	2	R23	0.3212	0.89	6.21
	3	R6	0.3592	0.82	6.39
	4	R33	0.4091	0.90	5.48
	5	R18	0.4116	1.00	5.65
	6	R14	0.4137	0.82	2.73
	7	R12	0.4265	0.79	6.02
	8	R39	0.4361	1.10	6.39
	9	R26	0.4496	0.76	4.39
	10	R38	0.4546	1.00	5.12
MBD^{34} MBD^{35} VD^{36} MBD^{37}	1	R30	0.4590	1.12	5.85
	2	R9	0.6022	1.14	6.03
	3	R27	0.6119	1.08	6.03
	4	R37	0.6255	1.08	6.21
	5	R29	0.6372	0.92	6.21
	6	R35	0.7068	1.06	5.29
	7	R8	0.7331	1.06	5.49
	8	R31	0.7343	0.91	5.86
	9	R19	0.7451	1.08	5.68
	10	R5	0.7493	1.01	4.55
	1	R10	0.8059	1.13	5.29
	2	R28	0.8183	0.60	4.00
	3	R20	0.8200	0.88	4.39
	4	R1	0.8350	1.00	4.94
	5	R15	0.8588	0.88	5.66
	6	R36	0.8672	1.00	6.21
	7	R17	0.9209	0.67	5.12
	8	R22	0.9288	1.00	5.29
	9	R21	0.9911	0.96	6.03

A7: Raw Data for Logistic Regression Analysis of Aggregated Construction Management Practices and Productivity

a. 3-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Aggregated Construction Management Practices*
Validation Dataset^{11} Model Building Dataset ^{12} Model Building Dataset ^{13}	1	R7	0.0083	0.78	30.59
	2	R34	0.0160	1.08	26.77
	3	R11	0.0363	0.59	17.06
	4	R32	0.0561	1.14	30.59
	5	R25	0.1277	0.96	13.55
	6	R24	0.1442	0.92	16.09
	7	R2	0.1600	0.88	29.86
	8	R16	0.2287	1.00	21.03
	9	R4	0.2297	1.02	27.22
	10	R13	0.2753	1.07	22.75
	11	R3	0.2984	1.02	25.47
	12	R23	0.3212	0.89	24.48
	13	R6	0.3592	0.82	25.74
Model Building Dataset^{21} Validation Dataset ^{22} Model Building Dataset ^{23}	1	R33	0.4091	0.90	14.44
	2	R18	0.4116	1.00	21.69
	3	R14	0.4137	0.82	15.05
	4	R12	0.4265	0.79	24.39
	5	R39	0.4361	1.10	29.88
	6	R26	0.4496	0.76	17.36
	7	R38	0.4546	1.00	23.09
	8	R30	0.4590	1.12	25.52
	9	R9	0.6022	1.14	26.09
	10	R27	0.6119	1.08	28.38
	11	R37	0.6255	1.08	31.45
	12	R29	0.6372	0.92	25.13
	13	R35	0.7068	1.06	16.90
Model Building Dataset^{31} Model Building Dataset ^{32} Validation Dataset ^{33}	1	R8	0.7331	1.06	26.33
	2	R31	0.7343	0.91	21.82
	3	R19	0.7451	1.08	18.80
	4	R5	0.7493	1.01	21.91
	5	R10	0.8059	1.13	27.72
	6	R28	0.8183	0.60	10.07
	7	R20	0.8200	0.88	16.60
	8	R1	0.8350	1.00	19.25
	9	R15	0.8588	0.88	22.84
	10	R36	0.8672	1.00	24.98
	11	R17	0.9209	0.67	17.16
	12	R22	0.9288	1.00	27.15
	13	R21	0.9911	0.96	22.25

b. 4-fold Cross Validation

Codes	*No.*	*Respondents*	*Random Numbers*	*Productivity Factor (PF)*	*Aggregated Construction Management Practices Scores*
VD^{14} MBD^{15} MBD^{16} MBD^{17}	1	R7	0.0083	0.78	30.59
	2	R34	0.0160	1.08	26.77
	3	R11	0.0363	0.59	17.06
	4	R32	0.0561	1.14	30.59
	5	R25	0.1277	0.96	13.55
	6	R24	0.1442	0.92	16.09
	7	R2	0.1600	0.88	29.86
	8	R16	0.2287	1.00	21.03
	9	R4	0.2297	1.02	27.22
	10	R13	0.2753	1.07	22.75
MBD^{24} VD^{25} MBD^{26} MBD^{27}	1	R3	0.2984	1.02	25.47
	2	R23	0.3212	0.89	24.48
	3	R6	0.3592	0.82	25.74
	4	R33	0.4091	0.90	14.44
	5	R18	0.4116	1.00	21.69
	6	R14	0.4137	0.82	15.05
	7	R12	0.4265	0.79	24.39
	8	R39	0.4361	1.10	29.88
	9	R26	0.4496	0.76	17.36
	10	R38	0.4546	1.00	23.09
MBD^{34} MBD^{35} VD^{36} MBD^{37}	1	R30	0.4590	1.12	25.52
	2	R9	0.6022	1.14	26.09
	3	R27	0.6119	1.08	28.38
	4	R37	0.6255	1.08	31.45
	5	R29	0.6372	0.92	25.13
	6	R35	0.7068	1.06	16.90
	7	R8	0.7331	1.06	26.33
	8	R31	0.7343	0.91	21.82
	9	R19	0.7451	1.08	18.80
	10	R5	0.7493	1.01	21.91
	1	R10	0.8059	1.13	27.72
	2	R28	0.8183	0.60	10.07
	3	R20	0.8200	0.88	16.60
	4	R1	0.8350	1.00	19.25
	5	R15	0.8588	0.88	22.84
	6	R36	0.8672	1.00	24.98
	7	R17	0.9209	0.67	17.16
	8	R22	0.9288	1.00	27.15
	9	R21	0.9911	0.96	22.25

APPENDIX 6: RAW DATA FOR COMPANY PROFILES

Company Code	*Number of years in Industry*	*Company Size (No. of Employees)*	*Annual Turnover*
R1	44.0	440.0	529.0
R2	76.0	-	-
R3	25.0	550.0	652.0
R4	19.0	200.0	612.0
R5	16.0	31.0	-
R6	68.0	210-500	449.0
R7	54.0	3750.0	2505.0
R8	54.0	3750.0	2505.0
R9	54.0	3750.0	2505.0
R10	21.0	51-200	199.0
R11	21.0	51-200	199.0
R12	18.0	501-1000	702.0
R13	58.0	>10000	2762.0
R14	98.0	501-1000	904.0
R15	12.0	51-200	-
R16	12.0	-	-
R17	41.0	5001-10000	541.0
R18	20.0	65.0	-
R19	20.0	65.0	-
R20	37.0	40.0	-
R21	44.0	440.0	529.0
R22	43.0	>250	470.0
R23	68.0	210-500	449.0
R24	-	-	-
R25	11.0	11-50	-
R26	10.0	-	-
R27	29.0	1001-5000	1098.0
R28	10.0	11-50	-
R29	29.0	1001-5000	1098.0
R30	66.0	201-500	246.0
R31	14.0	51-200	-
R32	29.0	1001-5000	1098.0
R33	104.0	1300.0	722.0
R34	58.0	>10000	2762.0
R35	43.0	>250	470.0
R36	32.0	1001-5000	-
R37	45.0	11-50	-
R38	43.0	>250	470.0
R39	61.0	51-200	196.0

Notes: Codes for company size during analysis are: 1 for 0-19 employees, 2 for between 20-199 employees and 3 for greater than 200 employees.

APPENDIX 7: INTERVIEW RESULTS

Respondent 1	Respondent 2	Respondent 3	Respondent 4 and 5
"The main contractor sends the monthly report to us (client representative). The program is prepared using MS project and percent complete reports for each floor is submitted by the main contractor. For example, Structural progress report is submitted as FRPL17P1 meaning ‘Formwork’, ‘Reo,’ ‘Pour’ for level seventeen pour number 1; we make monthly site visit. Company XXX is the best structural sub-contractor and it is leading the local construction industry in using different technologies such as jump formwork, slip formwork and similar technologies. The company uses kibbles having different capacities to pour concrete. It takes between 5-6 days to complete casting a floor including columns. Wind and rain are the main reasons for variation of the pouring days."	"The most common building project procurement methods practiced in the context of Australia are: - i. Traditional Procurement • Lump sum • Measurement • Cost reimbursement ii. Design and Construct Procurement iii. Management Procurement"	"After the reinforcement has been placed and it is ready for casting, the structural engineer shall inspect and give his comments prior to pouring the concrete. The comments are provided to the main contractor and then forwarded with cover letter to the concreting subcontractor. Crane is used to cast concrete for columns using kibbles and pump is used for slab. The slab is post tensioned in both ways. • The precast cast concrete subcontractor delivers the materials using just-in-time approach. • Crane is owned by structural sub-contractor, and other subcontractors also use the crane when it is not used for concreting and related works. As concrete is on the critical path, priority is given for this item. For instance, the day after casting concrete, the crane is entirely used by the structural subcontractor as they will transport their panels and make ready for another pour. There is meeting every day regarding the usage of crane. • More than 80% of the structure of our projects is subcontracted to the same contractor due to its capacity and good working relationship."	"1. Organization Structure of a Project • There are more than twenty sub-contractors which execute various works like concrete, electrical, mechanical, glass, tiles etc., and the main contractor has 6 supervisors to oversee the activities of the subbies. The main contractor has also consultancy agreement with one structural consultant. 2. Organizational Structure of the Main Builder • The construction manager usually sits at the head office and is also responsible for the management of other projects too. The project manager sits on site and he may or may not manage other sites. There is one site manager who is responsible for coordination of the works of the six supervisors under the project manager. 3. Organization for Concrete Work • The concrete sub-contractor has its own site supervisor which is me and I am responsible for overseeing the tasks of different crews (bar benders, Concrete floater, Concrete Formwork Stripper others). I supervise all the concreting operations from formwork laying to casting concrete to stripping the formwork. I report to construction manager who is sitting at the head office. There is also supervisor from main contractor who is also responsible for crane scheduling, structure works, drop zone that is giving permission to sub-contractors working underneath and making sure that their working zone is free. He also manages main contractor’s laborers that execute general works which are not sub-contracted such as housekeeping."

Respondent 6					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Materials Delivery Schedule	"Material delivery schedule has an effect on productivity and we really manage it so much."	Suitable	Retention Plan for Experienced Personnel	"It is through promotion. They promote their personnel. That does not necessarily have to people who have been there for long time. It is people who they believe fit for the role. If you are not efficient at your job, there will be less likely to promote you."	Suitable
Short Interval Planning	"we have contract program, works program, target programs and two weekly programs."	Suitable	Exit interviews	"There is a process for them. But I don't think there are very well used"	Suitable
Well Defined Scope of Work	"In a contract, there is a section called scope of works which we line items of all the works they have to do. And then also within the contract, we can even nominate the site team that we want."	Suitable	Integrated Schedule	"Program and finance is integrated. Labour from subcontractor is integrated back into reporting financing and programming."	Suitable
Use of Software in Planning workpackages	"I am familiar with MS project, pretty standard."	Suitable	Work Schedule Strategies	"We just use the union calendar. It is 36 hours per week. The enterprise bargaining agreement stipulates how long we can work for. If you want to	Suitable
Dedicated Planner	"Absolutely yeah, they have a planning team. There is someone who is responsible for the works program and for example the two-year program for this project is produced by an in-house planner. But once it is given to the site, the site team plans the short term activities."	Suitable	Dynamic Site Layout Plan	"It always moves. The office will move at least once. The car park is usually used as an area for storage. That is planned for."	Suitable
Design Readiness for Construction	"There is a logistic planner, someone who reviews the design from a constructability point of view."	Suitable	Site Security Plan	"There is security system on weekends in particular. We employ security staff. It is not as such. I think, crime is not as big on building sites."	Suitable
Employees Technical Training	"Skilled trades like electricians and plumbers are the ones that have regulatory obligations that they have to do in the apprenticeship training."	Suitable	Machinery Positioning Strategy	"A good example is we looked quite closely at how big the precast panels were on our site project. So our panels were too big for our crane so the crane was not strong enough to up-lift the panels so a lot of panels got broken into two smaller ones so the crane can lift. A lot of work is done early on."	Suitable
Non-Financial Incentive Programs	"At a head contractor, they use that very heavily, non-financial benefits. There is a lot of variety in the work that I do. I find really interesting. I really enjoy the work that I do. It is not necessarily due to financial benefit."	Suitable	Innovations and New Technologies	"At the moment we are trying to use a new drawing review system where drawings are reviewed electronically rather than by a pen and paper."	Suitable
Financial Incentive Programs	"They provide financial incentives to motivate them not necessarily non-financial incentives."	Suitable	Formal Health and Safety Policy	"safe site is a happy site'. It is also far more productive site if people respect the work site"	Suitable
Social Activities	"My company has fitness days; they pay for people doing marathon things like that. They definitely use non-financial incentives"	Suitable	Clear Delegation of Responsibility	"People are given their roles; update the roles where there is lot of project. There is a clear structure that is in place. In my company, there is strong management processes."	Suitable
Maintain Stability of Organization Structure	"Preparing good organizational structures are considered good practices. Absolutely, yeah".	Suitable			

Respondent 7					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Short Interval Planning	'Depending on which tier and on the frequency of statusing short interval planning is conducted. The very lowest denominator tier 3 may be statused each week or each fort night.'	Suitable	Contract types	'Most of the contracts are fixed so that no extra costs that will be incurred. There is scope of works that may have a set of drawings that they have attended to.'	Suitable
Well Defined Scope of Work	'That is mainly done by the contract administrators and package managers. Broadly speaking, facade have its own scope of work, structure has its own scope of works, finishing and fit out has several scope of works'	Suitable	Crew Composition	'When it comes to any sub-contract work, they are responsible for their own formation of their crews and composition; for us we organize our crew.'	Suitable
Use of Software in Planning	'We use software in planning normally. MS project, p6 and other programs that we need. MS Project is pretty standard everyone uses it.'	Suitable	Integrated Schedule	'With schedules/programs, there is a couple of tiers. You high light critical areas, detail out these critical areas and sign up the subcontractors to those programs.'	Suitable
Dedicated Planner	'I am dedicated planner. Yes, dedicated planner on site is needed because people sometimes do not look ahead as far as the project planner needs to look. So strategic direction needs to be applied and it is good to have someone there.'	Suitable	Work Schedule Strategies	'If you are in delay, you request extra time to work over time. We work six days a week from CFMEU RDO calendar, so that is normal construction hours for us.'	Suitable
Construction Work Packages	'From scope of works; each one will have a program or work packages.'	Suitable	Schedule Control	'You get subcontractors feedback for the works they are in charge of; depending on what phase of the job you are you give their percentage complete, remaining duration and you have to forecast out whether they are going to be finished.'	Suitable
Buildability Review	'We are going to review the design before construction. We have design manager/ a team of the people depending on the scale of the job you might have one person or several people. Obviously we have to design for safety as well like the way they do a balustrade detail and how we actually install has to be considered. apprenticeship training.'	Suitable	Dynamic Site Layout Plan	'These are implemented at stages; there is always a construction plan. When you get to certain level and depending on which job; from the start of the job you generally write up a construction plan and have a certain set off where you think your site shade is going to be. Yes, we do maneuver those elements; and that is all part of your project program.'	Suitable

Respondent 8					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘For example, you want to procure a façade; you are going to have concept, you are going to have an indication of what you need to do, what is the performance criteria, what is the façade for, what does it looks like / what is architecture which is the design; then you look into the detail requirements of that façade/performance of that facade; then you need to understand how to deliver it or manage it, you break up the building in to packages.’	Suitable	Well- Defined Scope of Work	‘You must define your scope. That is the biggest problem today. To me it is the biggest risk the industry face. It is our ability to communicate in detail and in plan the scopes; and the inputs of those scope to each trade; and dependency of those scope to each other.’	Suitable
Long-Lead Materials Identification	‘Usually the long lead times are façade, services such as lifts, generators, boilers all these key primary elements have long lead times.’	Suitable	Dedicated Planner	‘Oh yes. Planner is critical that he gets by his own experience, records, and referencing durations. Most companies will find that they have the durations to build. I can build a floor and finish a floor in X days. So he is plugging in that, the guys on site try to deliver as per that.’	Suitable
Materials Delivery Schedule	‘It is about managing, identifying and procuring the critical path materials. And to ensure that is kept. Well, there are. The tendency here is the same people building the job are doing inspection. If you get your architect doing defect, you got sign off that the quality has been achieved.’	Suitable	Buildability Review	‘Design reviews and checking even in here you need to do regularly. You always reviewing and checking and testing whether design is right. That is why people go for shop drawings, RFI’s etc.'	Suitable
Material Inspection Process	‘Well, there are. The tendency here is the same people building the job are doing inspection. If you get your architect doing defect, you got sign off that the quality has been achieved.’	Suitable	Contract types	‘What people doing are giving them the drawings and allow for everything. So the contractor really tries to get the subcontractor take risk.’	Suitable
Construction Machinery Maintenance	‘Under the contract, you provide notices for rectification order in subcontract. Occupational health and safety obligations usually address these issues, equipment must be maintained, serviced, signed off on regular basis. It is through subcontracting; most of all these issues are done by subcontractors.’	Suitable	Model Development	‘It is fantastic the more you can get that because it helps to communicate. The more 3D models and the more cuttings and drawings coming in the better off we are because they help to explain.’	Suitable
Site Tools Management Strategy	It is through subcontracting; most of all these issues are done by subcontractors.’	Not Suitable	Machinery Positioning Strategy	‘The crane is subject to each size. We need to have the five principles again (design, detail, sequence, program and cost). Design and detail for example relate to weight of crane. Weight and reach become fundamental not only in building but also in removing the crane.’	Suitable
Short Interval Planning	‘It is absolutely important. The project should have a minimum of a week ahead to four weeks ahead to six weeks ahead to a year ahead. Your planning should be within a week; you should always know what you will try to do next week. By addressing and checking back against the program, it will allow you to plan mitigation strategies. It will help you to identify what makes you sleep’	Suitable			

Respondent 9 and 10					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	'We hire subcontractors to procure materials.'	Suitable	Non-Financial Incentive Programs	'Not really.'	Not Suitable
Long-Lead Materials Identification	'Lift and other lead time items are identified earlier.20 weeks for lift. Lift is always a long lead item. The items vary for site to site.'	Suitable	Financial Incentive Programs	'You are given a job and you will do. No incentive'	Suitable
Procurement Team	'We usually use supply and install contracting method'	Suitable	Social Activities	Soccer, dinner, beer on Friday after noon'	Suitable
On-Site Materials Tracking Technology	'We do not let materials on site for robbery. We use just in time technique.'	Not Suitable	Stability of Organization Structure	'The project team vary from project to project but generally anyone above PM will stay the same.'	Suitable
Materials Delivery Schedule	'We give the delivery dates for subcontractors. The Forman on site sit down with them and fix the schedule.'	Suitable	Clear Delegation of Responsibility	We do have all clear delegation of responsibility that also comes with our job descriptions.	Suitable
Material Inspection Process	'Forman on site makes sure that materials come to site as per the specification.'	Suitable	Retention Plan for Experienced Personnel Exit interviews	'No retention plan.'	Not Suitable
Procurement Plan for Construction Equipment	'Most of our subcontractors use their own lifting mechanisms.'	Suitable	Exit interviews	'I had one from my last company.'	Suitable
Construction Machinery Productivity Analysis	'Project manager, project coordinator and site Forman sit down and fix the position of crane. The subcontractor is responsible for its machinery unless tower crane is required for the project. We get specialist contractor for tower crane and make use of its knowledge in choosing appropriate crane.'	Suitable	Integrated Schedule	'We have master programs which are integrated to procurement program'	Suitable
Site Tools Management	'We have only basic tools.'	Not Suitable	Work Schedule Strategies	'6 days a week for our contractors.'	Suitable
Tools Tracking Technologies	'Each tool has its number kit and it is registered. Site Forman controls. However, it is not a big concern as our laborers do prelims.'	Suitable	Schedule Control	'Forty nightly subby meetings. We identify who is ahead and who is not. There is constant monitor.'	Suitable
Short Interval Planning	'Yeah, we do forty nightly programs, monthly programs and overall programs.'	Suitable	Dynamic Site Layout Plan	'It depends on the site. Every time we move shade, water and power depending on the stage of work. We might use building as our site office.'	Suitable
Well- Defined Scope of Work	'Generally, as a rule of thumb subcontractors know their scope of works. We try to tie things to contract.'	Suitable	Traffic Control Plan	Yeah we employ someone to do for us by providing a copy of our plan and tell them our activities. It is done by certified traffic	Suitable
Use of Software in Planning Dedicated Planner	'MS project, job pack, team binder, Aconex is good for variation and RFI.'	Suitable	Site Security Plan	'It varies from job to job.'	Suitable
Dedicated Planner	'No, the project manager can do that.	Not Suitable	Machinery Positioning Strategy	'We have spoken about that.'	Suitable

Respondent 9 and 10 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Construction Work Packages	‘It is all combined in to one. We tie up the scope of works. The contractor agreed to bring in more labour if he is behind the schedule and agreed to time framework. All these things are included in contract together with the scope of works.’	Suitable	Project Completion Plan	‘We bring building surveyors and request for certificate of occupancy. In case of novation we novate building surveyors.’	Suitable
Buildability Review	‘During tender phase architects ask us for cost saving. It incurs us lot of cost.’	Suitable	Innovations and New Technologies	‘Not really.’	Not Suitable
Contract types	‘Lump sum and design plus construct.’	Suitable	Housekeeping	‘It is important for productivity. The site needs to be clean otherwise it is subjected to accident.’	Suitable
Model Development	‘It is fantastic; especially structural steel works need 3D models.’	Suitable	Health and Safety Policy	‘Massive safety plans.’	Suitable
Regulatory Requirements	‘Traffic management permits, service permit; it all depends on project types.’	Suitable	Safe work Method Statement	‘SWMS/task safety analysis is the responsibility of subcontractor.’	Suitable
Crews Composition	‘We do that.’	Suitable	Drugs and Alcohol Testing Program	‘No it is not conducted on site.’	Not Suitable
Skills Assessment and Evaluation	‘We know by word of mouth who best subcontractor is. It depends on the size of the work package too.’	Suitable	Health and Safety Training Programs	‘Yes, OHS’	Suitable
Employees Training	‘The company provide training for us. Administrative, first aid and OSH training.’	Suitable	Toolbox Safety Meetings	‘It is conducted on weekly basis.’	Suitable
Career Development	‘Yes, again it depends on the company you are working with.’	Suitable			

Respondent 11					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘There are two persons responsible for controlling the procurement procedures. Based on our budget we tender to make sure of competitiveness. Sub-contractors are tendered to purchase their own materials and all their own access such as scaffolding. We analysed some gains from purchasing reinforcement bar for this project and we procure it ourselves. Majority of other materials are packaged out.’	Suitable	Regulatory Requirements	‘We have safety system and quality assurance system in our company. Building surveyor, fire engineer, CMP requires permit.’	Suitable
Materials Delivery Schedule	‘We track during manufacturing, when it is on site, after installation of façade. We write on white board the delivery of materials and track every day.’	Suitable	Crew Composition	‘Two engineers, Formen, general Forman, senior project manager, construction manager, labourers.’	Suitable
Material Inspection Process	‘For plaster boards there is no really that much quality assurance; for concrete we get concrete mix dockets, concrete strength test; check the painting; Glass before it comes to site at factory(China).’	Suitable	Skills Assessment and Evaluation	‘They need to have proper training to do specific task. Scaffolding by licensed scaffolder, we see the cards for dogging, rigging, crane works before workers start job. This is done during induction stage.’	Suitable
Material Inspection team	‘We get independent building surveyor for checking fire ceiling and other items.’	Suitable	Career Development	‘Our company is fairly good in this aspect.’	Suitable
Post Receipt Preservation & Maintenance	‘We do not have storage on site.’	Suitable	Non-Financial Incentive Programs	‘They do some advertising if you do good job.’	Suitable
Construction Machinery Productivity Analysis	‘For the structure, for instance, we do analyse by tracking how many tracks are poured per day with the help of cranes.’	Suitable	Financial Incentive Programs	‘Pay for performance scheme is practiced at our company.’	Suitable
Construction Equipment Maintenance	‘For the cranes, there are periodic maintenance that we have to meet.	Suitable	Social Activities	‘There is an allocated budget for every project.’	Suitable
Site Tools Management Strategy	‘We have few, up to 5 to 6 construction labourers on site. Generally, they do safety related works.’	Not Suitable	Stability of Organization Structure	‘Regarding our team site setup, we have PM, CM, general Forman (site manager). It is fairly good at the moment.’	Suitable
Tools Tracking Technologies	‘There is an asset register.’	Not Suitable	Clear Delegation of Responsibility	‘We have clear roles and responsibilities that you sign in to it.’	Suitable
Short Interval Planning	‘We have two weekly plans and relate it with main contract program.’	Suitable	Retention Plan for Experienced Personnel	‘The more experience the more you get paid. The company look after those persons but there is no	Suitable
Well- Defined Scope of Work	‘We have templates from previous projects which have been built over a number of years. We normally adapt to specific site. For example, for tiles and other items and put in some inclusions.’	Suitable	Exit interviews	‘When you quitting there is an interview to understand why you quit? Where are you going? Please come back and see us when you need.’	Suitable
Use of Software in Planning	‘We use primavera P6; two weekly plan on excel spread sheet.’	Suitable	Integrated Schedule	‘We do have procurement schedule for long lead items. Specially for this project FFE (fittings, fixture and equipment) schedules are integrated to work schedule.’	Suitable

Respondent 11 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Dedicated Planner	'We have dedicated planner at head office. But depending on the size of project we have also on site dedicated planner. For example, for Royal Melbourne Hospital we used to have dedicated planner.'	Suitable	Work Schedule Strategies	'We work one every two Saturdays which is scheduled. There is 6 RDO's per year and you are encouraged not to come on these days.'	Suitable
Construction Work Packages	'The project is broken down in to approximately to 20-25 packages. Tiling, façade, structure, landscape, civil works etc. Lift as separate package.'	Suitable	Schedule Control	'We have practical completion date in the contract and monitor it. We mark on the plan the areas which is available for subcontractor to start its work.'	Suitable
Buildability Review	'The design is mostly not ready enough for construction. We get input from subcontractors as a design input.'	Suitable	Dynamic Site Layout Plan	'Our site lay out is dynamic, at the middle of the project it is the same.	Suitable
Contract types	'Over $50,000 we go for major contracts which is a more detailed contract and minor works contract for less than $50,000. We have also PSA (professional service agreement) contract. For subcontractors we prefer lump sum which is broken down to the details so that we check how they come up	Suitable	Traffic Control Plan	'Being on community road, we have traffic controller and put different signages.'	Suitable
Model Development	'It is much more important for advertising than for construction. We have some drop ceiling and services clashing which can be identified using 3D.'	Suitable	Site Security Plan	'It is tied to site lay out and all gates are pad locked etc.'	Suitable
Machinery Positioning Strategy	'As crane is costly item we need to fix the number of crane at the beginning. There is crane study during tendering phase.'	Suitable	Innovations and New Technologies	'ACONEX is great software. OMTRAK is defecting software. Supervisor go on site and send to subcontractor to rectify the defects.'	Suitable
Project start-up plan	'There is project start up plan which is done by PM.'	Suitable	Health and Safety Policy	'safe site is a happy site'. It is also far more productive site if people respect the work site.'	Suitable
Project Completion Plan	'Every six weeks there is project meeting with operation managers on how we go concerning time, safety, cost and other issues.'	Suitable			

Respondent 12					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	'We track our procurement from contract award to delivery on site.'	Suitable	Employees Training	'There are trainings for our staff; crane courses, scaffolding courses and others which are related to their works.'	Suitable
Long-Lead Materials Identification	'It come through experience. We talk with contractors about the lead time. Lifts and facades are the two biggest items with long lead time.'	Suitable	Career Development	'There are discussions where people want to go say site management, contract administrator etc.'	Suitable
Procurement Team for Materials	'We do not have one person who is responsible for procurement. We have a person having a combined role.'	Not Suitable	Non-Financial Incentive Programs	'It is mainly for subcontractor.'	Suitable
Materials Status Database	'Façade is tracked using spread sheet. In general, the big picture of materials is tracked by coordination teams.'	Suitable	Financial Incentive Programs	'We sign up to the contract and it is not common.'	Suitable
On-Site Materials Tracking Technology	'We do not track materials on site. Not as I am aware of.'	Not Suitable	Social Activities	'We do team exercises with our project team.'	Suitable
Materials Delivery Schedule	'We work back form construction program and prepare material delivery schedule. We normally provide short buffer in case something go wrong.'	Suitable	Stability of Organization Structure	'Depending on the life cycle of the project the organization changes, we try to keep the stability of the structure because that can be disruptive.'	Suitable
Material Inspection Process	'We inspect upfront; we engage consultants on occasion to conduct factory inspection. We try to conduct at each phase.'	Suitable	Clear Delegation of Responsibility	'We have role and responsibility for all of our staff. That is important for efficiency sit down with line manager and do that.'	Suitable
Material Inspection team	'Project coordinator together with industry experts. For example, for façade we have façade expert.'	Suitable	Retention Plan for Experienced Personnel	'Communication with line manager is important and we strive not to loose the staff. We try to promote internally rather than recruiting externally.'	Suitable
Post Receipt Preservation and Maintenance	'Our site is pretty limited in space. Building projects have limited storage area and we try to avoid risk by storing materials on site.'	Not Suitable	Exit interviews	'The organization does it.'	Suitable
Procurement Plan for Construction equipment	'We subcontract everything. We have separate company that supply crane or we might package it up with formwork contractor.'	Suitable	Integrated Schedule	'We do. It comes to our program. When we tracking the trade.'	Suitable
Construction Machinery Productivity Analysis	'If the building is tall we need high speed hoist as opposed to mid speed hoist. If the precast is heavy, we need certain size crane. It comes to the knowledge of site management.'	Suitable	Work Schedule Strategies	'We do on occasions on RDO, on Sundays. It depends on the project restrictions by authority. Sometimes you are forced to do if you are behind the schedule.'	Suitable
Construction Equipment Maintenance	'It is separate agreement and if they provide crane, they have to maintain. Our supervisor monitors it.'	Suitable	Schedule Control	'We have site supervisors who work closely with subcontractor and monitor their progress. For example, we have structural supervisor, façade supervisor etc.'	Suitable

Respondent 12 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Site Tools Management Strategy	‘We have tool registers on site. But there are only few labourers say if the project has got 200 workers only 20 of them are our labourers.’	Not Suitable	Dynamic Site Layout Plan	‘We try to keep consistency. We try to set up our layout with site logistics and consistently with delivery.’	Suitable
Tools Tracking Technologies	‘We use tool register for the limited tools that are purchased for our labourers.’	Not Suitable	Traffic Control Plan	‘We do that and get approval from the council.’	Suitable
On-site Tools Maintenance	‘The site manager order maintenance or discard them.’	Not Suitable	Site Security Plan	‘It is normally done by site management team at the start of the project.’	Suitable
Short Interval Planning	‘we have contract program, works program, target programs and two weekly programs.’	Suitable	Project start-up plan	‘we prepare project start up.’	Suitable
Well- Defined Scope of Work	‘It is normally prepared at the tender phase and keep the copy on site for the site team to refer to it.’	Suitable	Project Completion Plan	‘we do also prepare project completion.’	Suitable
Use of Software in Planning	‘We use MS project, excel spread sheet. There is no special software.’	Suitable	Housekeeping	‘It is managed by our site team.’	Suitable
Construction Work Packages	‘We tend to package work which suits to the capacity of a contractor. For example, one contractor does formwork, reinforcement and concreting.’	Suitable	Health and Safety Policy	‘There is a company policy and we have fully accredited.’	Suitable
Buildability Review	‘We normal pick it up during design phase. We have design manager, a project coordinator looks at it and refine it. We sometimes bring defect staff right at the very beginning.’	Suitable	Safe work Method Statement	‘We do detail safe work method statement.’	Suitable
Utilities Alignment	‘We talk to authorities. We do that power, gas whatever it is. The subcontractors also talk to the respective authority. We normally do a survey prior to starting the jobs.’	Suitable	Hazards Analysis	‘The same thing as above, yes we do.’	Suitable
Contract types	‘We preferred to work on scope of works and fixed contract. If we are not sure on scope of works, we will do by our labour as we cannot fix the price.’	Suitable	Drugs and Alcohol Testing Program	‘We do not do any testing.’	Not Suitable
Model Development	‘It is important for consultants. It depends on the type of project. For structural steel we use 3-D models.’	Suitable	Health and Safety Training Programs	‘Industry red card training is provided.’	Suitable
Regulatory Requirements	‘Traffic management plan and construction management plan the response time from council is inconsistent and needs management.’	Suitable	Toolbox Safety Meetings	‘On weekly and fortnight basis we conduct meeting.’	Suitable
Crew Composition	‘The subcontract organizes their own labour. We do half more than half a dozen of supervisors, project coordinators, Project Manager.’	Suitable			
Skills Assessment and Evaluation	‘It is part of the induction process OH and S to demonstrate their competency.’	Suitable			

Respondent 13					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘Estimate the required materials up front. Successful procurement systems look at the lead times. You need to know what you are ordering, when to order, and how much you need. There is procurement schedules for various materials.’	Suitable	Career Development	‘Company has its own culture for career paths.’	Suitable
Long-Lead Materials Identification	‘Tiles are from Italy or overseas. You get quotations for these items during tendering. You identify materials up front including their lead times for example tiles from Italy, 8 weeks.’	Suitable	Non-Financial Incentive Programs	‘There are incentives like health care, and other which are not paid for us directly’	Suitable
Procurement Team for Materials	‘Generally contract Administrator and project engineers are responsible for checking when these materials arrive on site.’	Not Suitable	Financial Incentive Programs	‘There are bonus if you complete the project less than the targeted budget.’	Suitable
Materials Status Database	‘We match estimated time during tender with actual quantity; double check quantities. We bring materials one day before installation.’	Suitable	Social Activities	‘To reward the team when the team meet the target, there are such activities.’	Suitable
On-Site Materials Tracking Technology	‘The person on site ticks the delivery docket. Purchase order, delivery docket and invoice are checked. If there is surplus it is returned back by the supplier. Materials are not stored on site as it is costly to handle them’	Not Suitable	Stability of Organization Structure	‘Change is constant otherwise the company will die. ’	Suitable
Materials Delivery Schedule	‘There are both delivery and procurement schedules.’	Suitable	Clear Delegation of Responsibility	‘We have meetings, most people know their roles, if it is not clear they ask during the meeting.’	Suitable
Material Inspection Process	‘We conduct various inspections, reinforcement, formwork, concrete test/crack test. We take copy of every delivery docket of the concrete.’	Suitable	Retention Plan for Experienced Personnel	‘It depends on person's performance.’	Suitable
Material Inspection team	‘Structural engineer inspects reinforcement bars. Other consultants do depending on the type of work.’	Suitable	Exit interviews	‘Depending on the company structure, there is an exit interview.’	Suitable
Procurement Plan for Construction equipment	‘Based on SWMS we select appropriate equipment and machinery.’	Suitable	Work Schedule Strategies	‘I work on RDO's and finish early. It depends on the budget of project.’	Suitable
Construction Machinery Productivity Analysis	‘We see what is the maximum distance that is covered by the crane. We are checking weather conditions; we look at forecasts. For example, if it is windy there is no point to bring crane to site.’	Suitable	Schedule Control	‘We look at the target program and prepare percentage complete’	Suitable
Construction Equipment Maintenance	‘There is log book and plant risk register. If there are no maintenance checks done recently, it cannot be used for the project.’	Suitable	Traffic Control Plan	‘You need to be mindful of how the traffic is coming. You have people with radis, check the capacity of the road etc.’	Suitable
Site Tools Management Strategy	‘Most main builders do not have labour; generally, we want our subcontractors to do the main activities.’	Suitable	Site Security Plan	‘As the project progresses, you have different levels of security.’	Suitable

Respondent 13 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Short Interval Planning	'Yes, we do through project team meeting. Project manager, contract administrator, project engineer and Forman sit together to plan. Construction manager might involve based on the size of the project.'	Suitable	Machinery Positioning Strategy	You look at what you reach safely. You need to assess the worst case scenario.	Suitable
Well- Defined Scope of Work	'Review all the documentation to understand what to build and how to build. And prepare who is doing what and when.'	Suitable	Project start-up plan	'It is how you are going to build.'	Suitable
Use of Software in Planning	'ACONEX is good for picking up items such as defects and for communication. MS project is generally used for time planning.'	Suitable	Project Completion Plan	'It is how we handover to the owner. How you dismantle temporary works.'	Suitable
Dedicated Planner	'Generally, project manager is a planner.'	Suitable	Innovations & New Technologies	'Always new software, printers, new forms etc.'	Suitable
Construction Work Packages	'We generally do not want to break the structure into packages. We conduct interview with subcontractor. Before engaging we need to gage subcontractor.'	Suitable	Housekeeping	'Documentation is done by contract administrator; our laborers do general cleaning; subcontractors' trades clean their own working areas.'	Suitable
Buildability Review	'You should get recommendations from minimum of three recommendations from other builders before engaging a contractor.'	Suitable	Health and Safety Policy	'Yes, we have OH& S manager.'	Suitable
Utilities Alignment	'Dial before you Dig will locate for you before starting construction.'	Suitable	Health and Safety Plan	We try to prepare Safe work method statement'	Suitable
Contract types	'You always try to minimize your risk by subcontracting. Your conditions in the head contract will be reflected in subcontracts too.'	Suitable	Safe work Method Statement	'We do detail safe work method statement.'	Suitable
Model Development	'It is starting now by different architects. It is very good for big projects; it will help you fix the ceiling height.'	Suitable	Hazards Analysis	'It is risk assessment.'	Suitable
Regulatory Requirements	'Planning approval, development approval and building approval. Demolitions permit, footpath permits etc.'	Suitable	Drugs and Alcohol Testing Program	'We cover during induction but there is no formal testing program.'	Not Suitable
Crew Composition	'It depends on the project.'	Suitable	Health and Safety Training Programs	'Everybody has to take a minimum of construction safety induction training (white card).'	Suitable
Skills Assessment and Evaluation	'We ask recommendations from previous employer, photos of what they have done previously'	Suitable	Toolbox Safety Meetings	We do it every Friday,	Suitable

Respondent 14					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	'We sign contract with subcontractors that will procure materials with the help of our contract administrator. We will research how much each supplier charges when we decide to procure materials by ourselves. We develop shop drawings before ordering the materials. Generally, we prefer to package work on supply and install basis. Procurement plan is right on the front end. We identify the potential suppliers which might be in China or Italy.'	Suitable	Employees Training	'There is training on usage of new machineries for our site managers, labourers. Legislations and regulations changes and training is important.'	Suitable
Long-Lead Materials Identification	'During tendering, we look at job and identify long lead items like tiles (from Italy), lift, façade etc tabulate them and put in the program. Power or sub-station are also identified as long lead item so that we commission the building in time.'	Suitable	Career Development	'There is a yearly review to discuss about the career of an individual.'	Suitable
Procurement Team for Materials	'Contracts administrator selects subcontractors, pays them and manage the variations. Our company has got PM, contract manager, project engineer and site manager.'	Not Suitable	Non-Financial Incentive Programs	'No.'	Not Suitable
Materials Status Database	'It is the responsibility of subcontractor to quantify the materials which is sufficient for the job. We provide the documents and ask subcontractors whether everything that we need from us is satisfactory or not. If they say yes, it is then their own risk.'	Suitable	Financial Incentive Programs	'Project managers get bonus. But you are not working for your bonus.'	Suitable
On-Site Materials Tracking Technology	'We do not have direct labour and this eliminates the need to track materials on site and usage of such technologies. Most building companies do not have carpenters, plumbers etc.'	Not Suitable	Social Activities	'Every two months there is an event.'	Suitable

Respondent 14 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Materials Delivery Schedule	‘On certain jobs, you cannot deliver during the day time, due to school days and the fact that the road is in CBD etc. We have big white board at our project site office and subcontractors book in the time slot.’	Suitable	Stability of Organization Structure	‘Towards the end, there is less manpower on site. The company may say only contract administrator and labourers should be sufficient to run the project.’	Suitable
Material Inspection Process	‘We can also go to China or other country if needed. We generally inspect before installation, take photo graph and email	Suitable	Clear Delegation of Responsibility	‘Yeah. You have got roles and responsibility written in your contract.’	Suitable
Material Inspection team	‘We create an ITP (inspection test plan). We prepare the checklist for each item and our site manager ticks it.’	Suitable	Retention Plan for Experienced Personnel	‘There is not actually a plan. But if you do good job they will pay more money.’	Not Suitable
Post Receipt Preservation & Maintenance	‘It depends on project site's size. Sometimes we store materials based on the availability of space on site. We provide 10% for wastage.’	Not Suitable	Exit interviews	‘Yeah. The person leaving the company go through this process.’	Suitable
Procurement Plan for Construction equipment	‘You have to book your crane early when the industry is busy if you get the job. You have to lock in the price with the supplier too before commencement of the work.’	Suitable	Integrated Schedule	‘We run a cost against time. It is a gage where you are. 50% of the job you should be 50% of money spend.’	Suitable
Construction Machinery Productivity Analysis	‘Longest reach (radius) is analysed to position the crane. The heaviest lift is also considered. We approach crane company for advice.’	Suitable	Work Schedule Strategies	‘We provide a standard 10hrs for four days per week for subcontractors in a contract. But they prefer to work five days including Saturday. The individual get more money on Saturday than company. People are not productive on Saturdays, Sundays and RDO.’	Suitable
Construction Equipment Maintenance	‘There is standard maintenance. You got inspections that you need to do based on regulations say on weekly, monthly and yearly basis.’	Suitable	Schedule Control	‘There is always changes and management case by case is preferred. You manage design form the front end and resolve the issues with a client early.’	Suitable
Site Tools Management Strategy	‘We buy and keep in the container.’	Not Suitable	Dynamic Site Layout Plan	‘We have system in place and changes over time. We set up the areas.’	Suitable
Tools Tracking Technologies	‘You will be better off including the cost of tools in the cost job than purchasing by yourselves.’	Not Suitable	Traffic Control Plan	‘We have ticketed workers/controllers. Sometimes subcontractors do their own controlling.’	Suitable
On-site Tools Maintenance	‘The site manager controls the tools. For smaller items we do not worry about it.’	Not Suitable	Site Security Plan	‘Depending the type of work we might have plan for working with children, police checks; swap cards etc. Controlling accesses.’	Suitable
Short Interval Planning	‘Generally two weekly look ahead. The project manager sits with site manager and look what we do for next two week and track against main program.’	Suitable	Machinery Positioning Strategy	‘Similar to what we have discussed above (machinery productivity analysis)’	Suitable

Respondent 14 Continued					
Well- Defined Scope of Work	‘We get subcontractors price based on our tender price. We have generic scope and specific scope for a project. We dissect the work because we want to vary the scope.’	Suitable	Project start-up plan	‘We have a list of everything before mobilizing to site; we have done all permits, procurement etc. We fine tune what we are doing.’	Suitable
Use of Software in Planning	‘Primavera, MS project.’	Suitable	Project Completion Plan	‘Yes for sure.’	Suitable
Dedicated Planner	‘No, generally the project manager do the program.’	Not Suitable	Innovations & New Technologies	‘There is no specific department at our company which is dedicated for technology research. It is project specific. For example, we seek for technology which helps to cure concrete earlier in one of our projects due to inclement weather.’	Suitable
Construction Work Packages	‘It is a bit risky splitting works. For example, we do not want to spilt concrete package twice.’	Suitable	Housekeeping	‘We make sure that our scope includes cleaning in subcontractor’s contract.’	Suitable
Buildability Review	‘The front end work is to review the document. You cannot catch everything but we understand the design and review from constructability point of view.’	Suitable	Health and Safety Policy	‘We have got our own policy and it is displayed on site. It is part of the induction process.’	Suitable
Utilities Alignment	‘The client does but on occasion we get involved in to reduce delay on our job.’	Suitable	Health and Safety Plan	‘Lost time injury, medical injuries. Construction industry is a long way from it.	Suitable
Contract types	‘D and C provides opportunity to mold and helps to save money.’	Suitable	Safe work Method Statement	‘We do risk assessment at the beginning of the job. Accordingly, subcontractors prepare their own SWMS.’	Suitable
Model Development	‘For coordination of services, for steel work we use 3D models.	Suitable	Hazards Analysis	‘The same as above(SWMS).’	Suitable
Regulatory Requirements	‘We involve in building permit which is the biggest one. Asset protection permit, permit for connection of services that you need to go for.	Suitable	Drugs and Alcohol Testing Program	‘We do not do as a requirement at the moment.’	Not Suitable
Crew Composition	‘We let sub-contractors to start the job on this date and at an agreed price. We organise the management crew.’	Suitable	Health and Safety Training Programs	‘We do training on use of equipment, use of Asbestos.’	Suitable
Skills Assessment and Evaluation	‘We do not necessarily assess the skill except for special works like crane driver. We look at CV, competencies, tickets, and references.’	Suitable	Toolbox Safety Meetings	‘Every week/ Thursday and it is minuted.’	Suitable

Respondent 15					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘We develop procurement programs. There is sample intake and data process. We prepare tracking sheets and charts. We work back from the date we request to date of manufacture. Different stages of the procurement are represented using different colours on the chart.’	Suitable	Employees Training	‘There are various trainings; precast errection, supervision, cranes, health and safety etc.’	Suitable
Long-Lead Materials Identification	‘Anything that we import from overseas are categorized as long lead item. Eg. Façade, tiles, light fittings are some of the long lead item materials. We identify these materials early and let the work packages.’	Suitable	Career Development	‘We have development plans in our company. We meet three times a year with our employees.’	Suitable
Procurement Team for Materials	‘No, a project coordinator oversees the procurement of materials for specific trade.’	Not Suitable	Non-Financial Incentive Programs	‘If you meet your target time and budget you keep your work.’	Suitable
Materials Status Database	‘We do off-site inspection, materials installed on site. We do weekly report and monthly report to track the status of materials.’	Suitable	Financial Incentive Programs	‘There can be. There is certain agreement with the company depending on your position.’	Suitable
On-Site Materials Tracking Technology	‘We rely on subcontractors for tracking materials. We generally inspect off-site.’	Not Suitable	Social Activities	‘At certain interval/ month we have social activities.’	Suitable
Materials Delivery Schedule	‘There is weekly materials schedule.’	Suitable	Stability of Organization Structure	‘It is the director who allocates the employees for a project. Our structure comprises of PM, Contract administrator, project coordinator, site manager, supervisors (structure, façade, joinery, carpentry etc.). We try to maintain the stability of our structure.’	Suitable
Material Inspection Process	‘We have quality management plan at the start of the job. In that plan we identify the quality management process: supply, manufacture and install. We get sample; we hold that sample until the end of the jo so that we check against that. We also get the technical data or product data signed off by the architect/client/building surveyor. We have also defecting process: our supervisor inspects the installation; our coordinator reports that it is inspected; we make monthly visit with consultants. So we have got various people who constantly inspects.’	Suitable	Clear Delegation of Responsibility	‘Yes I do. There is clear delegation of responsibilities.’	Suitable

Respondent 15 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Material Inspection team	'Site supervisor, consultant, building surveyor, coordinator is involved in the inspection of materials.'	Suitable	Retention Plan for Experienced Personnel	'It is our target to retain our key personnel (site managers, contract managers)'	Suitable
Post Receipt Preservation & Maintenance	'We do not store materials on site and the practice is not common.'	Not Suitable	Exit interviews	'I have not done any exit interview but the company does.'	Suitable
Procurement Plan for Construction equipment	'We procure construction plants and equipment under hire agreement. There is maintenance obligations provided in the agreement. Alimak provides maintenance, the same for crane and scissor lifts. We have maintenance records that the machineries are working properly.'	Suitable	Integrated Schedule	'The work schedule, material schedule and finance schedule are all integrated in one program.'	Suitable
Construction Machinery Productivity Analysis	'Yes we do. For example, for the building with 20 to 30 storeys, we provide the standard hoists. So the height of the building determines the type of hoist. For more than 30 storeys we have high speed hoists. The foot print or the size of the building also determines the number of hoists. The whole logistic regarding crane is planned early.'	Suitable	Work Schedule Strategies	'Yes, we schedule the works based on where we are in terms of program, safety/ risk and what the work requires. For instance, we are currently doing crane jump and we do out of work hours.'	Suitable
Construction Equipment Maintenance	'There is regular interval inspections. We have to get calibration records; electrical items are tested and tagged; there is regulatory requirement for inspecting equipment six monthly and annually; when every new equipment comes to site there is induction.'	Suitable	Schedule Control	'We have weekly meetings with subcontractors. We get status program and we keep meeting every we.'	Suitable
Site Tools	'We have limited site tools and in terms of	Not Suitable	Dynamic Site Layout	'We tender based on our site logistics plan	Suitable
Tools Tracking Technologies	'No, not really.'	Not Suitable	Traffic Control Plan	'Yes we have traffic management plan.'	Suitable
On-site Tools	'Our direct labour is minimal. For example,	Not Suitable	Site Security Plan	'We do not have project specific plan but the	Suitable
Short Interval Planning	'We prepare short term works program. First there is a contract program with the client; after that we prepare works program that develop into trade program and the trade program develop into completion program. Besides the short work programs there are procurement programs.'	Suitable	Machinery Positioning Strategy	'We have discussed earlier, there is strategy in place.'	Suitable
Well- Defined Scope of Work	'When we are tendering each trade package, each scope of works outlines specifics & general items, site items, quality, safety and environment. The well-defined scope of works will reference the drawings and specification this will minimize the external variations.'	Suitable	Project start-up plan	'We have a project management plan and construction management plan which everyone has to sign on to.'	Suitable
Use of Software in Planning	'MS project, and there is head office support in statusing the project every month.'	Suitable	Project Completion Plan	'There is project completion program. There are things that need to be completed for closure of the project.'	Suitable

Respondent 15 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Dedicated Planner	‘There is dedicated planner at head office. We have programmer.’	Suitable	Innovations & New Technologies	‘We are always looking for new technologies and innovations on how we do things/construct, safety, new technologies for our subcontractors.’	Suitable
Construction Work Packages	‘Each trade has its own package that we put for tender which includes program, drawings, specifications, scope of works, invitation to tender, site logistics. Building is split in two 20-30 packages. The capacity of local subcontractors is taken in to account when the project is packaged.’	Suitable	Housekeeping	‘We do a safety walk each week. Housekeeping is the responsibility of subcontractors. There are bins on each floor. We have safety committee checking every day.’	Suitable
Buildability Review	‘We have a RED STICK process. When a consultant issues a drawing the document controller receives the drawing and put on a red drawing stick. Coordinators, design manger, project manager, services managers review the drawings and send back for revision to the consultant. So any drawing is reviewed by us for compliance and for any scope changes which has a major cost impact.’	Suitable	Health and Safety Policy	‘There is companywide policy and project specific.’	Suitable
Utilities Alignment	‘We engage DIAL BEFORE DIG during early phase. We engage the underground detection company for checking. Generally, for utilities we do not accept that risk it is the client's risk. All of the external works are excluded from our contract.’	Suitable	Health and Safety Plan	‘We target our lost time and injuries. We have target criteria those.’	Suitable
Contract types	‘It is driven by dollar value for us. D& C subcontract agreement are over $50,000. Anything over $25,000 minor works agreement. Anything less than $25,000 we can do under purchase order for minor works. This one is fixed lump sum D & C. We have also guaranteed maximum price, construct only, supply agreement, consultancy agreement.’	Suitable	Safe work Method Statement	‘Every task has a Safe work method statement (SWMS).’	Suitable
Model Development	‘We do use it to review based on the complexity of the project. But we rely on our consultants to provide us/ for visualization.’	Suitable	Hazards Analysis	‘Check list to be filled every two months. There are risk workshops to identify other hazards which are not identified during task safety analysis.’	Suitable
Regulatory Requirements	‘There is demolition permit, building permit for each phase of the building, occupancy permit, other permits from authorities to do certain works during construction phase.’	Suitable	Drugs and Alcohol Testing Program	‘No, it is not started.’	Suitable
Crew Composition	‘Our subcontractors have their own crews. We do management crews.’	Suitable	Health and Safety Training Programs	‘All employees should go through certificate 4 in health and safety, and first aid. Graduates and cadets should take about six months training on safety during their rotation on different sites.’	Suitable
Skills Assessment and Evaluation	‘When we are letting the job we make sure that subcontractor has competency to do specific task.’	Suitable	Toolbox Safety Meetings	‘We conduct a minimum of two weekly safety talks with our subcontractors’	Suitable

Respondent 16					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘As a lot of our products or more than half of them are imported from China / overseas, we identify critical materials and schedule their procurement early. We prepare good documentation and track what is changing during the procurement.’	Suitable	Employees Training	‘OHS and sort of training is provided for our staff / supervisors and site managers.’	Suitable
Long-Lead Materials Identification	‘Before starting the work, we start ordering long lead time by considering, manufacturing, transportation and installation times.’	Suitable	Career Development	‘It is up to the employee to perform well and get promotion. There is no formal development plan.’	Suitable
Procurement Team for Materials	‘We work with subcontractors that can procure materials.’	Not Suitable	Non-Financial Incentive Programs	‘Not really.’	Suitable
Materials Status Database	‘We quantify major items such as doors, windows and follow up; but for other items like tiles subcontractors quantify by themselves and take the risk. As it is difficult to work wastage for some trades than others.’	Suitable	Financial Incentive Programs	‘There is no bonus scheme.’	Suitable
On-Site Materials Tracking Technology	‘Our labours do only prelims such as removing rubbish. Major jobs are subcontracted.’	Not Suitable	Social Activities	‘There is Christmas party, media and catch up for dinner.’	Suitable
Materials Delivery Schedule	‘There is delivery board on site. We do not want to store materials on site.’	Suitable	Stability of Organization Structure	‘It is pretty clear. Project coordinator, junior contract administrator, coordinators, site manager. I think it is good set up to have project manager on site than offsite as the decision will be quick.’	Suitable
Material Inspection Process	‘Our suppliers ensure the quality of the materials.’	Suitable	Clear Delegation of Responsibility	‘The roles for our staff is clearly provided to them. What supervisors roles are, what site manager’s role are etc. exists.’	Suitable
Material Inspection team	‘Project coordinators and supervisors inspect materials.’	Suitable	Retention Plan for Experienced Personnel	‘There have been a lot of changes over last six months.’	Suitable
Post Receipt Preservation & Maintenance	‘No there is no storage area for materials on site, there is limited area for sub-contractors.’	Not Suitable	Integrated Schedule	‘We are adjusting our labour based on the intensity of job. I suppose there is but no formal analysis.’	Suitable
Procurement Plan for Construction equipment	‘Alimak and crane are the critical machineries for building construction.’	Suitable	Work Schedule Strategies	‘We work every Saturday, everyday to 5pm; The best way to is adjust your labour hours between Monday to Friday. Working on Sunday is expensive. If you get labour during week days, it is a bit cheaper.’	Suitable
Construction Machinery Productivity Analysis	‘We do time and motion study. How long does it take? and how many panels/windows does it take?’	Suitable	Schedule Control	‘We have contract program and target program, we adjust our target program and monitor subcontractor how much labour they have got on site and how long does it take to execute certain activity.’	Suitable

Respondent 16 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Construction Equipment Maintenance	'There is weekly services.'	Suitable	Dynamic Site Layout Plan	'It is always changing. We have set up /plan before we actually change our site layout. For example, we have moved our office twice.ch changes based on the stage of construction.'	Suitable
Site Tools Management Strategy	'There are very small tools on site. We do not have major tools.'	Not Suitable	Traffic Control Plan	'There is traffic management plan; when we transport heavy precast we have one TMP (traffic management plan) and there are 3-4 TMP's for our project.'	Suitable
On-site Tools Maintenance	'When tool is brocken we buy new ones.'	Not Suitable	Site Security Plan	'Yes, it changes with site layout plan.'	Suitable
Short Interval Planning	'We provide more simple program which is two weeks ahead for our subcontractors.'	Suitable	Machinery Positioning Strategy	'The biggest factor is the weight of precast panels. We position cranes near our loading bays. Sometimes we break precast panels to reduce cost of heavy weight lifting cranes.'	Suitable
Well- Defined Scope of Work	'We try to capture everything in the contact before awarding to the subcontractor. There are not so many variations as the contract type is design and construct.'	Suitable	Project start-up plan	'There is a check list to make sure that the given elements are in place.'	Suitable
Use of Software in	'MS project and excel is utilized.'	Suitable	Project Completion Plan	'There is also project completion plan.'	Suitable
Dedicated Planner	'No, we do not have dedicated planner. Project manager, contract administrator,	Suitable	Innovations & New Technologies	'I keep abreast with technologies like materials etc..'	Suitable
Construction Work Packages	'Structure, façade (internal and external), external works are some of our packages. Sometimes we separate concrete packages as PT but to reduce risk we provide to one contractor.'	Suitable	Housekeeping	'We work to make sure that subcontractors clean the site.'	Suitable
Buildability Review	'We do that but it is minor. We are pretty limited in what we are changing. But buildability issues are on our hand.'	Suitable	Health and Safety Policy	'There is ISO certified OH and S policy.'	Suitable
Utilities Alignment	'Underground power is the biggest thing. It actually varies from project to project.'	Suitable	Health and Safety Plan	'No matter what you do there might be accident.'	Not Suitable
Contract types	'Always lump sum is preferred'	Suitable	Safe work Method Statement	'Sub-contractor prepare SWMS and we review that)'	Suitable
Model Development	'We check for different services: mechanical, fire and electrical and see whether they work together or not.'	Suitable	Hazards Analysis	'The biggest thing is external window installation and fall protection system.'	Suitable
Regulatory Requirements	'There is noise restrictions and we comply with that.'	Suitable	Drugs and Alcohol Testing Program	'I have never heard of alcohol testing but it is up to safety representative to figure out drunken worker.'	Suitable
Crew Composition	'Our team is structured in a way that works for us. Sub-contractors do for themselves.'	Suitable	Health and Safety Training Programs	'Everyone on site should have certificate and there is pretty good procedure.'	Suitable
Skills Assessment and Evaluation	'We do not assess the subcontractors' skill.'	Suitable			

Respondent 17					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘We do not physically procure materials. We prepare brief and tender out to subcontractors. We sit down with consultant and specify the materials; sometimes we do not pay for materials until they are delivered to site. We also provide subcontractors an advance payment to facilitate the delivery of materials. The best practice in my opinion is to pay materials when it is supplied on site. Any horizontal movement of materials are the responsibility of the sub-contractor.’	Suitable	Employees Training	‘Safety training, negotiation, mental resilience training as the work is stressful.’	Suitable
Long-Lead Materials Identification	‘Providing buffer time in the schedule of these critical materials is recommended. However, long buffer time may sometimes hold the cash flow of a contractor and reasonable buffer time should be provided.’	Suitable	Career Development	‘Definitely.’	Suitable
Procurement Team for Materials	‘Cost planner do the estimate, I prepare the brief and we tender.’	Not Suitable	Non-Financial Incentive Programs	‘It is available. You can speak to PM/CM to get the incentives.’	Suitable
Materials Status Database	‘Break the installation areas into little chunks, produce shop drawings for each section, and prioritize the manufacturing of the materials accordingly.’	Suitable	Financial Incentive Programs	‘I do not think there is for this project. It does exist for other projects.’	Suitable
On-Site Materials Tracking Technology	‘We use ACONEX to track defects and report it. It shows the location of defects, who is responsible to rectify etc. Subcontractors can log in and see the details which are sent to them. They can also send RFI. However, ACONEX is not an on-site materials technology.’	Not Suitable	Social Activities	‘Company definitely encourages that.’	Suitable
Materials Delivery Schedule	‘There is delivery schedule for the supply of materials on site. There is even an hourly delivery schedule for precast panels.’	Suitable	Stability of Organization Structure	‘We have project matrix which shows the responsibility of the employees. The senior managers constantly update it. The team comprises of Forman, site engineer, senior project engineer, area manager and construction manager.’	Suitable
Material Inspection Process	‘We check reinforcement bars, ligatures and other issues before the precast concrete is poured by going to manufacturing plant.’	Suitable	Clear Delegation of Responsibility	‘Internally, within the company the work is delegated to me.’	Suitable
Material Inspection team	‘The engineer appointed for specific trade is responsible from design to installation and all other bits and pieces for that trade.’	Suitable	Retention Plan for Experienced Personnel	‘I am sure there is.’	Suitable
Post Receipt Preservation and Maintenance	‘Cost and availability of space on site determines. We follow just in time approach.’	Not Suitable	Exit interviews	‘I heard of a few people had an exit interview.’	Suitable
Procurement Plan for Construction equipment	‘We do hire cranes. We got the crane inside and remove the crane after completing installing precast panels. Depending on the lifting capacity of the crane, we hire it. We use tower crane.’	Suitable	Integrated Schedule	‘Absolutely work schedule and material delivery schedules are integrated.’	Suitable

Respondent 17 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Construction Machinery Productivity Analysis	‘It is measured as the number of lifts per hour. If there is clash in the usage of crane on site, we schedule its usage in a way that is suitable for different subcontractors.’	Suitable	Work Schedule Strategies	‘We work every Saturday and RDO's. They do trade off work life balance.’	Suitable
Construction Equipment Maintenance	‘Maintenance is done for the sake of safety. We ask the latest maintenance record and details of the product. We carry out inspection at times.’	Suitable	Schedule Control	‘Yeah definitely. I track based on the two weekly plan.’	Suitable
Site Tools Management Strategy	‘Typically, our laborers bring their own tools and we pay them.’	Not Suitable	Dynamic Site Layout Plan	‘We change several times as the team working on the site increases/changes.’	Suitable
Short Interval Planning	‘We do that. We get overall program done by senior construction manager, area managers do their plan with some buffer and site engineers do more detailed one. Forman and site engineer do the day to day planning usually in the form of two weekly plan.’	Not Suitable	Traffic Control Plan	‘We do have one.’	Suitable
Well- Defined Scope of Work	‘I produced scope of work based on the previous scopes developed for other projects.’	Not Suitable	Site Security Plan	‘We do have that too.’	Suitable
Use of Software in Planning	‘P6 is used a lot, excel spread sheet.’	Suitable	Machinery Positioning Strategy	‘We discussed above. (machinery productivity analysis)’	Suitable
Dedicated Planner	‘Depending on the scale of a project we have regional planner and project specific planner.’	Suitable	Project Completion Plan	‘It is captured in construction program as key mile stones.’	Suitable
Construction Work Packages	‘We do not want to break in to very small packages. We breakdown in a way that it worths subcontractors to tender.’	Suitable	Innovations & New Technologies	‘Generally, construction industry is naturally slow in picking up the technology. Our company give the opportunity for its employee to keep abreast with technology.’	Suitable
Buildability Review	‘Yes, we definitely do that.’	Suitable	Housekeeping	‘We have team of labourers who are responsible for housekeeping.’	Suitable
Utilities Alignment	‘It depends on the project type. Sometimes we can use existing services.’	Suitable	Health and Safety Policy	‘We call it GMR (Global Minimum Requirement). Literally it is a bible for safety. We have thinner version for each project which we give to each subcontractor.’	Suitable
Contract types	‘Always lump sum. You take risk out of you. Daily labour is very difficult to manage.’	Suitable	Health and Safety Plan	‘For example we look at detail design of precast panel cast in plate and modify/redesign it so that it is safe to work with it. ’	Suitable
Model Development	‘If the project is big, we use 3D software. For small project we do not as it is expensive.’	Suitable	Safe work Method Statement	‘We do SWMS.’	Suitable
Crew Composition	‘There are set up team (to measure distance and height) and installing team for precast panels.’	Suitable	Hazards Analysis	‘Definitely.’	Suitable
Skills Assessment and Evaluation	‘We do see the previous experience to assess the competency.’	Suitable	Drugs and Alcohol Testing Program	‘Not in the past but we are planning to start its implementation.’	Not Suitable
Health and Safety Training Programs	‘Training is usually conducted online.’	Suitable	Toolbox Safety Meetings	‘Once every week and we request our subcontractors to do every morning'	Suitable

Respondent 18					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	‘We go through at the start of all our programs and report down on package leading. Package leading is a program to suit the long lead time items. We have fair understanding of long lead items ‘	Suitable	Employees Training	‘Yes, absolutely. I have got three lead hands here at the moment; two of them have finished carpentry apprenticeship, one will finish in October.’	Suitable
Long-Lead Materials Identification	‘We identify all of the long lead time items and we set the program up to suit.’	Suitable	Career Development	‘We have performance reviews basically every six months which is a formal sit down to discuss how you are going whether you are progressing well, whether you are enjoying etc.’	Suitable
Procurement Team for Materials	‘We do not manage it but we engage people to manage it for us. We keep track of them; and we work through with them how we provide that information and how we go about doing it. And we monitor them by getting statuses of where they are up to with their works. But we do not actually do it ourselves.’	Not Suitable	Non-Financial Incentive Programs	‘Some companies do.’	Suitable
Materials Status Database	‘We get report back from the contractors on where we are. We go through and do that statusing alone which comprises of percentage complete on all of these items that gives us the date; we go through and monitor that on a regular basis; we also identify remaining durations, where we were up to (percentage complete); we also do with the procurement. If it is procurement of lift items and similar items, we will more likely set up spread sheet.’	Suitable	Financial Incentive Programs	‘Non-financial programs are probably easy ones that I can think of and financial that is minimal.’	Suitable
On-Site Materials Tracking Technology	‘We try to bring materials on site when it is needed on site. Because if you bring it on site beforehand, then you have storage issues and that become problems, and we do not want to do that.’	Not Suitable	Social Activities	‘We try to catch up together with the team every time.’	Suitable
Materials Delivery Schedule	‘We will generally use spread sheet for tracking items: whether materials are manufactured, they are on the boat and coming to Australia, they got through customs; they are on site. Then we start putting in the dates when it starts getting installed. We will be able to monitor that very thoroughly through’	Suitable	Stability of Organization Structure	‘Absolutely, that is an absolute fundamental. You do not want the people to leave the job if you want the stability going because knowledge of where the job and how the job is priced running through right to the end to what the defects that knowledge is just gold. ’	Suitable
Material Inspection Process	‘The subcontractors go through quality assurance and they will provide us the quality assurance documents for all the items that they are bringing on site; and we will go through and do quality assurance checks on them to make sure that has been according to the plan that has been put forward.’	applicable	Clear Delegation of Responsibility	‘Yeah we do. It is really hard to get clear delegation of responsibility set out in writing to cover everything there is always be gap’	Suitable

Respondent 18 Continued

Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Short Interval Planning	‘We do two weekly look a heads. Generally the site team including foremen pulled out of that information and they will have a duration for activities and works.’	Suitable	Machinery Positioning Strategy	‘We sit down, attend time and work through all of these elements; it mixes in with lot of things such as traffic control plan, what are our access points; how we are able to get materials in; how big is the foot print of the job do we need one cranes, two/three cranes, where do we put those cranes, we put them in for the maximum flexibility, we put them in to make sure we get as much coverage as you can;’	Suitable
Well- Defined Scope of Work	‘That is always the aim. It depends on how clear the job is; how good the documentation is; and how good the administrator is whether or not that is possible. I like to get a set of drawings and put a highlight around the outside of the drawings and say everything inside this study for example concrete is yours.’	Suitable	Project start-up plan	‘Project start up plan should be done during the tender phase. If you do when the job you often running, then you are ready to start straight away.’	Suitable
Use of Software in Planning	‘It certainly improves productivity for programmer. We use P6/primavera.’	Suitable	Project Completion Plan	‘Project completion plan should really start on day one. All this should go through spread sheet and listing out all of the things that need to be completed that you need to hand over for closure of the project.’	Suitable
Dedicated Planner	‘Absolutely. The more complex the job, the more time you need for your planners; the less complex the job the less time you need for your planners. It is fundamental to have good planner on job and have them from the start and have them follow through.’	Suitable	Innovations & New Technologies	‘I try to keep abreast of them but it can sometimes be awkward to find the right ones.’	Suitable
Construction Work Packages	‘We try to do that by size chunks that suits different contractors. So depending on who the contractor is and what their particular skill set is and depending on what budget constraints are that we are trying to work to, we sit down and try to shape the package to suit contractors to get best price and the best productivity.’	Suitable	Housekeeping	‘Housekeeping is big one; we try to do that with all of the subcontractors. They are responsible for keeping their areas clean and cleaning up after themselves on a daily basis.’	Suitable
Buildability Review	‘We do or we like to. A lot of our design managers are architects who understand detailing but do not necessarily understand the building. Sometimes site based people are better to fulfil that role because it is how much time is it going to take to do can be as important as the actual cost of the item itself.’	Suitable	Health and Safety Policy	‘Formal health and safety policy is very important. It is something which is managed on a daily basis.’	Suitable

Respondent 18 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusio*
Utilities Alignment	‘That is the massive issue now because of the restrictions with connecting into the old networks. Some of the old sewers lines and the storm water do not necessarily have capability for hooking up the new buildings that has been put in place. So there is a lot of works needs to go into those things to make sure that you understand early where you are; and what is the best way to go about delivering those things. That becomes an item that will sit in long lead time items.’	Suitable	Health and Safety Plan	‘We have construction safety essential in our kit for working above the line. We put engineering control rather than relying on administrative controls’	Suitable
Contract types	‘It is best to back to back with the head contract. If you have got design and contact contract I would like to put my subcontractor as design and contract. If I have got fixed lump sum head contract, I would like fixed lump sum for all of the subcontracts.’	Suitable	Safe work Method Statement	‘Absolutely we do these for everything’	Suitable
Model Development	‘It makes a massive difference if it is done correctly. I think the investment is worth by client because it takes a lot of risk out of tendering especially for service contractors in complex projects’	Suitable	Hazards Analysis	‘Absolutely we do these for everything’	Suitable
Regulatory Requirements	‘It is not too much of a problem with building permit; it can be a problem with different councils to get them to sign off your construction management plans and all of those elements.’	Suitable	Drugs and Alcohol Testing Program	‘Generally on our jobs we do not have that policy because it is outside the employment arrangement for our employees.’	Not Suitab
Crew Composition	‘Generally it comes through sub-contractor. We have crew of management staff in here’	Suitable	Health and Safety Training Programs	‘Everyone who starts with us has to go through health and safety training giving as much information as we can and guidance on how to be safe on site.’	Suitable
Skills Assessment and Evaluation	‘We go through pretty much with all of our staff. The subcontractor is responsible for training of their tradesmen.’	Suitable	Toolbox Safety Meetings	‘We do those when we do specific task that requires people come together and work on specific task'	Suitable

Respondent 19					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Procurement Plans for Materials	'- There is a practice for exploring substitute materials by subcontractor before ordering materials. The cost saving which is obtained by substitution, if accepted, will be shared among main contractor and client. - Buffer time is provided in ordering materials. - Checks and balances are in place to make sure that the material is actually made and it is on the way. There mechanisms for confirmations: from manufacturers whether the material has been made via receipt dockets; from transporters via shipping dockets and bill of loading. - Sometimes the staff of the main builder will fly over to the country where material is manufactured to verify that it is actually been made and it is in progress. - Monitoring of materials is made by splitting the procurement in to levels by their dates. - There is weekly meeting to monitor to the progress of procurement. The progress of procurement of materials is reviewed against on site productivity.'	Suitable	Employees Training	'The company provides first aid training; put the employees on courses to become better leaders, negotiators and communicators; crane and scaffolding courses. The respondent described that the industry in construction is always changing, trying to become getting better and safer etc. so people need to be taught that and it needs to be communicated within the industry. Their company is doing for the same purpose.'	Suitable
Long-Lead Materials Identification	'The project team goes through each trade and understands what is typical and got longest lead time and firm up on that trade and its procurement first.'	Suitable	Career Development	'The company will promote you to do a job. They want you to become better as opposed to go and hire someone else.'	Suitable
Procurement Team for Materials	'There is no separate procurement team. A project coordinator that is looking after the specific trade with the assistance of project manager, who makes sure that the coordinator is procuring in the right time frame and right order, is responsible for follow up of the procurement.'	Not Suitable	Non-Financial Incentive Programs	'There is recognition program in a company. Sometimes they announce at team meeting, at medium function, your names are put on the board etc.'	Suitable
Materials Status Database	'The project team use an excel spreadsheet with a series of dates and subheading such as shop drawing, in production, ready for shipping, shipped, ETA (estimated time of arrival) and arrival date.'	Suitable	Financial Incentive Programs	'There is a promotion scheme in the firm; and if you are promoted with that promotion typically comes a pay rise depending on the level of responsibility and work now you have to do.'	Suitable
On-Site Materials Tracking Technology	'-It is not like all materials come to site and it is stacked somewhere and someone is going to find it. When material is brought to site it is straight away put in a location that is very close to where it is get installed. In terms of identifying where it goes on site, some materials are labelled.'	Not Suitable	Social Activities	'To keep the team fresh and exited, the team go for bowling, dinner and others refreshments say to celebrate the completion of a building.'	Suitable

Respondent 19 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Materials Delivery Schedule	‘It is scheduled on a weekly basis and it is done with one of our supervisors on site. Delivery schedule is monitored every day and can change. Material delivery schedule is displayed on a big white board in the meeting room, and everyone can see and know when things are coming and at what time.’	Suitable	Stability of Organization Structure	‘There is one dedicated person at head office that does look at all employees within the company and what they best suited to and whether they could go for next.’	Suitable
Material Inspection Process	‘Inspection is made through fabrication; when it is overseas; when it arrived, when it comes to site, and during installation.’	Suitable	Clear Delegation of Responsibility	‘Responsibility of an employee is always made very clear at the beginning of the project. Throughout the project, as the project changes, people's role might also change and that is done through team meeting. Everyone is delegated what they meant to be doing and also minuted in an email and send to everybody so they can always refer to what each person is responsible for.’	Suitable
Material Inspection team	‘The relevant coordinator in charge of that trade will carry out inspections.’	Suitable	Retention Plan for Experienced Personnel	‘With experienced personnel when they become too old to be on site the company still	Suitable
Post Receipt Preservation & Maintenance	‘There are means for protection offsite by subcontractors. They will have an offsite storage facility in a warehouse under cover and will not bring the material until it ready for installation.’	Not Suitable	Exit interviews	‘The company is very interested in understanding: Why the employees leave? How? What can the company do to change employees mind?’	Suitable
Procurement Plan for Construction equipment	‘- Hiring (leasing) techniques is used; crane and hoist are usually the common equipment to be hired. In scheduling machinery, the project team dissect the main program and produce trade specific schedule. - Analysis such as space availability on site, the capacity of machinery is conducted before deciding (hiring) the number of machineries to be deployed on site. The machineries are identified prior to commencement of construction and included in the sub-contract agreement. - Crane is the potential equipment that has issues of availability in commercial projects. Sometimes there are too many construction projects in Melbourne and hold all cranes and there are no cranes left for a particular job. This issue is solved by contacting crane companies at the very beginning of the job to secure crane for the project.’	Suitable	Integrated Schedule	‘There are programs like, We have got plaster being delivered on this date and plaster being installed on this date. So if plaster is not delivered on this date then we cannot install it on these dates”. These are done and updated weekly. Thus, material schedule and work schedule are integrated on the project site.’	Suitable

Respondent 19 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Construction Machinery Productivity Analysis	'-With a crane it is analysed as how fast it can move in the air. Crane's output is also determined by the type of power input (electric/diesel) is analysed. Electric crane does not make noise so it allows to start early in the morning without disturbing the neighbors whereas diesel crane that has got an engine that makes noise and does not allow to start early in the morning. - The types of hoists (high vs low speed) are analysed. The slower speed cost less money but it takes longer time; a higher speed goes faster and allows the transportation of materials quicker. - The choice of hoist/Alimak is also based on the number of stories of the building. For a very high rise building, say greater than thirty stories, it is recommended to use two high speed hoists side by side.'	Suitable	Work Schedule Strategies	'There is an agreement which dictates the minimum working hours of fifty-six per week1; and beyond that the main-builder negotiates with sub-contractor on the ability to work or not on a Sunday, after hours, on a Saturday, on RDO's etc. Sometimes it has to be because of safety and other issues.'	Suitable
Construction Equipment Maintenance	'The sub-contractor from which the pieces of plant are hired will come to the site and service them. Crane, for example, is serviced once every two weeks; the hoist is once a week. The sub-contractor provides receipt to the main builder describing that it has been maintained.'	Suitable	Schedule Control	'-When work program for a particular trade is prepared, the project manager/ project team and subcontractors in charge of that task discuss and fix the program. There is involvement of the subcontractor in programming. -The agreed program is then given to supervisor on site who is in charge of that trade and he monitors it. -If the sub-contractor is not progressing as per the agreement then the project manager rings and hold a meeting; and tell the subcontractor to take corrective action. -The subcontractor agrees to work on Sunday and RDO's; to bring extra crew and get back on program.'	Suitable
Site Tools Management Strategy	'Every tool which is purchased on site is placed in a register and it is then deemed to be leaving somewhere. However, there are a few labourers about five on site and it is not big issue.'	Not Suitable	Dynamic Site Layout Plan	'-The site plan is constantly changing for the sake of productivity. The gates in and out, for instance, might be changed throughout construction period. The gates might be changed after completion of excavation, during superstructure and landscaping works. -Gates to the site should be planned to allow easy movement of tracks and workers. -The respondent recommended that it is nice to have two gates (gate in and gate out). If you have only one gate, it takes longer time for trucks.'	Suitable

Respondent 19 Continued					
Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Tools Tracking Technologies	‘A tool register is used to track tools on site. The register shows who took the tool, where it is on site and when it purchased etc. There not many tools on site as our laborers do cleaning and safety related task’	Not Suitable	Traffic Control Plan	‘Traffic control plan is done at different stages during construction. There is one done during digging/excavation, there are others when pouring concrete when we finishing the project.’	Suitable
On-site Tools Maintenance	‘The life span of the tool is monitored and thrown away if it is beyond the life span, or gathered and given to service men to rectify or recondition.’	Not Suitable	Site Security Plan	‘There is strict regime on the project site in terms of how they build their hoardings, the lights going on the hoardings, after hour security guards, cameras, and localized standard lamps.’	Suitable
Short Interval Planning	‘-The project is broken down into trades and the project teams focus on a trade which is under execution at that point in time. They re-write a program that is faster than the original program. -There is a program for the whole building and there is also a program for smaller part of the building. For instance, if the main program dictates nine days for excavation, then the specific programs might be dig for three days, compact for two days, fill for two days etc.’	Suitable	Machinery Positioning Strategy	‘The critical machine or crane’s location on site is planned by considering the weight to be loaded, the street, distance of placement and the nearby buildings. The crane needs to reach the street; it needs to reach heaviest lift; it needs to reach entire site. There might be another building which is taller than the building under construction and the crane should not hit the building. All these factors are taken into account when positioning a crane.’	Suitable
Well- Defined Scope of Work	‘No one ever gets right in defining scope of works because there are so many things which are not known in construction. It is something that is done through experience. All the things that make the contract to build specific trade is included in the scope of works. Scope of works is basically clarifying in words what that sub-contractor needs to do to deliver their part of a project.’	Suitable	Project start-up plan	‘Prior to the start of the project, the project team conduct start up meeting which basically allows them to go through the list of items that trigger our knowledge and memory and say oh yes we have done that, we have done that, we have still to do this etc.’	Suitable
Use of Software in Planning	MS project and excel are commonly used as a planning tool.	Suitable	Project Completion Plan	‘This is more or less done towards the end of the job where the project team comes up with a regime on how they are going to finish the project on time and within the budget.’	Suitable
Dedicated Planner	At head office, there is dedicated planner/programmer. The planner has the most knowledge because he has written all the programs for other projects; he knows how long it is going to take to pour 100m2 of concrete etc. based on his previous experience.	Suitable	Innovations & New Technologies	‘All supervisors at the project site have got an IPADS and they use it for communication purpose such as email, inspections etc. Since the last five years the project team reduced the use of pen and paper for most of its communications. There are also projector, white board, automatic photocopy, and Wi-Fi on site. Supervisors got Wi-Fi having good signal from site office and that eases the communication.’	Suitable
Construction Work Packages	‘The main builder packages up a portion of work with one sub-contractor to improve productivity. When the main builder awards packages to concreter, for instance, the sub-contractor does concrete; reo; formwork; pump concrete; supply concrete and provide all the machines that come with it. The respondent prefers the subcontractor to be multi-skilled.’	Suitable	Housekeeping	‘There are two dedicated workers that look after the housekeeping. They make sure that the site is clean.’	Suitable

Respondent 19 Continued

Construction Management Practices	*Summary*	*Conclusion*	*Construction Management Practices*	*Summary*	*Conclusion*
Buildability Review	‘In most circumstances the design is 80% completed prior to award of the contract and the main builder will complete the reminder of 20% of the design with the consultants/designers. They are novated to the main builder.’	Suitable	Health and Safety Policy	‘There is one main policy at head office and there is another policy which is prepared for specific project site.’	Suitable
Utilities Alignment	The builder does not create the facilities. They are on street and will be supplied them.	Suitable	Health and Safety Plan	‘The respondent believes that there is always accident on project sites. However, the level of accident varies, for example someone’s finger might be hit with hammer and other minor accidents might occur during construction process.'	Suitable
Contract types	‘Predominantly lump sum or one figure contract is used. Sometimes when the scope of work is not clearly defined, main builder employs daily laborers to execute the activity.’	Suitable	Safe work Method Statement	‘-There is a practice in preparing a safe work method statement by conducting safety analysis for a particular trade. The whole step to carry out that task is identified; a hierarchy how risk will be minimized or eliminated is prepared; responsible person is assigned; and finally monitored to make sure that it is executed. -There is safety representative at head office that is in charge of Occupational Health and Safety analysis.’	Suitable
Model Development	‘Sometimes, depending on the difficulty of what the builder is constructing, there is the usage of models. With the structural steel, for instance, a structural steel contractor will model it up to come up with shop drawings and understand how to build.’	Suitable	Hazards Analysis	‘Hazard analysis, which is a global one, is conducted to identify the potential hazards during the construction process. Moreover, safe work method statement is also conducted to identify the potential hazard for specific task.’	Suitable
Regulatory Requirements	‘There are various bits and pieces that you need to get approval for prior to building in city or elsewhere. Sometimes there are known lead times, for example, construction management plan requires from 6-12 weeks to get approved and this should be considered during planning. Working on Saturday, past hours of 5 o’clock at night need a permit. These need to be planned ahead in order to make sure that you get approval from the council.’	Suitable	Drugs and Alcohol Testing Program	‘Drug and Alcohol testing is not conducted at the construction project. But the respondent believes that it is something coming to industry. Since there is work on Saturdays, workers come to site with hangover which has an impact on productivity and safety.’	Suitable
Crew Composition	‘The main builder requires each subcontractor to have one leading Forman or one leading manager within their crews. The subcontractors are required to make sure that they have experienced labour on site to achieve the desired outcome. We do have a management crew.’	Suitable	Health and Safety Training Programs	‘To adapt to lots of changes in the construction industry, there are training programs for the staff with the latest bit of information.’	Suitable
Skills Assessment and Evaluation	‘The main builder does not analyze the skill of tradesmen, they will defect their works and inform to the manager of the subcontractor to take corrective action. The main builder is constantly pressuring the subcontractor by making strict supervision of the trades. For instance, what is this? Where is silicon? What is missing? Thus, the subcontractors identify their weaknesses and take corrective action by either providing training to their employees or taking other measures.’	Suitable	Toolbox Safety Meetings	‘The project team meets every two weeks to talk about safety, access, weather, productivity, safety and other new things.’	Suitable

APPENDIX 8: LIST OF JOURNAL ARTICLES CONTAINING THE KEYWORDS ‘PRODUCTIVITY’ AND ‘CONSTRUCTION’

1. Journal of Construction Engineering and Management (JCEM)

No.	Title	Year	Author (s)
1	A Regional and Provincial Productivity Analysis of the Chinese Construction Industry: 1995 to 2012	2016	Chancellor, Will; Lu, Wilson W S
2	Estimating Cumulative Damages due to Disruptions in Repetitive Construction	2016	Lee, Jaeseob
3	Productivity Growth in Construction	2016	Sveikauskas, Leo;Rowe, Samuel;Mildenberger, James;Price, Jennifer;Young, Arthur
4	Deconstructing the Construction Industry: A Spatiotemporal Clustering Approach to Profitability Modeling	2016	Choi, Kunhee;Lee, Hyunwoo
5	Oops Simulation: Cost-Benefits Trade-Off Analysis of Reliable Planning for Construction Activities	2016	Hajifathalian, Kiarash;Howell, Gregory A.;Wambeke, Brad W.;Hsiang, Simon ORCID;Liu, Min
6	Development and Comparative Analysis of Construction Industry Labor Productivity Metrics	2016	Vereen, Stephanie C.;Rasdorf, William J.;Hummer, Joseph E.
7	Developing and Optimizing Context-Specific Fuzzy Inference System-Based Construction Labor Productivity Models	2016	Tsehayae, Abraham Assefa;Fayek, Aminah Robinson
8	Incorporating Multiskilling and Learning in the Optimization of Crew Composition	2016	Ahmadian Fard Fini, Alireza R.;Rashidi, Taha Hossein;Akbarnezhad, Ali;Travis Waller, S.
9	Effect of buildability on labor productivity: A practical quantification approach	2016	Jarkas, Abdulaziz M.
10	Applying Artificial Neural Networks for Measuring and Predicting Construction-Labor Productivity	2015	Heravi, Gholamreza;Eslamdoost, Ehsan
11	Influence Factors of Learning-Curve Effect in High-Rise Building Constructions	2015	Lee, Bogyeong;Lee, Hyunsoo;Park, Moonseo;Kim, Hyunsoo
12	Setting baseline rates for on-site work categories in the construction industry	2015	Shahtaheri, Maryam;Nasir, Hassan;Haas, Carl T M
13	Measuring the construction industry's productivity performance: Critique of international productivity comparisons at industry level	2015	Vogl, Bernard;Abdel-Wahab, Mohamed S.
14	Quality change and implications for productivity development: Housing construction in Sweden 1990-2010	2015	Borg, Lena;Song, Hansuck
15	Productivity forecasting of newly added workers based on time-series analysis and site learning	2015	Kim, Hyunsoo,Lee;Hyunsoo,Park; Moonseo;Ahn, Changbum;Hwang, Sungjoo
16	Method to assess the level of implementation of productivity practices on industrial projects	2015	Caldas, Carlos H.;Kim, Jungyeol;Haas, Carl T M;Goodrum, Paul M.; Zhang, Di

17	Implementing lean production in copper mining development projects: Case study	2015	Castillo, G., Alarcón, L.F., González, V.A.
18	Production system classification matrix: Matching product standardization and production-system design	2015	Jonsson, Henric;Rudberg, Martin
19	Formalized approach to discretize a continuous plant in construction simulations	2014	Lau, S.-C., Lu, M., Poon, C.-S.
20	Productivity in daytime and nighttime construction of urban sewer systems	2014	Nguyen, L.D., Nguyen, T.K.N., Tran, D.Q., Villiers, C.
21	Critical success factors and enablers for optimum and maximum industrial modularization	2014	O'Connor, J.T., O'Brien, W.J., Choi, J.O.
22	Cognitive workload demands using 2D and 3D spatial engineering information formats	2014	Dadi, G.B., Goodrum, P.M., Taylor, T.R.B., Carswell, C.M.
23	Automated productivity-based schedule animation: Simulation-based approach to time-cost trade-off analysis	2014	Gelisen, G., Griffis, F.H.
24	Improved baseline method to calculate lost construction productivity	2014	Zhao, T., Dungan, J.M.
25	Analysis of disruptions caused by construction field rework on productivity in residential projects	2014	Arashpour, M., Wakefield, R., Blismas, N., Lee, E.W.M.
26	Interpersonal conflict in construction: Cost, cause, and consequence	2014	Brockman, J.L.
27	Factors affecting construction labor productivity in Kuwait	2014	Jarkas, Abdulaziz M.;Bitar, Camille G.
28	Validation methodologies and their impact in construction productivity research	2014	Liu, J., Shahi, A., Haas, C.T., Goodrum, P., Caldas, C.H.
29	Automated lifting system integrated with construction hoists for table formwork in tall buildings	2014	Kim, T., Lim, H., Cho, H., Kang, K.-I.
30	State of practice of building information modeling in the electrical construction industry	2014	Hanna, A.S., Yeutter, M., Aoun, D.G.
31	Simulation-based and statistical analysis of the learning effect in floating caisson construction operations	2014	Panas, A., Pantouvakis, J.P.
32	Tower crane cycle times: Case study of remote-control versus cab-control operation	2014	Shapira, A., Elbaz, A.
33	Trade-level productivity measurement: Critical challenges and solutions	2013	Hwang, Bongang;Soh, Chinkiat
34	Organizational barriers to productivity and innovation in large-scale, U.S.-based photovoltaic system construction projects	2013	Yuventi, J., Levitt, R., Robertson, H.
35	Using contractor bid amounts to estimate the impact of night construction on cost for transportation construction	2013	R.E., Thurn, S.B., Ellis, R.D., Lewis, D.W.
36	Algorithmic method for scraper load-time optimization	2013	Marinelli, M., Lambropoulos, S.
37	Task demands in masonry work: Sources, performance implications, and management strategies	2013	Mitropoulos, P., Memarian, B.
38	Assessment of the productivity of nighttime asphalt paving operations	2012	Mostafavi, A., Valentin, V., Abraham, D.M., Louis, J.
39	Greenhouse gas emissions from onsite equipment usage in road construction	2012	Kim, B., Lee, H., Park, H., Kim, H.

40	Buildability factors influencing concreting labor productivity	2012	Jarkas, Abdulaziz M.
41	Identification and quantification of non-value-adding effort from errors and changes in design and construction projects	2012	Han, S., Lee, S., Peña-Mora, F.
42	Ergonomic analysis and the need for its integration for planning and assessing construction tasks	2012	Inyang, N., Al-Hussein, M., El-Rich, M., Al-Jibouri, S.
43	Dynamics of working hours in construction	2012	Alvanchi, A., Lee, S., Abourizk, S.
44	Construction small-projects rework reduction for capital facilities	2012	Zhang, D., Haas, C.T., Goodrum, P.M., Caldas, C.H., Granger, R.
45	Effects of production control strategy and duration variance on productivity and work in process: Simulation-based investigation	2012	Hajifathalian, K., Wambeke, B.W., Liu, M., Hsiang, S.M.
46	Streamlining the construction productivity improvement process with the proposed role of a construction productivity improvement officer	2012	Ranasinghe, Upul,Ruwanpura, Janaka Y.;Liu, Xin
47	Construction productivity measures for innovation projects	2012	Brchner, J., Olofsson, T.
48	Effects of omitted variable bias on construction real output and its implications on productivity trends in the United States	2012	Dyer, B., Goodrum, P.M., Viele, K.
49	Using last planner and a risk assessment matrix to reduce variation in mechanical related construction tasks	2012	Wambeke, B.W., Liu, M., Hsiang, S.M.
50	Influence of buildability factors on rebar installation labor productivity of columns	2012	Jarkas, Abdulaziz M.
51	Activity analysis for direct-work rate improvement in construction	2011	Gouett, M.C., Haas, C.T., Goodrum, P.M., Caldas, C.H.
52	Model to predict the impact of a technology on construction productivity	2011	Goodrum, P.M., Haas, C.T., Caldas, C., (...), Yeiser, J., Homm, D.
53	Causes of variation in construction project task starting times and duration	2011	Wambeke, B.W., Hsiang, S.M., Liu, M
54	Differences in perspectives regarding labor productivity between spanish-and english-speaking craft workers	2011	Dai, Jiukun;Goodrum, Paul M.
55	Site management of work-in-process buffers to enhance project performance using the reliable commitment model: Case study	2011	Gonzlez, V., Alarcn, L.F., Maturana, S., Bustamante, J.A.
56	Linear scheduling model with varying production rates	2011	Duffy, G.A., Oberlender, G.D., Seok Jeong, D.H.
57	Use of safety and lean integrated kaizen to improve performance in modular homebuilding	2011	Ikuma, L.H., Nahmens, I., James, J.
58	Improving productivity on a troubled bridge project	2011	Minchin, Robert Edward;Lewis, Don W.;McLeod, Luke
59	Analysis of factors influencing productivity using craftsmen questionnaires: Case study in a Chilean construction company	2011	Rivas, Rodrigo A.;Borcherding, John D;Alarcn, Luis Fernando;Gonzlez, Vicente
60	Critical investigation into the applicability of the learning curve theory to rebar fixing labor productivity	2010	Jarkas, A.M.

61	Analysis of adverse weather for excusable delays	2010	Nguyen, L.D., Kneppers, J., García De Soto, B., Ibbs, W.
62	Sleep deprivation and its consequences in construction workers	2010	Powell, R., Copping, A.
63	Cross-validation of short-term productivity forecasting methodologies	2010	Hwang, S.
64	Contemporaneous time series and forecasting methodologies for predicting short-term productivity	2010	Hwang, S., Liu, L.Y.
65	Benefits and barriers of construction project monitoring using high-resolution automated cameras	2010	Bohn, J.S., Teizer, J.
66	Improved baseline productivity analysis technique	2010	Lin, C.-L., Huang, H.-M.
67	Probabilistic duration estimation model for high-rise structural work	2009	Lee, H.-S., Shin, J.-W., Park, M., Ryu, H.-G
68	Analysis of observed skill affinity patterns and motivation for multiskilling among craft workers in the u.s. industrial construction sector	2009	Wang, Y., Goodrum, P.M., Haas, C.T., Glover, R.W.
69	Simulating learning dynamics in project networks	2009	Taylor, J.E., Levitt, R., Villarroel, J.A.
70	Relationship between automation and integration of construction information systems and labor productivity	2009	Zhai, D., Goodrum, P.M., Haas, C.T., Caldas, C.H.
71	Using agent-based modeling to study construction labor productivity as an emergent property of individual and crew interactions	2009	Watkins, M., Mukherjee, A., Onder, N., Mattila, K.
72	Latent structures of the factors affecting construction labor productivity	2009	Dai, Jiukun;Goodrum, Paul M.;Maloney, William F. ;Srinivasan, Cidambi
73	Safety as an emergent property: Investigation into the work practices of high-reliability framing crews	2009	Mitropoulos, P., Cupido, G.
74	Labor performance analysis for microtunneling projects	2009	Hegab, M., Smith, G.R.
75	Relationship between changes in material technology and construction productivity	2009	Goodrum, Paul M.;Zhai, Dong ;Yasin, Mohammed Fadzil
76	Impact of inspected buffers on production parameters of construction processes	2009	Sawhney, A., Walsh, K.D., Bashford, H.H., Palaniappan, S.
77	Construction craft workers' perceptions of the factors affecting their productivity	2009	Dai, Jiukun;Goodrum, Paul M. ;Maloney, William F.
78	Analysis of techniques leading to radical reduction in project cycle time	2008	Hastak, M., Gokhale, S., Goyani, K., Hong, T., Safi, B.
79	Measuring and modeling labor productivity using historical data	2008	Song, L., Abourizk, S.M.
80	Relative productivity in the AEC industries in the United States for on-site and off-site activities	2008	Eastman, C.M., Sacks, R.
81	Construction process reengineering by integrating lean principles and computer simulation techniques	2008	Mao, X., Zhang, X.
82	Vision system for tower cranes	2008	Shapira, A., Rosenfeld, Y., Mizrahi, I.
83	Analysis methods in time-based claims	2008	Arditi, D., Pattanakitchamroon, T.
84	Impact of shift work on labor productivity for labor intensive contractor	2008	Hanna, Awad;Chang, Chulki;Sullivan, Kenneth Timothy;Lackney, Jeffery A.

85	Document Slip-form application to concrete structures	2008	Zayed, T., Sharifi, M.R., Baciu, S., Amer, M.
86	Measuring the productivity of the construction industry in China by using DEA-based malmquist productivity indices	2008	Xue, X., Shen, Q., Wang, Y., Lu, J.
87	Productivity aspects of urban freeway rehabilitation with accelerated construction	2007	Lee, E.-B., Lee, H., Ibbs, C.W.
88	Modeling the effect of subjective factors on productivity of trenchless technology application to buried infrastructure systems	2007	Ali, S., Zayed, T., Hegab, M.
89	Improving employees' work-life balance in the construction industry: Project alliance case study	2007	Lingard, H., Brown, K., Bradley, L., Bailey, C., Townsend, K.
90	Contractor prebid planning principles	2007	Thomas, H.R., Ellis, R.D.
91	Technology development decision economics for real-time rolling resistance monitoring of haul roads	2007	Dunston, P.S., Sinfield, J.V., Lee, T.-Y.
92	Quantifying the impact of schedule compression on labor productivity for mechanical and sheet metal contractor	2007	Chang, Chulki ;Hanna, Awad;Lackney, Jeffery A.;Sullivan, Kenneth Timothy
93	Production equations for unsteady-state construction processes	2007	Walsh, K.D., Sawhney, A., Bashford, H.H.
94	Delay time analysis in microtunneling projects	2007	Hegab, M.Y., Smith, G.R.
95	Impact of overmanning on mechanical and sheet metal labor productivity	2007	Hanna, Awad;Chang, Chulki;Lackney, Jeffery A;Sullivan, Kenneth Timothy
96	Particle swarm optimization-supported simulation for construction operations	2006	Zhang, H., Tam, C.M., Li, H., Shi, J.J.
97	Structural insulated panels: Impact on the residential construction process	2006	Mullens, M.A., Arif, M.
98	Construction delays in Hong Kong civil engineering projects	2006	Lo, T.Y., Fung, I.W.H., Tung, K.C.F
99	Soil penetration modeling in microtunneling projects	2006	Hegab, M., Smith, G.R., Salem, O.M.
100	Fast-track urban freeway rehabilitation with 55-H weekend closures: I-710 long beach case study	2006	Lee, E.-B., Lee, H., Harvey, J.T.
101	Fundamental principles of workforce management	2006	Thomas, Herve Randolph;Horman, Michael J.
102	Measuring project level productivity on transportation projects	2006	Ellis Jr., R.D., Lee, S.-H.
103	Analysis of construction worker injuries that do not result in lost time	2006	Hinze, J., Devenport, J.N., Giang, G
104	Contractor process improvement for enhancing construction productivity	2006	Cottrell, David S.
105	Effects of schedule pressure on construction performance	2006	Nepal, M.P., Park, M., Son, B.
106	Impact of change's timing on labor productivity	2005	Ibbs, W.
107	Method for calculating schedule delay considering lost productivity	2005	Lee, H.-S., Ryu, H.-G., Yu, J.-H., Kim, J.-J.
108	Factors Affecting Absenteeism in Electrical Construction	2005	Hanna, Awad;Menches, Cindy L;Sullivan, Kenneth Timothy;Sargent, Joseph R.
109	Determination of most economical scrapers fleet	2005	Eldin, N.N., Mayfield, J.
110	Effects of delivery systems on change order size and frequency in mechanical construction	2005	Riley, D.R., Diller, B.E., Kerr, D.
111	Crew production rates for contract time	2005	O'Connor, J.T., Huh, Y.

	estimation: Bent footing, column, and cap of highway bridges		
112	Predicting industrial construction labor productivity using fuzzy expert systems	2005	Fayek, Aminah Robinson;Oduba, Ayodele
113	Issues in subcontracting practice	2005	Arditi, D., Chotibhongs, R.
114	Benchmarking of Construction Productivity	2005	Park, H.-S., Thomas, S.R., Tucker, R.L
115	Productivity and cost regression models for pile construction	2005	Zayed, T.M., Halpin, D.W.
116	Role of inventory buffers in construction labor performance	2005	Horman, Michael J.;Thomas, Herve Randolph
117	Web-based benchmarking system for the construction industry	2005	Lee, S.-H., Thomas, S.R., Tucker, R.L.
118	Development model for competitive construction industry in the people's republic of China	2005	Xu, T., Tiong, R.L.K., Chew, D.A.S., Smith, N.J.
119	Fundamental principles of site material management	2005	Thomas, Herve Randolph;Riley, David R. ;Messner, John I
120	Pile construction productivity assessment	2005	Zayed, T.M., Halpin, D.W.
121	Impact of extended overtime on construction labor productivity	2005	Hanna, A.S., Taylor, C.S., Sullivan, K.T.
122	Productivity and cost assessment for continuous flight auger piles	2005	Zayed, T.M.
123	Utility-function model for engineering performance assessment	2005	Georgy, M.E., Chang, L.-M., Zhang, L.
124	Waste-based management in residential construction	2005	Zhang, J., Eastham, D.L., Bernold, L.E.
125	Change orders impact on labor productivity	2005	Moselhi, Osama El Sayed;Assem, Ihab;El-Rayes, Khaled Rayes
126	Describing a beta probability distribution function for construction simulation	2005	Schexnayder, C., Knutson, K., Fente, J.
127	Stochastic time-cost optimization model incorporating fuzzy sets theory and nonreplaceable front	2005	Zheng, D.X.M., Ng, S.T.
128	Quantifying levels of wasted time in construction with meta-analysis	2005	Horman, M.J., Kenley, R.
129	Cumulative Effect of Project Changes for Electrical and Mechanical Construction	2004	Hanna, A.S., Camlic, R., Peterson, P.A., Lee, M.-J.
130	Predicting construction company decline	2004	Koksal, A., Arditi, D.
131	Selection of concrete pump using the superiority and inferiority ranking method	2004	Tam, C.M., Tong, T.K.L., Wong, Y.W.
132	Impact of change orders on small labor-intensive projects	2004	Hanna, A.S., Gunduz, M.
133	Document Process versus data oriented techniques in pile construction productivity assessment	2004	Zayed, T.M., Halpin, D.W.
134	Implementing and applying six sigma in construction	2004	Pheng, L.S., Hui, M.S.
135	Quantitative assessment for piles productivity factors	2004	Zayed, T.M., Halpin, D.W.
136	Simulation as a tool for pile Productivity assessment	2004	Zayed, T.M., Halpin, D.W.
137	Analysis of trends in construction research: 1985-2002	2004	Abudayyeh, O., Dibert-DeYoung, A., Jaselskis, E.

138	Calculating roller requirements for chip seal projects	2004	Gransberg, D.D., Karaca, I., Senadheera, S.
139	Constructability concepts in Kuala Selangor Cable-Stayed Bridge in Malaysia	2004	Nima, M.A., Abdul-Kadir, M.R., Jaafar, M.S., Alghulami, R.G.
140	Establish concrete placing rates using quality control records from Hong Kong building construction projects	2004	Lu, M., Anson, M.
141	Long-term impact of equipment technology on labor productivity in the U.S. construction industry at the activity level	2004	Goodrum, Paul M.;Haas, Carl T M
142	Analytical model for analyzing construction claims and opportunistic bidding	2004	Ho, S.P., Liu, L.Y.
143	Integrated electronic commerce model for the construction industry	2003	Zhang, N., Tiong, R.
144	HKCONSIM: A practical simulation solution to planning concrete plant operations in Hong Kong	2003	Lu, M., Anson, M., Tang, S.L., Ying, Y.C
145	Project delivery systems and project change: Quantitative analysis	2003	Ibbs, C.W., Kwak, Y.H., Ng, T., Murat Odabasi, A.
146	Improving labor flow reliability for better productivity as lean construction principle	2003	Thomas, H.R., Horman, M.J., Minchin Jr., R.E., Chen, D.
147	Bridge falsework productivity - Measurement and influences	2003	Tischer, T.E., Kuprenas, J.A.
148	Laboratory-based productivity study on alternative masonry systems	2003	Anand, K.B., Ramamurthy, K.
149	Management's perception of key performance indicators for construction	2003	Cox, R.F., Issa, R.R.A., Ahrens, D.
150	Novel method of excavation	2003	Brown, D.C.
151	Is construction labor productivity really declining?	2003	Rojas, E.M., Aramvareekul, P.
152	Partial factor productivity and equipment technology change at activity level in U.S. construction industry	2002	Goodrum, Paul M.;Haas, Carl T M
153	Physiological demands during construction work	2002	Abdelhamid, T.S., Everett, J.G.
154	Factors in Productivity and Unit Cost for Advanced Machine Guidance	2002	Jonasson, S., Dunston, P.S., Ahmed, K., Hamilton, J.
155	Identification and resolution of work space conflicts in building construction	2002	Guo, S.-J.
156	Benchmarking productivity indicators for electrical/mechanical projects	2002	Hanna, A.S., Peterson, P., Lee, M.-J.
157	Case study of obsolescence and equipment productivity	2002	Bhurisith, I., Touran, A.
158	Multiple simulation analysis for probabilistic cost and schedule integration	2002	Isidore, L.J., Back, W.E.
159	Site layout planning using nonstructural fuzzy decision support system	2002	Tam, C.M., Tong, T.K.L., Leung, A.W.T., Chiu, G.W.C.
160	Reducing variability to improve performance as a lean construction principle	2002	Thomas, H.R., Horman, M.J., De Souza, U.E.L., Zavřski, I.
161	2000 Peurifoy lecture: Construction practices in developing countries	2002	Thomas, H.R.
162	Estimating labor production rates for industrial construction activities	2001	Abourizk, S., Knowles, P., Hermann, U.R.
163	Linear scheduling model: Float characteristics	2001	Harmelink, D.J.
164	Role of the fabricator in labor productivity	2000	Thomas, H.R., Sanvido, V.E.
165	Importance of capacity constraints to construction	2000	O'Brien, W.J., Fischer, M.A.

	cost and schedule		
166	Schedule acceleration, work flow, and labor productivity	2000	Thomas, H.R.
167	U.S. construction labor productivity trends, 1970-1998	2000	Allmon, E., Haas, C.T., Borcherding, J.D., Goodrum, P.M.
168	Adaptive control for safe and quality rebar fabrication	2000	Dunston, P.S., Bernold, L.E.
169	Loss of labor productivity due to delivery methods and weather	1999	Thomas, H.R., Riley, D.R., Sanvido, V.E.
170	Effect of truck payload weight on production	1999	Schexnayder, C., Weber, S.L., Brooks, B.T.
171	Physiological demands of concrete slab placing and finishing work	1999	Abdelhamid, T.S., Everett, J.G.
172	Construction baseline productivity: Theory and practice	1999	Thomas, H.R., Završki, I.
173	Impact of change orders on labor efficiency for mechanical construction	1999	Hanna, A.S., Russell, J.S., Gotzion, T.W., Nordheim, E.V.
174	Earthmoving productivity estimation using linear regression techniques	1999	Smith, S.D.
175	Time series analysis for construction productivity experiments	1999	Abdelhamid, T.S., Everett, J.G.
176	Construction labor productivity modeling with neural networks	1998	Sonmez, R., Rowings, J.E.
177	Multiskilled labor utilization strategies in construction	1998	Burleson, R.C., Haas, C.T., Tucker, R.L., Stanley, A.
178	Quantitative effects of construction changes on labor productivity	1995	Thomas, H.R., Napolitan, C.L
179	Action-response model and loss of productivity in construction	1994	Halligan, D.W., Demsetz, L.A., Brown, J.D., Pace, C.B.
180	Effects of design-integrated process planning on productivity in rebar placement	1994	Salim, M.D., Bernold, L.E.
181	Forecasting labor productivity using factor model	1994	Thomas, H.R., Sakarcan, A.S.
182	Automation and robotics opportunities: Construction versus manufacturing	1994	Everett, J.G., Slocum, A.H.
183	Source evaluation of solid waste in building construction	1994	Gavilan, R.M., Bernold, L.E.
184	Introducing new process technologies into construction companies	1994	Laborde, M., Sanvido, V.
185	Modified roof erection system	1994	Stevens, J.D., Murray, A.L.
186	Human factors in introducing on-site construction automation	1993	Navon, R., Kelly, P.W., Johnston, D.W.
187	Masonry productivity forecasting model	1993	Sanders, S.R., Thomas, H.R.
188	CRANIUM: Device for improving crane productivity and safety	1993	Everett, J.G., Slocum, A.H.
189	Interaction between subcycles: One key to improved methods	1993	Howell, G., Laufer, A., Ballard, G.
190	Span of control of construction foreman: Situational analysis	1991	Laufer, A., Shohet, I.M.
191	Applying computer-integrated manufacturing concepts to construction	1990	Sanvido, V.E., Medeiros, D.J.
192	Bar codes: Prescription for precision, performance, and productivity	1990	Blakey, L.H.

2. Construction Management and Economics (CME)

No.	Title	Year	Author (s)
1	Creating a baseline for labour productivity of reinforced concrete building construction in Kuwait	2015	Jarkas, A.M., Horner, R.M.W.
2	The Australian construction industry: is the shadow economy distorting productivity?	2015	Chancellor, W., Abbott, M.
3	The construction productivity debate and the measurement of service qualities	2014	Sezer, A.A., Bröchner, J.
4	An analysis of construction productivity differences between Canada and the United States	2014	Nasir, H., Ahmed, H., Haas, C., Goodrum, P.M.
5	Economic development and construction productivity in Malaysia	2014	Chia, F.C., Skitmore, M., Runeson, G., Bridge, A.
6	An exploratory study of the relationship between construction workforce physical strain and task level productivity	2014	Gatti, U.C., Migliaccio, G.C., Bogus, S.M., Schneider, S.
7	Searching for value: Construction strategy exploration and linear planning	2014	Russell, A.D., Tran, N., Staub-French, S.
8	Effects of the location-based management system on production rates and productivity	2014	Seppänen, O., Evinger, J., Mouflard, C.
9	Managing short-term efficiency and long-term development through industrialized construction	2014	Eriksson, P.E., Olander, S., Szentes, H., Widén, K.
10	Industrialized construction in the Swedish infrastructure sector: Core elements and barriers	2014	Larsson, J., Eriksson, P.E., Olofsson, T., Simonsson, P.
11	Challenges and opportunities for productivity improvement studies in linear, repetitive, and location-based scheduling	2014	Lucko, G., Alves, T.D.C.L., Angelim, V.L.
12	The role of the supply chain in the elimination and reduction of construction rework and defects: an action research approach	2014	Taggart, M., Koskela, L., Rooke, J.
13	Remuneration and absenteeism on a large construction site	2014	Kim, J., Philips, P.
14	Can project monitoring and control be fully automated?	2014	Isaac, S., Navon, R.
15	A total factor productivity measure for the construction industry and analysis of its spatial difference: A case study in China	2013	Wang, X., Chen, Y., Liu, B., Shen, Y., Sun, H.
16	Market structure of China's construction industry based on the Panzar-Rosse model	2013	Liu, B., Wang, X., Chen, Y., Shen, Y.
17	An analysis of construction productivity in Malaysia	2012	Chia, F.C., Skitmore, M., Runeson, G., Bridge, A.
18	The efficient scheduling of resources in engineering construction projects: Reflections on a case study from Iran	2012	Greenwood, D., Gledson, B.J.
19	Construction of multi-storey concrete structures in Italy: Patterns of productivity and learning curves	2012	Pellegrino, R., Costantino, N., Pietroforte, R., Sancilio, S.
20	Evaluation of trends in the UK construction industry using growth and productivity accounts	2011	Ruddock, L., Ruddock, S.
21	Effectiveness of craft time utilization in construction	2011	Gong, J., Borcherding, J.D., Caldas, C.H.
22	A value chain statistical definition of construction and the performance of the sector	2011	Squicciarini, M., Asikainen, A.-L.

23	Trends of productivity growth in the construction industry across Europe, US and Japan	2011	Abdel-Wahab, M., Vogl, B.
24	An innovative approach for generation of a time location plan in road construction projects	2011	Shah, R.K., Dawood, N.
25	Revisiting the applicability of learning curve theory to formwork labour productivity	2011	Jarkas, A., Horner, M.
26	The impact of management practices on mechanical construction productivity	2011	Shan, Yongwei ;Goodrum, Paul M. ;Zhai, Dong;Haas, Carl T M ;Caldas, Carlos H.
27	Malmquist indices of total factor productivity changes in the Australian construction industry	2010	Li, Y., Liu, C.
28	The influence of buildability factors on rebar fixing labour productivity of beams	2010	Jarkas, A.M.
29	Reassessing productivity in the construction sector to reflect hidden innovation and the knowledge economy	2009	Ruddock, L., Ruddock, S.
30	Using the IKEA model and virtual prototyping technology to improve construction process management	2008	Li, H., Guo, H., Skibniewski, M.J., Skitmore, M.
31	Application of AHP in improving construction productivity from a management perspective	2008	Doloi, H.
32	MBNQA-oriented self-assessment quality management system for contractors: Fuzzy AHP approach	2008	Lam, K.-C., Lam, M.C.-K., Wang, D
33	Analysis of craft workers' and foremen's perceptions of the factors affecting construction labour productivity	2007	Dai, Jiukun ;Goodrum, Paul M.; Maloney, William F.
34	Perspective of UK housebuilders on the use of offsite modern methods of construction	2007	Pan, W., Gibb, A.F., Dainty, A.R.J.
35	Document Process planning methodology: Dynamic short-term planning for off-site construction in Slovenia	2007	Radosavljevic, M., Horner, M.
36	Construction equipment productivity estimation using artificial neural network model	2006	Ok, S.C., Sinha, S.K.
37	Technology transfer: International collaboration in Sri Lanka	2006	Ganesan, S., Kelsey, J.
38	Growth, employment and the construction industry in Trinidad and Tobago	2006	Ramsaran, R., Hosein, R.
39	Productivity and delays assessment for concrete batch plant-truck mixer operations	2005	Zayed, T.M., Halpin, D.W., Basha, I.M
40	Benefits and disadvantages of ERP in industrialised timber frame housing in Sweden	2005	Bergström, M., Stehn, L.
41	The JIT materials management system in developing countries	2005	Polat, G., Arditi, D.
42	Deterministic models for assessing productivity and cost of bored piles	2005	Zayed, T.M., Halpin, D.W.
43	Using linear model for learning curve effect on highrise floor construction	2005	Couto, J.P., Teixeira, J.C.
44	Cost vs. production: Labour deployment and productivity in social housing construction in England, Scotland, Denmark and Germany	2004	Clarke, L., Herrmann, G.
45	The use of construction specifications in Singapore	2004	Lam, P.T.I., Kumaraswamy, M.M., Ng, S.T.
46	The impact of non- financial incentives on bricklayers' productivity in Nigeria	2004	Fagbenle, O.I., Adeyemi, A.Y., Adesanya, D.A.

47	Document A longitudinal analysis on the relationship between construction output and GDP in Hong Kong	2004	Yiu, C.Y., Lu, X.H., Leung, M.Y., Jin, W.X.
48	Total factor productivity growth accounting in the construction industry of Singapore	2003	Zhi, M., Hua, G.B., Wang, S.Q., Ofori, G.
49	The construction industry as a loosely coupled system: Implications for productivity and innovation	2002	Dubois, A., Gadde, L.-E.
50	Predicting downtime costs of tracked hydraulic excavators operating in the UK opencast mining industry	2002	Edwards, D.J., Holt, G.D., Harris, F.C.
51	The divergence in aggregate and activity estimates of US construction productivity	2002	Goodrum, P.M., Haas, C.T., Glover, R.W.
52	The evidence of complex variability in construction labour productivity	2002	Radosavljević M., Malcom W.
53	Schedule-dependent evolution of site layout planning	2001	Elbeltagi, E., Hegazy, T., Hosny, A.H., Eldosouky, A.
54	Benchmarking on-site productivity in France and the UK: A CALIBRE approach	2001	Winch, G., Carr, B.
55	Implementing a multiskilled workforce	2001	Haas, T.C., Rodriguez, A.M., Glover, R., Goodrum, P.M.
56	Design for manufacture: A strategy for successful application to buildings	2001	Fox, S., Marsh, L., Cockerham, G.
57	Productivity oriented analysis of design revisions	2001	Manavazhi, M.R., Xunshi, Z.
58	The predictive ability of Bromilow's time-cost model	2001	Ng, S.T., Mak, M.M.Y., Skitmore, R.M., Lam, K.C., Varnam, M.
59	The European construction industry and its competitiveness: A construct of the European commission	2000	Janssen, J.
60	Forecasting construction industry demand, price and productivity in Singapore: The Box-Jenkins approach	2000	Hua, G.B., Pin, T.H.O.
61	Trends in productivity improvement in the US construction industry	2000	Arditi, D., Mochtar, K.
62	The application of JIT philosophy to construction: A case study in site layout	1999	Pheng, L.S., Hui, M.S.
63	The impact of change orders on mechanical construction labour efficiency	1999	Hanna, A.S., Russell, J.S., Vandenberg, P.J.
64	Construction resource/method factors influencing productivity for high rise concrete construction	1999	Proverbs, D.G., Holt, G.D., Olomolaiye, P.O.
65	How 'just-in-time' wastages can be quantified: Case study of a private condominium project	1998	Pheng, L.S., Tan, S.K.L.
66	The growth of self-employment in British construction	1998	Winch, G.
67	Holistic enhancement of the production analysis of bituminous paving operations	1998	Gowda, R.K., Singh, A., Connolly, M
68	Contributors to construction delays	1998	Kumaraswamy, M.M., Chan, D.W.M.
69	Factors influencing construction time and cost overruns on high-rise projects in Indonesia	1997	Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Harris, F.C.
70	A survey of constraints on Iranian construction operatives' productivity	1996	Zakeri, M., Olomolaiye, P.O., Holt, G.D., Harris, F.C.

71	The elasticity of capital-labour substitution in Singapore construction	1996	Tan, W.
72	Productivity improvement in the Indonesian construction industry	1996	Arditi, D., Mochtar, K.
73	Determinants of construction duration	1995	Kumaraswamy, M.M., Chan, D.W.M.
74	An investigation into construction time performance	1995	Walker, D.H.T.
75	Estimating industry-level productivity trends in the building industry from building cost and price data	1993	Chau, K.W.
76	What does the construction foreman do?	1991	Shohet, I.M., Laufer, A.
77	Research of factors influencing construction productivity	1990	Herbsman, Z., Ellis, R.
78	An evaluation of the relationships between bricklayers' motivation and productivity	1990	Olomolaiye, P.O.
79	A system for monitoring and improving construction operative productivity in Nigeria	1989	Olomolaiye, P.O., Ogunlana, S.O.
80	Forecasting Productivity By Work Sampling	1989	Handa, V.K., Abdalla, O.
81	The measurement of productivity in the construction industry	1987	Lowe, J.G.
82	An improved systematic activity sampling technique for work study	1986	Peer, S.
83	Incentives and motivation in the construction industry: A critique	1985	Hague, D.J.
84	US productivity and fast tracking starts on the drawing board	1983	Gray, C., Flanagan, R.

3. Engineering, Construction and Architectural Management (ECAM)

No.	Title	Year	Author (s)
1	Construction labor productivity convergence: A conditional frontier approach	2016	Ma, L., Liu, C., Mills, A.
2	Trust and productivity in Australian construction projects: A subcontractor perspective	2016	Chalker, M., Loosemore, M.
3	Linking employee empowerment with productivity in off-site construction	2015	Alazzaz, F., Whyte, A.
4	Climate and construction delays: Case study in Chile	2015	Ballesteros-Pérez, P., Del Campo-Hitschfeld, M.L., González-Naranjo, M.A., González-Cruz, M.C
5	Valuing innovation in construction and infrastructure: Getting clients past a lowest price mentality	2015	Loosemore, M., Richard, J.
6	A case productivity model for automatic climbing system	2014	Zayed, T., Mohamed, E.
7	Improving construction productivity: A subcontractor's perspective	2014	Loosemore, M.
8	Relationship between building floor and construction labor productivity A case of structural work	2013	Dunlop, P., Smith, S.D.
9	Why do work sampling studies in construction? the case of plumbing work in Scandinavia	2013	Josephson, P.-E., Bjorkman, L.
10	Contractors perspective toward factors affecting labor productivity in building construction	2013	Mahamid, I.

11	Productivity losses in smoking breaks on construction sites: A case study	2012	Yung, P., Agyekum-Mensah, G.
12	Simulation modeling and sensitivity analysis of a tunneling construction project's supply chain	2011	Ebrahimy, Y., AbouRizk, S.M., Fernando, S., Mohamed, Y.
13	Comparative analysis of operational coefficients' impact on excavation operations	2010	Panas, A., Pantouvakis, J.P.
14	Trends of skills and productivity in the UK construction industry	2008	Abdel-Wahab, M.S., Dainty, A.R.J., Ison, S.G., Bowen, P., Hazlehurst, G.
15	Nonlinear optimisation and rational cash flow	2007	Beran, V., Dlask, P.
16	Worker safety issues in night-time highway construction	2005	Arditi, D., Ayrancioglu, M., Shi, J.J.
17	Downtime model development for construction equipment management	2004	Nepal, M.P., Park, M.
18	Planning, estimation and productivity in the lean concrete pour	2004	Dunlop, P., Smith, S.D.
19	Rule induction in productivity analysis: A rough set approach	2003	Attoh-Okine, N.O.
20	Assessment of risks in high rise building construction in Jakarta	2003	Santoso, D.S., Ogunlana, S.O., Minato, T.
21	Testing Herzberg's two-factor theory in the Thai construction industry	2003	Ruthankoon, R., Ogunlana, S.O.
22	An example of developing a business model for information and communication technologies (ICT) adoption on construction projects - The National Museum of Australia project	2003	Duyshart, B., Walker, D., Mohamed, S., Hampson, K.
23	Experiences with multiskilling among non-union craft workers in US industrial construction projects	2003	Carley, L.A., Haas, C.T., Borcherding, J.D., Goodrum, P.M.
24	Photo-net: An integrated system for controlling construction progress	2003	Authors of Document Abeid, J., Arditi, D.
25	Building competitive advantage: Construction education in Japan	2003	Tan, W.
26	How building design imperatives constrain construction productivity and quality	2002	Fox, S., Marsh, L., Cockerham, G.
27	ESTIVATE: A model for calculating excavator productivity and output costs	2000	Edwards, D.J., Holt, G.D.
28	Breakwater construction: An effective method for industrial waste utilization	1999	Abraham, D.M., Joanne Yeh, M.H.
29	Promoting the health of construction workers	1998	Uher, T.E., Ritchie, J.
30	Planned construction times and labour utilization — a comparison of UK and French contractors	1996	Proverbs, D.G., Olomolaiye, P.O., Harris, F.C.
31	Do site managers and the head office perceive productivity factors differently?	1996	Naoum, S., Hackman, J.

4. Journal of Management in Engineering (JME)

No.	Title	Year	Author (s)
1	Statistical Analysis of the Effectiveness of Management Programs in Improving Construction Labor Productivity on Large Industrial Projects	2016	Shan, Y., Zhai, D., Goodrum, P.M., Haas, C.T., Caldas, C.H.
2	Analysis of workflow variability and its impacts on productivity and performance in construction of multistory buildings	2015	Arashpour, M., Arashpour, M.

3	Utilization of 3D visualization of mobile crane operations for modular construction on-site assembly	2015	Han, S.H., Hasan, S., Bouferguène, A., Al-Hussein, M., Kosa, J
4	Factors influencing construction labor productivity in Egypt	2014	El-Gohary, K.M., Aziz, R.F.
5	Motivational factors impacting the productivity of construction master craftsmen in Kuwait	2013	Jarkas, A.M., Radosavljevic, M.
6	Identifying, recruiting, and retaining quality field supervisors and project managers in the electrical construction industry	2013	Rojas, E.M.
7	Lean transformation in a modular building company: A case for implementation	2013	Yu, H., Al-Hussein, M., Al-Jibouri, S., Telyas, A.
8	Work flow variation and labor productivity: Case study	2011	Liu, M., Ballard, G., Ibbs, W.
9	Factors affecting engineering productivity	2011	Liao, P.-C., O'Brien, W.J., Thomas, S.R., Dai, J., Mulva, S.P.
10	Comparative study of activity-based construction labor productivity in the united states and china	2011	Shen, Z., Jensen, W., Berryman, C., Zhu, Y.
11	Critical issues and possible solutions for motivating foreign construction workers	2008	Han, S.H., Park, S.H., Jin, E.J., Kim, H., Seong, Y.K.
12	Six sigma-based approach to improve performance in construction operations	2008	Han, S.H., Chae, M.J., Im, K.S., Ryu, H.D.
13	Case for drug testing of construction workers	2006	Minchin Jr., R.E., Glagola, C.R., Guo, K., Languell, J.L.
14	Strategic management of human resources in construction	2006	Brandenburg, S.G., Haas, C.T., Byrom, K.
15	Baseline determination in construction labor productivity-loss claims	2003	Gulezian, R., Samelian, F.
16	Benchmarking, benchaction, and benchlearning: Rework mitigation in projects	2003	Love, P.E.D., Smith, J.
17	Labor productivity drivers and opportunities in the construction industry	2003	Rojas, E.M., Aramvareekul, P.
18	Role of workforce management in bridge superstructure labor productivity	2003	Thomas, H.R., Minchin Jr., R.E., Chen, D.
19	Motivation parameters for engineering managers using Maslow's theory	1999	Shoura, M.M., Singh, A.
20	Summary of Construction Congress V	1998	Russell, Jeffrey S., Jaselskis, Edward J., Anderson, Stuart D., Hendrickson, Mark L.
21	Partnering: Agreeing to agree	1998	Slater, Thomas S.
22	Construction quality auditing	1997	Calder, Doug A.J.
23	Subcontractor partnering: I'll believe it when I see it	1997	Love, Sally
24	Regional comparison of Indonesian construction productivity	1997	Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Harris, F.C.
25	Difficulties with implementation of goal setting for construction	1994	Hadavi, A., Krizek, R.J.
26	TQM: A view from the playing field	1993	Strange, P.S., Vaughan, G.D.
27	Empowering high-performing people to promote project quality	1993	Tener, R.K.
28	Design productivity: A quality problem	1988	McGeorge, J.F.

5. International Journal of Project Management (IJPM)

No.	Title	Year	Author (s)
1	Cultural differences in motivation factors influencing the management of foreign laborers in the Korean construction industry	2015	Kim, S., Kim, J.-D., Shin, Y., Kim, G.-H.
2	Construction industry productivity and the potential for collaborative practice	2014	Fulford, R., Standing, C.
3	Dynamic modeling of labor productivity in construction projects	2013	Nasirzadeh, F., Nojedehi, P.
4	The view of freedom and standardisation among managers in Swedish construction contractor projects	2013	Polesie, P.
5	An improved methodology for selecting similar working days for measured mile analysis	2011	Ibbs, W., Liu, M.
6	Construction quality in China during transition: A review of literature and empirical examination	2010	Yung, P., Yip, B.
7	Major factors influencing productivity of water and wastewater treatment plant construction: Evidence from the deep south USA	2008	Mojahed, S., Aghazadeh, F.
8	Labor productivity: Benchmarking and variability in Egyptian projects	2007	Abdel-Razek, R.H., Abd Elshakour M, H., Abdel-Hamid, M.
9	Large construction projects in developing countries: A case study from Vietnam	2004	Long, N.D., Ogunlana, S., Quang, T., Lam, K.C.
10	Demotivating factors influencing the productivity of civil engineering projects	2004	Ng, S.T., Skitmore, R.M., Lam, K.C., Poon, A.W.C.
11	An overview into the concept of partnering	2001	Naoum, S.
12	A satisfying leadership behaviour model for design consultants	2001	Cheung, S.O., Thomas Ng, S., Lam, K.C., Yue, W.M.
13	A GA-based fuzzy optimal model for construction time-cost trade-off	2001	Leu, S.-S., Chen, A.-T., Yang, C.-H.
14	The management of labour on high rise construction projects: An international investigation	1999	Proverbs, D.G., Holt, G.D., Olomolaiye, P.O.
15	Back to the basics: Biblical wisdom for effective construction project management	1998	Low, S.P.
16	The role of system dynamics in understanding the impact of changes to key project personnel on design production within construction projects	1998	Chapman, R.J.
17	Severity diagnosis of productivity problems - A reliability analysis	1998	Kaming, P.F., Holt, G.D., Kometa, S.T., Olomolaiye, P.O.
18	Total quality management in the construction process	1997	Arditi, D., Gunaydin, H.M.
19	Site organization and supervision in housing projects in the Gaza Strip	1997	Enshassi, A.
20	Construction crew design processes	1997	Hassanein, A.A.G., Melin, J.
21	Factors influencing craftsmen's productivity in Indonesia	1997	Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Harris, F.C.
22	Issues encountered by contractors in Singapore	1995	Alum, J.
23	Conceptual phase of construction projects	1995	Abdul-Kadir, M.R., Price, A.D.F.

24	Quality circles in temporary organizations: lessons from construction projects	1991	Rosenfeld, Y., Warszawski, A., Laufer, A.

6. Automation in Construction (AIC)

No.	Title	Year	Author (s)
1	Micro-motion level simulation for efficiency analysis and duration estimation of manual operations	2016	Golabchi, A., Han, S., AbouRizk, S., Kanerva, J.
2	Linear scheduling with multiple crews based on line-of-balance and productivity scheduling method with singularity functions	2016	Su, Y., Lucko, G.
3	Systems information modeling: From file exchanges to model sharing for electrical instrumentation and control systems	2016	Love, P.E.D., Zhou, J., Matthews, J.
4	Measuring the impact of BIM on labor productivity in a small specialty contracting enterprise through action-research	2015	Poirier, E.A., Staub-French, S., Forgues, D.
5	Optimization-based excavator pose estimation using real-time location systems	2015	Vahdatikhaki, F., Hammad, A., Siddiqui, H.
6	Process reengineering and improvement for building precast production	2015	Chen, J.-H., Yang, L.-R., Tai, H.-W.
7	Simulation-based construction productivity forecast using Neural-Network-Driven Fuzzy Reasoning	2015	Mirahadi, F., Zayed, T.
8	Productivity improvement of precast shop drawings generation through BIM-based process re-engineering	2015	Nath, T., Attarzadeh, M., Tiong, R.L.K., Chidambaram, C., Yu, Z.
9	Dynamic planning of construction activities using hybrid simulation	2015	Alzraiee, H., Zayed, T., Moselhi, O.
10	Smart scanning and near real-time 3D surface modeling of dynamic construction equipment from a point cloud	2015	Wang, C., Cho, Y.K.
11	Physiological condition monitoring of construction workers	2014	Gatti, U.C., Schneider, S., Migliaccio, G.C.
12	A new approach for automation of location-based earthwork scheduling in road construction projects	2014	Shah, R.K.
13	Parallel vs. Sequential cascading MEP coordination strategies: A pharmaceutical building case study	2014	Lee, G., Kim, J.W.
14	Documentation errors in instrumentation and electrical systems: Toward productivity improvement using System Information Modeling	2013	Love, P.E.D., Zhou, J., Sing, C.-P., Kim, J.T.
15	Computer simulation and analysis framework for floating caisson construction operations	2013	Pantouvakis, J.-P., Panas, A.

16	Location tracking and data visualization technology to advance construction ironworkers' education and training in safety and productivity	2013	Teizer, J., Cheng, T., Fang, Y.
17	Lifting demand-based zoning for minimizing worker vertical transportation time in high-rise building construction	2013	Park, M., Ha, S., Lee, H.-S., (...), Kim, H., Han, S.
18	Development of optimized point cloud merging algorithms for accurate processing to create earthwork site models	2013	Kwon, S., Lee, M., Lee, M., Lee, S., Lee, J.
19	Productivity and CO2 emission analysis for tower crane utilization on high-rise building projects	2013	Hasan, S., Bouferguene, A., Al-Hussein, M., Gillis, P., Telyas, A.
20	Automated task-level activity analysis through fusion of real time location sensors and worker's thoracic posture data	2013	Cheng, T., Teizer, J., Migliaccio, G.C., Gatti, U.C.
21	Automatic spatio-temporal analysis of construction site equipment operations using GPS data	2013	Pradhananga, N., Teizer, J.
22	Supervised vs. unsupervised learning for construction crew productivity prediction	2012	Oral, M., Oral, E.L., Aydin, A.
23	Evolution of the i-Booth© onsite information management kiosk	2012	Ruwanpura, J.Y., Hewage, K.N., Silva, L.P.
24	Analysis of field applicability of the rotation-controllable tower-crane hook block	2012	Lee, C., Lee, G., Park, S., Cho, J.
25	Document An object recognition, tracking, and contextual reasoning-based video interpretation method for rapid productivity analysis of construction operations	2011	Gong, J., Caldas, C.H.
26	Evaluation of image-based modeling and laser scanning accuracy for emerging automated performance monitoring techniques	2011	Golparvar-Fard, M., Bohn, J., Teizer, J., Savarese, S., Peña-Mora, F.
27	Static and dynamic performance evaluation of a commercially-available ultra wideband tracking system	2011	Saidi, K.S., Teizer, J., Franaszek, M., Lytle, A.M.
28	Formalisms for query capture and data source identification to support data fusion for construction productivity monitoring	2011	Pradhan, A., Akinci, B., Haas, C.T.
29	Document Predicting construction crew productivity by using Self Organizing Maps	2010	Oral, E.L., Oral, M.
30	Document Estimation of earthworks execution time cost by means of artificial neural networks	2010	Authors of DocumentHola, B., Schabowicz, K.
31	Optimizing the utilization of multiple labor shifts in construction projects	2010	Jun, D.H., El-Rayes, K.
32	Assessing the impact of materials tracking technologies on construction craft productivity	2009	Grau, D., Caldas, C.H., Haas, C.T., Goodrum, P.M., Gong, J.

33	Development of automated change order impact detection and quantification system	2009	Lee, M.-J., Ryoo, B.Y., Sullivan, K.T., Hanna, A.S.
34	A performance evaluation of a Stewart platform based Hume concrete pipe manipulator	2009	Kim, Y.S., Lee, J.H., Yoo, H.S., Lee, J.B., Jung, U.S.
35	IT usage in Alberta's building construction projects: Current status and challenges	2008	Hewage, K.N., Ruwanpura, J.Y., Jergeas, G.F.
36	Integrating discrete event and lighting simulation for analyzing construction work zones lighting plans	2008	Nassar, K.
37	Automated retrieval of 3D CAD model objects in construction range images	2008	Bosche, F., Haas, C.T.
38	Simulation study on construction process of FRP bridge deck panels	2007	Hong, T., Hastak, M.
39	Cell-based representation and analysis of spatial resources in construction simulation	2007	Zhang, C., Hammad, A., Zayed, T.M., Wainer, G., Pang, H.
40	Document Synergising R&D initiatives for e-enhancing management support systems	2006	Kumaraswamy, M.M., Palaneeswaran, E., Rahman, M.M., Ugwu, O.O., Ng, S.T.
41	Modeling the ready mixed concrete delivery system with neural networks	2006	Graham, L.D., Forbes, D.R., Smith, S.D.
42	Automated project performance control of construction projects	2005	Navon, R.
43	Planning gang formwork operations for building construction using simulations	2004	Huang, R.-Y., Chen, J.-J., Sun, K.-S.
44	A fuzzy based multi-objective path planning of construction sites	2004	Soltani, A.R., Fernando, T.
45	A CAD-based model for site planning	2004	Sadeghpour, F., Moselhi, O., Alkass, S.
46	Strategic implementation of IT/IS projects in construction: A case study	2002	Stewart, R.A., Mohamed, S., Daet, R.
47	Development of virtual and real-field construction management systems in innovative, intelligent field factory	2000	Authors of DocumentMaruyama, Y., Iwase, Y., Koga, K., (...), Ito, T., Tamaki, K.
48	Document Automated construction system for high-rise reinforced concrete buildings	2000	Wakisaka, T., Furuya, N., Inoue, Y., Shiokawa, T.
49	The impact of information technology in design and construction: The owner's perspective	1998	Johnson, R.E., Clayton, M.J.
50	Automation of existing tower cranes: Economic and technological feasibility	1998	Rosenfeld, Y., Shapira, A.
51	Planning and estimating in practice and the use of integrated computer models	1997	Laptali, E., Bouchlaghem, N., Wild, S.

52	Development of automated weather-unaffected building construction system	1997	Tanijiri, Hideo, Ishiguro, Bunya, Arai, Takashi, (...), Morishima, Yasuto, Takasaki, Nobuhiro
53	What can real-time positioning do for construction?	1996	Beliveau, Y.J.
54	Conceptual design of a flooring robot: development methodology and results	1995	Navon, R.
55	Document Construction process simulation with rule-based robot path planning	1994	Stouffs, R., Krishnamurti, R., Lee, S., Oppenheim, I.J.
56	An enhanced construction specific SQL	1994	Kibert, C.J., Hollister, K.C.
57	Site layout of construction temporary facilities using an enhanced-geographic information system (GIS)	1994	Cheng, M.-Y., O'Connor, J.T.
58	Determining functional requirements for large scale manipulators	1994	Hsieh, T.-y., Haas, C.

7. Building Research and Information (BRI)

No.	Title	Year	Author (s)
1	Mapping rework causes and effects using artificial neural networks	2008	Palaneeswaran, E., Love, P.E.D., Kumaraswamy, M.M., Ng, T.S.T.
2	Competitiveness assessment system for China's construction industry	2008	Sha, K., Yang, J., Song, R.
3	Measuring productivity in the construction industry	2006	Crawford, P., Vogl, B.
4	How useful and reliable are construction statistics?	2006	Briscoe, G.
5	Good thinking and poor value: On the socialization of knowledge in construction	2006	Tombesi, P.
6	Performance-based building: Lessons from implementation in New Zealand	2005	Duncan, J.
7	Design quality in buildings	2004	Eley, J.
8	POE in England's Local Government context: A client perspective	2002	Cordy, P.
9	Walking the tightrope: The Probe team's response to BRI commentaries	2002	Bordass, B., Leaman, A., Cohen, R.
10	Predicting construction plant maintenance expenditure	2001	Edwards, D.J., Holt, G.D.
11	Reforming China's construction state-owned enterprises	2001	Sha, K., Lin, S.
12	Assessing building performance in use 5: Conclusions and implications	2001	Bordass, B., Leaman, A., Ruyssevelt, P.
13	Construction process performance variability: Focus on labour productivity	1996	Lema, N.M., Price, A.D.F.

14	Project managers' perception of production problems - An Indonesian case study:	1996	Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Kometa, S.T., Harris, F.C.
15	An expert-simulation system for construction productivity forecasting	1996	Boussabaine, A.H., Duff, A.R.
16	Factors affecting the safety of the construction industry	1996	Jannadi, M.O.

8. Building and Environment (BAE)

No.	Title	Year	Author (s)
1	The air emission assessment of a South Korean traditional building during its life cycle	2016	Sim, J., Sim, J.
2	Evaluating the impacts of high-temperature outdoor working environments on construction labor productivity in China: A case study of rebar workers	2016	Li, X., Chow, K.H., Zhu, Y., Lin, Y.
3	Optimizing work-rest schedule for construction rebar workers in hot and humid environment	2013	Yi, W., Chan, A.P.C.
4	Drivers of productivity among construction workers: A study in a developing country	2007	Kazaz, A., Ulubeyli, S.
5	Improved productivity using a modified table formwork system for high-rise building in Korea	2005	Kim, G.-H., An, S.-H., Cho, H.-H., Seo, D.-S., Kang, K.-I.
6	Document Benchmarking change order impacts on productivity for electrical and mechanical projects	2005	Gunduz, M., Hanna, A.S.
7	A quantitative approach for evaluation of negative impact of overmanning on electrical and mechanical projects	2004	Gunduz, M.
8	A different approach to construction labour in Turkey: Comparative productivity analysis	2004	Kazaz, A.Y., Ulubeyli, S.
9	JIT in developing countries-a case study of the Turkish prefabrication sector	2003	Oral, E.L., Mistikoglu, G., Erdis, E.
10	Thermal environment and construction workers' productivity: Some evidence from Thailand	2003	Srinavin, K., Mohamed, S.
11	Recourse to earth for low-cost housing in Nigeria	2002	Olotuah, A.O.
12	Integrating buildability in ISO 9000 quality management systems: Case study of a condominium project	2001	Pheng, L.S., Abeyegoonasekera, B.
13	A method for estimating labour requirements and costs for international construction projects at inception	1999	Proverbs, D.G., Holt, G.D., Olomolaiye, P.O.
14	A comparative evaluation of planning engineers' formwork productivity rates in European construction	1998	Proverbs, D.G., Holt, G.D., Olomolaiye, P.O.

9. Canadian Journal of Civil Engineering (CJCE)

No.	Title	Year	Author (s)
1	Calculating Cumulative Inefficiency using Earned Value Management in Construction Projects	2015	Lee, J.-S.
2	Identification and comparative analysis of key parameters influencing construction labour productivity in building and industrial projects	2014	Tsehayae, A.A., Fayek, A.R.
3	Framework for improving workflow stability: Deployment of optimized capacity buffers in a synchronized construction production	2014	Arashpour, M., Wakefield, R., Blismas, N., Lee, E.W.M.
4	Development and implementation of a benchmarking and metrics program for construction performance and productivity improvement	2012	Nasir, H., Haas, C.T., Rankin, J.H., (...), Forgues, D., Ruwanpura, J. Year the Document was Publish
5	Generational differences on craft workers' perceptions of the factors affecting labour productivity	2012	Dai, J., Goodrum, P.M.
6	Estimating productivity of earthmoving operations using spatial technologies	2012	Montaser, A., Bakry, I., Alshibani, A., Moselhi, O.
7	Assessing key factors impacting the performance and productivity of oil and gas projects in Alberta	2012	Chanmeka, A., Thomas, S.R., Caldas, C.H., Mulva, S.P.
8	Understanding construction workforce absenteeism in industrial construction	2011	Sichani, M.S., Lee, S., Fayek, A.R.
9	Schematic cost estimating model for super tall buildings using a high-rise premium ratio	2011	Authors of DocumentLee, J.-S., Lee, H.-S., Park, M.-S.
10	Delay analysis considering production rate	2011	Lee, J.-S., Diekmann, J.E.
11	Scheduling model for repetitive construction processes for high-rise buildings	2011	Cho, K., Hong, T., Hyun, C.
12	Buildability factors affecting formwork labour productivity of building floors	2010	Jarkas, A.M.
13	Enhancing construction project supply chains and performance evaluation methods: A case study of a bridge construction project	2010	Pan, N.-H., Lin, Y.-Y., Pan, N.-F.
14	A novel solution for construction on-site communication - The information booth	2009	Hewage, K.N., Ruwanpura, J.Y.
15	Soft computing approach to construction performance prediction and diagnosis	2008	Dissanayake, M., Fayek, A.R.

16	Production prediction of conventional and global positioning system-based earthmoving systems using simulation and multiple regression analysis	2008	Han, S., Hong, T., Lee, S.
17	Document Application of lean thinking to improve the productivity of water and sewer service installations	2007	Kung, D., Alex, D.P., Al-Hussein, M., Fernando, S.
18	Impact of occasional overtime on construction labor productivity: Quantitative analysis	2007	Sonmez, R.
19	Predicting construction productivity using situation-based simulation models	2006	Choy, E., Ruwanpura, J.Y.
20	Workforce training initiatives for megaproject success	2006	Fayek, A.R., Yorke, M., Cherlet, R.
21	Simulation analysis of productivity variation by global positioning system (GPS) implementation in earthmoving operations	2006	Han, S., Lee, S., Hong, T., Chang, H.
22	Carpentry workers issues and efficiencies related to construction productivity in commercial construction projects in Alberta	2006	Hewage, K.N., Ruwanpura, J.Y.
23	Workflow management and productivity control for asphalt pavement operations	2006	Choi, J., Minchin Jr., R.E.
24	Cost management for concrete batch plant using stochastic mathematical models	2006	Zayed, T.M., Nosair, I.A.
25	Current situation with the production and use of supplementary cementitious materials (SCMs) in concrete construction in Canada	2005	Bouzoubaâ, N., Fournier, B.
26	Quantified benefit of implementing enterprise resource planning through process simulation	2004	Lee, S., Arif, A.U., Jang, H.
27	Results of a pilot study to examine the effective integration of apprentices into the industrial construction sector	2003	Robinson Fayek, A., Shaheen, A., Oduba, A.
28	An optimal construction resource leveling scheduling simulation model	2002	Leu, S.-S., Hung, T.-H.
29	Special purpose simulation templates for tunnel construction operations	2001	Ruwanpura, J.Y., AbouRizk, S.M., Er, K.C., Fernando, S.
30	Analysis of cycle excavation and productivity of large-scale rock tunnel projects - Lesson learned in Taiwan	2001	Guo, S.-J.
31	A fuzzy expert system for design performance prediction and evaluation	2001	Fayek, A.R., Sun, Z.
32	Simulation of the construction of cable-stayed bridges	1998	Abraham, D.M., Halpin, D.W.

33	Representing a project's physical view in support of project management functions	1998	Russell, A., Chevallier, N.
34	Factors affecting construction productivity: Newfoundland versus rest of Canada	1994	Hanna, A.S., Heale, Donald G.
35	Factors influencing formwork productivity	1993	Smith, Gary R., Hanna, Awad S.
36	Document Impact of change orders on construction productivity	1991	Moselhi, Osama, Leonard, Charles, Fazio, Paul
37	Robotics in construction. Implementation and economic evaluation	1989	Moselhi, Osama, Hason, Stanley

10. Journal of Computing in Civil Engineering (JCCE)

No.	Title	Year	Author (s)
1	Framework of the virtual construction simulator 3 for construction planning and management education	2015	Lee, S., Nikolic, D., Messner, J.I.
2	Automated real-time monitoring system to measure shift production of tunnel construction projects	2013	Ranaweera, K., Ruwanpura, J., Fernando, S.
3	Automated visual recognition of dump trucks in construction videos	2012	Rezazadeh Azar, E., McCabe, B.
4	Planning-based approach for fusing data from multiple sources for construction productivity monitoring	2012	Pradhan, A., Akinci, B.
5	Near real-time motion planning and simulation of cranes in construction: Framework and system architecture	2012	Albahnassi, H., Hammad, A.
6	Reliability-based hybrid data fusion method for adaptive location estimation in construction	2012	Razavi, S.N., Haas, C.T.
7	Epistemic model to monitor the position of mobile sensing nodes on construction sites with rough location data	2012	Grau, D.
8	Integrated simulation system for construction operation and project scheduling	2010	Lee, D.-E., Yi, C.-Y., Lim, T.-K., Arditi, D.
9	Computer vision-based video interpretation model for automated productivity analysis of construction operations	2010	Gong, J., Caldas, C.H.
10	Simulation-based identification of possible locations for mobile cranes on construction sites	2008	Tantisevi, K., Akinci, B.
11	Using hue, saturation, and value color space for hydraulic excavator idle time analysis	2007	Zou, J., Kim, H.

12	Decision tree approach to classify and quantify cumulative impact of change orders on productivity	2004	Lee, M.-J., Hanna, A.S., Loh, W.-Y.
13	An ontology for relating features with activities to calculate costs	2003	Authors of DocumentStaub-French, S., Fischer, M., Kunz, J., Paulson, B.
14	Document Building project model support for automated labor monitoring	2003	Sacks, R., Navon, R., Goldschmidt, E.
15	Statistical-fuzzy approach to quantify cumulative impact of change orders	2002	Hanna, A.S., Lotfallah, W.B., Lee, M.-J.
16	Production scheduling for precast plants using a flow shop sequencing model	2002	Chan, W.T., Hu, H.
17	Estimating labor productivity using probability inference neural network	2000	Lu, M., Abourizk, S.M., Hermann, U.H.
18	Design-integrated process planner for rebar placement	1995	Salim, M., Bernold, L.E.
19	Estimating construction productivity: Neural-network-based approach	1994	Chao, L.-C., Skibniewski, M.J.
20	Speech-based data-entry systems for construction	1993	Bernold, L.E.

11. International Journal of Productivity and Performance Management

No.	Title	Year	Author (s)
1	Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey	2016	Naoum, S.G.
2	Influence of occupational heat stress on labour productivity – a case study from Chennai, India	2016	Chinnadurai, J., Venugopal, V., Kumaravel, P., Paramesh, R.
3	Converging early contractor involvement (ECI) and lean construction practices for productivity enhancement some preliminary findings from Singapore	2015	Pheng, L.S., Gao, S., Lin, J.L.
4	Labour productivity in Iranian construction projects perceptions of chief executive officers	2015	Ghoddousi, P., Poorafshar, O., Chileshe, N., Hosseini, M.R.
5	Prominent demotivational factors influencing the productivity of construction project managers in Qatar	2014	Jarkas, A.M., Radosavljevic, M., Wuyi, L.

12. Construction Innovation (CI)

No.	Title	Year	Author
1	Labour productivity model for reinforced concrete construction projects	2011	Jang, H., Kim, K., Kim, J., Kim, J.
2	Analysis of labour productivity of formwork operations in building construction	2010	Moselhi, O., Khan, Z.

3	Estimating productivity using simulation: A case study of Gaza beach embankment protection project	2007	Rustom, R.N., Yahia, A.

13. Australasian Journal of Construction Economics and Building (AJCEB) or CEB

No.	Title	Year	Author (s)
1	Drivers of productivity: A case study of the Australian construction industry	2015	Chancellor, W.
2	Factors promoting innovation and efficiency in the construction industry: A comparative study of New Zealand and Australia	2015	Chancellor, W., Abbott, M., Carson, C.
3	Document Strategies for effective management of health and safety in confined site construction	2013	Spillane, J., Oyedele, L.
4	International comparisons of cost and productivity in construction: A bad example	2012	Best, R.

14. Journal of Civil Engineering and Management (JCiEM)

No.	Title	Year	Author (s)
1	Evaluating motivation of construction workers: a comparison of fuzzy rule-based model with the traditional expectancy theory	2016	Yeheyis, M., Reza, B., Hewage, K., Ruwanpura, J.Y., Sadiq, R.
2	An it model of a knowledge map which supports management in small and medium-sized companies using selected polish construction enterprises as an example	2015	Hoła, B., Sawicki, M., Skibniewski, M.
3	Predicting productivity loss caused by change orders using the evolutionary fuzzy support vector machine inference model	2015	Cheng, M.-Y., Wibowo, D.K., Prayogo, D., Roy, A.F.V.
4	Modelling masonry crew productivity using two artificial neural network techniques	2015	Gerek, I.H., Erdis, E., Mistikoglu, G., Usmen, M.
5	Measuring information dependency for construction engineering projects	2013	Liao, P.-C., Thomas, S.R., O'brien, W.J.
6	Benchmarking project level engineering productivity	2012	Liao, P.-C., Thomas, S.R., O'Brien, W.J., (...), Mulva, S.P., Kim, I.
7	Document Technical comparisons of simulation-based productivity prediction methodologies by means of estimation tools focusing on conventional earthmovings	2011	Han, S., Hong, T., Kim, G., Lee, S.
8	The impacts of buildability factors on formwork labour Productivity of columns	2010	Jarkas, A.M.
9	Organizational effectiveness of ugandan building firms as viewed by craftsmen	2009	Alinaitwe, H., Mwakali, J.A., Hansson, B.

10	Effect of basic motivational factors on construction workforce productivity in Turkey	2008	Kazaz, A., Manisali, E., Ulubeyli, S.
11	An assessment of clients' performance in having an efficient building process in Uganda	2008	Alinaitwe, H.M.
12	Factors affecting labour productivity in building projects in the Gaza strip	2007	Enshassi, A., Mohamed, S., Mustafa, Z.A., Mayer, P.E.
13	Factors affecting the productivity of building craftsmen - Studies of Uganda	2007	Alinaitwe, H.M., Mwakali, J.A., Hansson, B.
14	Mathematical-neural model for assessing productivity of earthmoving machinery	2007	Schabowicz, K., Hola, B.
15	Assessing the degree of industrialisation in construction - A case of Uganda	2006	Alinaitwe, H.M., Mwakali, J., Hansson, B.

15. Structural Survey (SS)

No.	Title	Year	Author (s)
1	On-site construction productivity in Malaysian infrastructure projects	2016	Durdyev, S., Ismail, S.
2	Factors affecting construction labour productivity for Malaysian residential projects	2005	Abdul Kadir, M.R., Lee, W.P., Jaafar, M.S., Sapuan, S.M., Ali, A.A.A.
3	Quantifying the relationships between buildability, structural quality and productivity in construction	2001	Pheng Low, S.
4	A linear programming decision tool for selecting the optimum excavator	2001	Edwards, D.J., Malekzadeh, H., Yisa, S.B.

16. Journal of Infrastructure Systems (JIS)

No.	Title	Year	Author (s)
1	An integrated productivity-practices implementation index for planning the execution of infrastructure projects	2016	Nasir, H., Haas, C.T., Caldas, C.H., Goodrum, P.M.
2	Framework for modeling on-site productivity of preventive maintenance activities for wastewater collection systems	2015	Zaman, H., Bouferguene, A., Al-Hussein, M., Lorentz, C.
3	Productivity impact of infrastructure in Turkey, 1987-2006	2014	Fedderke, J.W., Kaya, T. E.
4	Evaluation of On-Site Fuel Use and Emissions over the Duration of a Commercial Building Project	2012	Rasdorf, W., Lewis, P., Marshall, S.K., Arocho, I., Frey, H.C.

5	Critical Assessment Indicators for Measuring Benefits of Rural Infrastructure Investment in China	2012	Shen, L., Lu, W., Peng, Y., Jiang, S.
6	Cost structure and efficiency of korea's road and rail in the manufacturing industries	2011	Min, S.
7	Dynamic life-cycle modeling of pavement overlay systems: Capturing the impacts of users, construction, and roadway deterioration	2010	Zhang, H., Lepech, M.D., Keoleian, G.A., Qian, S., Li, V.C.
8	Efficient use of regional transport infrastructure, communication networks, and human capital	2009	Schaffer, A., Siegele, J.
9	Subway station diagnosis index condition assessment model	2009	Semaan, N., Zayed, T.
10	Infrastructure management: Integrated AHP/ANN model to evaluate municipal water mains' performance	2008	Al-Barqawi, H., Zayed, T.
11	Method for comparative performance assessment and evaluation of consolidating community water systems as a regional water system	2007	Rogers, R.J., Louis, G.E.
12	Evaluation of trenchless technology methods for municipal infrastructure system	2007	Jung, Y.J., Sinha, S.K.
13	Minimizing total cost for urban freeway reconstruction with integrated construction/traffic analysis	2005	Lee, E.-B., Ibbs, C.W., Thomas, D.
14	Estimation on regional benefit and optimal level of road capital stock	2002	Kim, E., Shin, M.
15	Cost/benefits of robotics in infrastructure and environmental renewal	2000	Gregory, R.A., Kangari, R.
16	Infrastructure and economic development: Airport capacity in Chicago region, 2001-18	1997	Hewings, G.J.D., Schindler, G.R., Israilevich, P.R.
17	Vehicle size and weight regulations and highway infrastructure management	1997	Fekpe, E.S.K.
18	Infrastructure's impact on development: Lessons from WDR 1994	1995	Kessides, C., Ingram, G.K.

17. Additional Articles

No.	Title	Year	Author (s)
1	Productivity improvements: understand the workforce perceptions of productivity first	2007	Chan, P. W. & Kaka, A
2	On-site labour productivity of New Zealand construction industry: Key constraints and improvement measures.	2011	Durdyev, S. & Mbachu, J.
3	A survey of the factors affecting the productivity of construction projects in Iran	2012	Ghoddousi, P. & Hosseini, M. R.
4	A review of enabling factors in construction industry productivity in an Australian environment	2014	Hughes, R. & Thorpe, D.
5	Construction Productivity Improvement: A Study of Human, Management and External Issues	2003	Liberda, M., Ruwanpura, J. & Jergeas, G.
6	Critical factors influencing construction productivity in Thailand	2004	Makulsawatudom, A., Emsley, M. & Sinthawanarong, K.

18. Final List of Articles

Journal	No.	Title	Year	Author(s)
JCEM	1	Effect of buildability on labor productivity: A practical quantification approach	2016	Jarkas, Abdulaziz M.
	2	Applying Artificial Neural Networks for Measuring and Predicting Construction-Labor Productivity	2015	Heravi, Gholamreza;Eslamdoost, Ehsan
	3	Method to assess the level of implementation of productivity practices on industrial projects	2015	Caldas, Carlos H.;Kim, Jungyeol;Haas, Carl T M;Goodrum, Paul M.; Zhang, Di
	4	Factors affecting construction labor productivity in Kuwait	2014	Jarkas, Abdulaziz M.;Bitar, Camille G.
	5	Assessment of the productivity of night time asphalt paving operations	2012	Mostafavi, A., Valentin, V., Abraham, D.M., Louis, J.
	6	Buildability factors influencing concreting labor productivity	2012	Jarkas, Abdulaziz M.
	7	Streamlining the construction productivity improvement process with the proposed role of a construction productivity improvement officer	2012	Ranasinghe, Upul,Ruwanpura, Janaka Y.;Liu, Xin
	8	Influence of buildability factors on rebar installation labor productivity of columns	2012	Jarkas, Abdulaziz M.
	9	Differences in perspectives regarding labor productivity between spanish-and english-speaking craft workers	2011	Dai, Jiukun;Goodrum, Paul M.
	10	Improving productivity on a troubled	2011	Minchin, Robert

		bridge project		Edward;Lewis, Don W.;McLeod, Luke
	11	Analysis of factors influencing productivity using craftsmen questionnaires: Case study in a Chilean construction company	2011	Rivas, Rodrigo A.;Borcherding, John D;Alarcn, Luis Fernando;Gonzlez, Vicente
	12	Latent structures of the factors affecting construction labor productivity	2009	Dai, Jiukun;Goodrum, Paul M.;Maloney, William F. ;Srinivasan, Cidambi
	13	Relationship between changes in material technology and construction productivity	2009	Goodrum, Paul M.;Zhai, Dong ;Yasin, Mohammed Fadzil
	14	Construction craft workers' perceptions of the factors affecting their productivity	2009	Dai, Jiukun;Goodrum, Paul M. ;Maloney, William F.
	15	Impact of shift work on labor productivity for labor intensive contractor	2008	Hanna, Awad;Chang, Chulki;Sullivan, Kenneth Timothy;Lackney, Jeffery A.
	16	Quantifying the impact of schedule compression on labor productivity for mechanical and sheet metal contractor	2007	Chang, Chulki ;Hanna, Awad;Lackney, Jeffery A.;Sullivan, Kenneth Timothy
	17	Impact of overmanning on mechanical and sheet metal labor productivity	2007	Hanna, Awad;Chang, Chulki;Lackney, Jeffery A;Sullivan, Kenneth Timothy
	18	Fundamental principles of workforce management	2006	Thomas, Herve Randolph;Horman, Michael J.
	19	Contractor process improvement for enhancing construction productivity	2006	Cottrell, David S.
	20	Impact of change's timing on labor productivity	2005	Ibbs, W.
	21	Factors Affecting Absenteeism in Electrical Construction	2005	Hanna, Awad;Menches, Cindy L;Sullivan, Kenneth Timothy;Sargent, Joseph R.
	22	Fundamental principles of site material management	2005	Thomas, Herve Randolph;Riley, David R. ;Messner, John I
	23	Impact of extended overtime on construction labor productivity	2005	Hanna, A.S., Taylor, C.S., Sullivan, K.T.
	24	Change orders impact on labor productivity	2005	Moselhi, Osama El Sayed;Assem, Ihab;El-Rayes, Khaled Rayes
	25	Cumulative Effect of Project Changes for Electrical and Mechanical Construction	2004	Hanna, A.S., Camlic, R., Peterson, P.A., Lee, M.-J.
	26	Impact of change orders on small labor-intensive projects	2004	Hanna, A.S., Gunduz, M.
	27	Long-term impact of equipment technology on labor productivity in the U.S. construction industry at the activity level	2004	Goodrum, Paul M.;Haas, Carl T M
	28	Partial factor productivity and equipment technology change at activity level in U.S. construction industry	2002	Goodrum, Paul M.;Haas, Carl T M
	29	Role of the fabricator in labor productivity	2000	Thomas, H.R., Sanvido, V.E.

	30	Schedule acceleration, work flow, and labor productivity	2000	Thomas, H.R.
	31	Loss of labor productivity due to delivery methods and weather	1999	Thomas, H.R., Riley, D.R., Sanvido, V.E.
	32	Impact of change orders on labor efficiency for mechanical construction	1999	Hanna, A.S., Russell, J.S., Gotzion, T.W., Nordheim, E.V.
	33	Construction labor productivity modeling with neural networks	1998	Sonmez, R., Rowings, J.E.
	34	Quantitative effects of construction changes on labor productivity	1995	Thomas, H.R., Napolitan, C.L
	35	Action-response model and loss of productivity in construction	1994	Halligan, D.W., Demsetz, L.A., Brown, J.D., Pace, C.B.
	36	Forecasting labor productivity using factor model	1994	Thomas, H.R., Sakarcan, A.S.
CME	37	An exploratory study of the relationship between construction workforce physical strain and task level productivity	2014	Gatti, U.C., Migliaccio, G.C., Bogus, S.M., Schneider, S.
	38	The impact of management practices on mechanical construction productivity	2011	Shan, Yongwei ;Goodrum, Paul M. ;Zhai, Dong;Haas, Carl T M ;Caldas, Carlos H.
	39	The influence of buildability factors on rebar fixing labour productivity of beams	2010	Jarkas, A.M.
	40	Application of AHP in improving construction productivity from a management perspective	2008	Doloi, H.
	41	Analysis of craft workers' and foremen's perceptions of the factors affecting construction labour productivity	2007	Dai, Jiukun ;Goodrum, Paul M.; Maloney, William F.
	42	The JIT materials management system in developing countries	2005	Polat, G., Arditi, D.
	43	The impact of non- financial incentives on bricklayers' productivity in Nigeria	2004	Fagbenle, O.I., Adeyemi, A.Y., Adesanya, D.A.
	44	Implementing a multiskilled workforce	2001	Haas, T.C., Rodriguez, A.M., Glover, R., Goodrum, P.M.
	45	Trends in productivity improvement in the US construction industry	2000	Arditi, D., Mochtar, K.
	46	The impact of change orders on mechanical construction labour efficiency	1999	Hanna, A.S., Russell, J.S., Vandenberg, P.J.
	47	Construction resource/method factors influencing productivity for high rise concrete construction	1999	Proverbs, D.G., Holt, G.D., Olomolaiye, P.O.
	48	A survey of constraints on Iranian construction operatives' productivity	1996	Zakeri, M., Olomolaiye, P.O., Holt, G.D., Harris, F.C.
	49	Productivity improvement in the Indonesian construction industry	1996	Arditi, D., Mochtar, K.
	50	Research of factors influencing construction productivity	1990	Herbsman, Z., Ellis, R.
	51	An evaluation of the relationships between bricklayers’ motivation and productivity	1990	Olomolaiye, P.O.
	52	A system for monitoring and improving construction operative productivity in Nigeria	1989	Olomolaiye, P.O., Ogunlana, S.O.

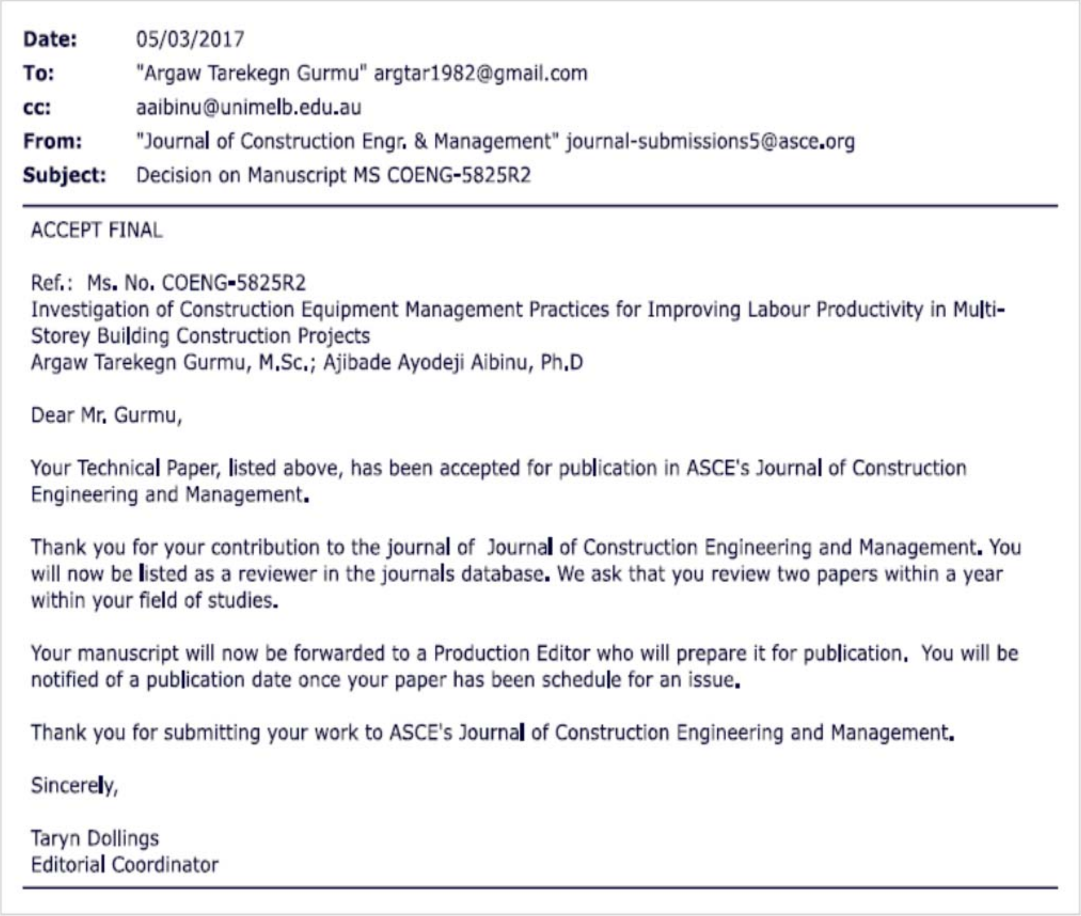
ECAM	53	Trust and productivity in Australian construction projects: A subcontractor perspective	2016	Chalker, M., Loosemore, M.
	54	Improving construction productivity: A subcontractor's perspective	2014	Loosemore, M.
	55	Contractors perspective toward factors affecting labor productivity in building construction	2013	Mahamid, I.
	56	Do site managers and the head office perceive productivity factors differently?	1996	Naoum, S., Hackman, J.
JME	57	Statistical Analysis of the Effectiveness of Management Programs in Improving Construction Labor Productivity on Large Industrial Projects	2016	Shan, Y., Zhai, D., Goodrum, P.M., Haas, C.T., Caldas, C.H.
	58	Factors influencing construction labor productivity in Egypt	2014	El-Gohary, K.M., Aziz, R.F.
	59	Motivational factors impacting the productivity of construction master craftsmen in Kuwait	2013	Jarkas, A.M., Radosavljevic, M.
	60	Labor productivity drivers and opportunities in the construction industry	2003	Rojas, E.M., Aramvareekul, P.
IJPM	61	Construction industry productivity and the potential for collaborative practice	2014	Fulford, R., Standing, C.
	62	Dynamic modeling of labor productivity in construction projects	2013	Nasirzadeh, F., Nojedehi, P.
	63	Major factors influencing productivity of water and wastewater treatment plant construction: Evidence from the deep south USA	2008	Mojahed, S., Aghazadeh, F.
	64	Demotivating factors influencing the productivity of civil engineering projects	2004	Ng, S.T., Skitmore, R.M., Lam, K.C., Poon, A.W.C.
	65	Severity diagnosis of productivity problems - A reliability analysis	1998	Kaming, P.F., Holt, G.D., Kometa, S.T., Olomolaiye, P.O.
	66	Factors influencing craftsmen's productivity in Indonesia	1997	Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Harris, F.C.
	67	Issues encountered by contractors in Singapore	1995	Alum, J.
AIC	68	Measuring the impact of BIM on labor productivity in a small specialty contracting enterprise through action-research	2015	Poirier, E.A., Staub-French, S., Forgues, D.
	69	Assessing the impact of materials tracking technologies on construction craft productivity	2009	Grau, D., Caldas, C.H., Haas, C.T., Goodrum, P.M., Gong, J.
BRI	70	Project managers' perception of production problems - An Indonesian case study:	1996	Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Kometa, S.T., Harris, F.C.
BAE	71	Evaluating the impacts of high-temperature outdoor working environments on construction labor productivity in China: A case study of rebar workers	2016	Li, X., Chow, K.H., Zhu, Y., Lin, Y.
	72	Drivers of productivity among construction workers: A study in a developing country	2007	Kazaz, A., Ulubeyli, S.
	73	A quantitative approach for evaluation of negative impact of overmanning on electrical and mechanical projects	2004	Gunduz, M.

	74	JIT in developing countries-a case study of the Turkish prefabrication sector	2003	Oral, E.L., Mistikoglu, G., Erdis, E.
	75	Thermal environment and construction workers' productivity: Some evidence from Thailand	2003	Srinavin, K., Mohamed, S.
CJCE	76	Identification and comparative analysis of key parameters influencing construction labour productivity in building and industrial projects	2014	Tsehayae, A.A., Fayek, A.R.
	77	Generational differences on craft workers' perceptions of the factors affecting labour productivity	2012	Dai, J., Goodrum, P.M.
	78	Buildability factors affecting formwork labour productivity of building floors	2010	Jarkas, A.M.
	79	Impact of occasional overtime on construction labor productivity: Quantitative analysis	2007	Sonmez, R.
	80	Carpentry workers issues and efficiencies related to construction productivity in commercial construction projects in Alberta	2006	Hewage, K.N., Ruwanpura, J.Y.
	81	Factors affecting construction productivity: Newfoundland versus rest of Canada	1994	Hanna, A.S., Heale, Donald G.
	82	Document Impact of change orders on construction productivity	1991	Moselhi, Osama; Leonard, Charles; Fazio, Paul
JCCE	83	Decision tree approach to classify and quantify cumulative impact of change orders on productivity	2004	Lee, M.-J., Hanna, A.S., Loh, W.-Y.
	84	Statistical-fuzzy approach to quantify cumulative impact of change orders	2002	Hanna, A.S., Lotfallah, W.B., Lee, M.-J.
IJPPM	85	Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey	2016	Naoum, S.G.
	86	Influence of occupational heat stress on labour productivity – a case study from Chennai, India	2016	Chinnadurai, J., Venugopal, V., Kumaravel, P., Paramesh, R.
	87	Labour productivity in Iranian construction projects perceptions of chief executive officers	2015	Ghoddousi, P., Poorafshar, O., Chileshe, N., Hosseini, M.R.
	88	Prominent demotivational factors influencing the productivity of construction project managers in Qatar	2014	Jarkas, A.M., Radosavljevic, M., Wuyi, L.
JCiEM	89	Predicting productivity loss caused by change orders using the evolutionary fuzzy support vector machine inference model	2015	Cheng, M.-Y., Wibowo, D.K., Prayogo, D., Roy, A.F.V.
	90	The impacts of buildability factors on formwork labour Productivity of columns	2010	Jarkas, A.M.
	91	Effect of basic motivational factors on construction workforce productivity in Turkey	2008	Kazaz, A., Manisali, E., Ulubeyli, S.
	92	Factors affecting labour productivity in building projects in the Gaza strip	2007	Enshassi, A., Mohamed, S., Mustafa, Z.A., Mayer, P.E.
	93	Factors affecting the productivity of building craftsmen - Studies of Uganda	2007	Alinaitwe, H.M., Mwakali, J.A., Hansson, B.
SS	94	On-site construction productivity in Malaysian infrastructure projects	2016	Durdyev, S., Ismail, S.

	95	Factors affecting construction labour productivity for Malaysian residential projects	2005	Abdul Kadir, M.R., Lee, W.P., Jaafar, M.S., Sapuan, S.M., Ali, A.A.A.
JiS	96	An integrated productivity-practices implementation index for planning the execution of infrastructure projects	2016	Nasir, H., Haas, C.T., Caldas, C.H., Goodrum, P.M.
Additional papers	97	Productivity improvements: understand the workforce perceptions of productivity first	2007	Chan, P. W. & Kaka, A
	98	On-site labour productivity of New Zealand construction industry: Key constraints and improvement measures.	2011	Durdyev, S. & Mbachu, J.
	99	A survey of the factors affecting the productivity of construction projects in Iran	2012	Ghoddousi, P. & Hosseini, M. R.
	100	A review of enabling factors in construction industry productivity in an Australian environment	2014	Hughes, R. & Thorpe, D.
	101	Construction Productivity Improvement: A Study of Human, Management and External Issues	2003	Liberda, M., Ruwanpura, J. & Jergeas, G.
	102	Critical factors influencing construction productivity in Thailand	2004	Makulsawatudom, A., Emsley, M. & Sinthawanarong, K.

APPENDIX 9: ACCEPTANCE LETTERS AND PUBLISHED PAPER

A. Journal of Construction Engineering and Management



Date: 05/03/2017
To: "Argaw Tarekegn Gurmu" argtar1982@gmail.com
cc: aaibinu@unimelb.edu.au
From: "Journal of Construction Engr. & Management" journal-submissions5@asce.org
Subject: Decision on Manuscript MS COENG-5825R2

ACCEPT FINAL

Ref.: Ms. No. COENG-5825R2
Investigation of Construction Equipment Management Practices for Improving Labour Productivity in Multi-Storey Building Construction Projects
Argaw Tarekegn Gurmu, M.Sc.; Ajibade Ayodeji Aibinu, Ph.D

Dear Mr. Gurmu,

Your Technical Paper, listed above, has been accepted for publication in ASCE's Journal of Construction Engineering and Management.

Thank you for your contribution to the journal of Journal of Construction Engineering and Management. You will now be listed as a reviewer in the journals database. We ask that you review two papers within a year within your field of studies.

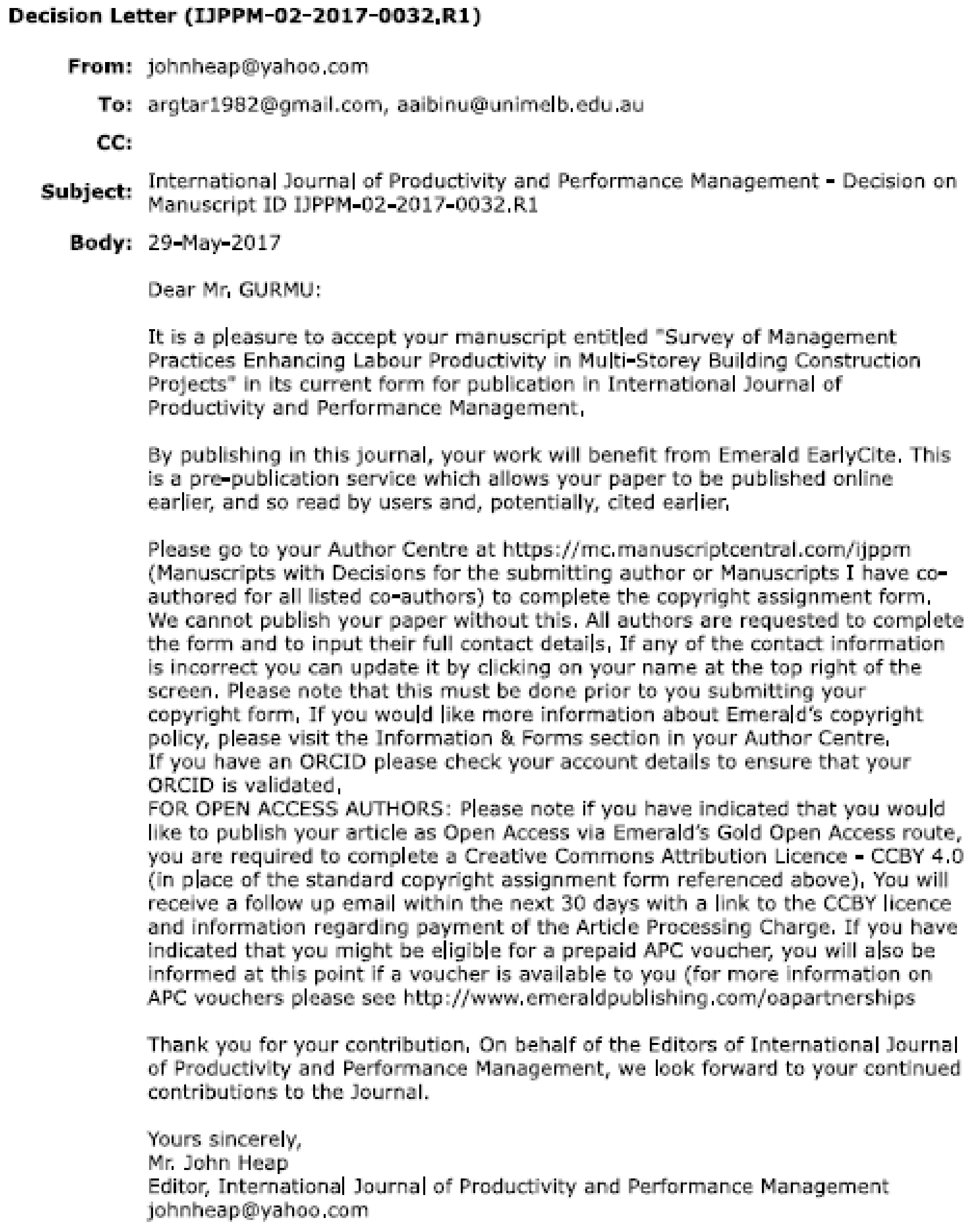
Your manuscript will now be forwarded to a Production Editor who will prepare it for publication. You will be notified of a publication date once your paper has been schedule for an issue.

Thank you for submitting your work to ASCE's Journal of Construction Engineering and Management.

Sincerely,

Taryn Dollings
Editorial Coordinator

B. International Journal of Productivity and Performance Management



Decision Letter (IJPPM-02-2017-0032.R1)

From: johnheap@yahoo.com
To: argtar1982@gmail.com, aaibinu@unimelb.edu.au
CC:
Subject: International Journal of Productivity and Performance Management - Decision on Manuscript ID IJPPM-02-2017-0032.R1
Body: 29-May-2017

Dear Mr. GURMU:

It is a pleasure to accept your manuscript entitled "Survey of Management Practices Enhancing Labour Productivity in Multi-Storey Building Construction Projects" in its current form for publication in International Journal of Productivity and Performance Management.

By publishing in this journal, your work will benefit from Emerald EarlyCite. This is a pre-publication service which allows your paper to be published online earlier, and so read by users and, potentially, cited earlier.

Please go to your Author Centre at https://mc.manuscriptcentral.com/ijppm (Manuscripts with Decisions for the submitting author or Manuscripts I have co-authored for all listed co-authors) to complete the copyright assignment form. We cannot publish your paper without this. All authors are requested to complete the form and to input their full contact details. If any of the contact information is incorrect you can update it by clicking on your name at the top right of the screen. Please note that this must be done prior to you submitting your copyright form. If you would like more information about Emerald's copyright policy, please visit the Information & Forms section in your Author Centre.
If you have an ORCID please check your account details to ensure that your ORCID is validated.
FOR OPEN ACCESS AUTHORS: Please note if you have indicated that you would like to publish your article as Open Access via Emerald's Gold Open Access route, you are required to complete a Creative Commons Attribution Licence - CCBY 4.0 (in place of the standard copyright assignment form referenced above). You will receive a follow up email within the next 30 days with a link to the CCBY licence and information regarding payment of the Article Processing Charge. If you have indicated that you might be eligible for a prepaid APC voucher, you will also be informed at this point if a voucher is available to you (for more information on APC vouchers please see http://www.emeraldpublishing.com/oapartnerships

Thank you for your contribution. On behalf of the Editors of International Journal of Productivity and Performance Management, we look forward to your continued contributions to the Journal.

Yours sincerely,
Mr. John Heap
Editor, International Journal of Productivity and Performance Management
johnheap@yahoo.com

C. Construction Economics and Building (Next Page)

Construction Economics and Building, 16(3), 1-19

A study of best management practices for enhancing productivity in building projects: construction methods perspectives

Argaw Tarekegn Gurmu[1], Ajibade Ayodeji Aibinu and Toong Khuan Chan

Melbourne School of Design, The University of Melbourne, Australia

Abstract

This research investigates management practices that have the potential to enhance productivity in building projects by focusing on construction methods. In phase 1 of the study, face-to-face interviews with nineteen experts were conducted to identify the best management practices for construction methods. The qualitative data analysis reached saturation and resulted in a list of best practices for construction methods that are relevant to the local industry. The second phase used an industry-wide survey to prioritize the best practices. Accordingly, project start-up plan, traffic control plan, machinery positioning strategy, project completion plan, and dynamic site layout plan were shown to be the top five best practices for construction methods. The study also revealed that high levels of implementation of best practices are associated with low levels of project delays. The use of best practices also varied according to the project costs. There were no discernible differences between the top five best practices. The authors suggest that they should be implemented jointly to improve productivity in building projects. Contractors could use the logistic regression model developed, to predict the probability of exceeding a baseline productivity factor and, on that basis, implement corrective actions to achieve the desired level of productivity.

Keywords: Best management practices, construction methods, construction productivity, Australia.

Paper type: Research article

Introduction

Productivity improvement in the construction industry is important for the growth of a country's economy at large and profitability of contractors in particular. Productivity is described as the ratio of output to input (Jarkas and Bitar, 2011). In this study, output represents the value of a completed building project in dollars and input refers to project

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duration in days. Previous studies indicate that management related problems such as lack of integration of works of sub-contractors, out of sequence work assignments, work overload, and poor site layouts are among the major factors impacting project productivity (Dai et al., 2009). However, these problems can be reduced by adopting best management practices that are suitable for particular project types such as building, infrastructure, and industrial. Best management practices are processes that, when executed effectively, lead to enhanced project performance (CII, 2016). Construction management practices that have the potential to improve productivity could be categorized into: construction methods (Caldas et al., 2014); construction materials management (long lead materials identification, materials procurement and delivery plans, and inspection and test plans) (Bell and Stukhart, 1987); construction equipment and tools management (procurement plans for machinery, maintenance of equipment and tools and productivity analysis of construction equipment) (Stewart, 2002); execution approaches (buildability review, short interval plans, work package, and the scope of works) (Lam, Wong and Chan, 2006); human resource management (crew composition, skill assessment, training and career development plans) (Hewage, Gannoruwa and Ruwanpura, 2011); health and safety practices (housekeeping, task safety analysis, tool box meetings, and safety training) (Hinze and Wilson, 2000). In this research, construction methods best practices were investigated while pre-construction activities such as buildability reviews were not considered. Although previous studies identified best practices for infrastructure and industrial projects, they cannot be directly adopted for building projects. For instance, while traffic control plan, project completion plan, communications, coordination, and agreements are identified as best practice for infrastructure projects, they are not included in the list of best practices for industrial projects (Nasir, 2013). Moreover, the priority given to some of the common elements of both project types are different. Thus, building projects could have different best practices. However, a little research has been done on what these best practices might be and which of them should be given priority in the context of Victoria, Australia. The objectives of this study are:

- To identify best practices for construction methods which have the potential to improve productivity in building projects
- To prioritize the best practices for construction methods and develop a tool to measure them
- To develop a logistic regression model that predicts the probability of exceeding a specific productivity value based on a score of the best practices for construction methods

Literature review

Construction methods influencing productivity in construction projects

Project management methods are defined as a system of practices, techniques, procedures, and rules used by those who work in the discipline (PMI, 2013). In construction projects, the techniques of integration of different schedules; schedule controlling methods; mechanisms used in the preparation of site layout, project start-up and completion procedures; and investigation of suitable technologies are some of the methods considered as best practices.

Arditi and Mochtar (1996) suggested integration of management functions is one of the areas where productivity gain could be obtained. Caldas et al. (2014) confirmed that integrated schedule is one of the best practices for improving productivity in industrial projects. In the context of the Victorian construction industry, since many sub-contractors are involved in the construction of a particular building project, principal contractors might require techniques for integrating the schedules of these sub-contractors. According to ABS, 78% of building construction works are executed by small and medium firms (Australian Bureau of Statistics, 2013).

Scheduled overtime has a positive impact on productivity, as it builds the morale of employees (CII, 2013a). Hanna et al. (2008) found that shift schedule is effective as compared to overtime and overmanning in reducing the project duration. The authors opined that the use of shift schedule reduces physical fatigue and site congestion that could occur if overtime and overmanning practices are implemented. Given the working hours restrictions set by various authorities in Victoria, such as Environmental Protection Authority, adopting different working hours strategies such as scheduled overtime could be important practices for delivery of building projects within the contract time.

Schedule execution and management refers to schedule controlling techniques such as methods for measuring work progress, analysing data, reporting results and taking corrective actions. Some of the techniques include units completed, incremental milestone, start/finish, supervisor judgment, S-Curve, time variance and forecast, analysis tree, percent complete report, activity crashing and activity overlapping (Attalla, 1997). Delay in the progress of a particular sub-contractor could affect the progress of others and lead to overall project delay. Thus, implementation of the schedule controlling techniques might be an important practice for principal contractors that manage numerous sub-contractors in the context of Victoria.

Dynamic site layout refers to a sequence of layouts each of which is used for a discrete time interval or for a certain project phase, and together covering the entire duration of a construction project (Tommelein and Zouein, 1993). As most building projects in the central business district of Melbourne, Australia, have restricted working spaces, dynamic site layout plans could help principal contractors in reducing congestion on sites. By using dynamic layout plan, some parts of a building under construction can be used as store, office and other temporary facility allowing early start of the external works.

Choi and Harris (1992) proposed a mathematical model for determining the most suitable tower crane location for building projects. Safe Work Australia implemented a code of practice to assist contractors in preparing good traffic management plans by providing information about traffic signs, distance between pedestrians and vehicles, and vehicles movement (Safe Work Australia, 2014). In Victoria, as most construction materials are imported from overseas, any loss or damage to them could incur loss of productivity due to unavailability of the materials locally. Thus, site security plans might be an important practice to reduce theft and loss of materials. Investigation of the most appropriate location for a crane could also be a significant practice in Victoria. If a crane is positioned wrongly, its relocation cost could be high. Thus, developing a strategy to position the crane using different models might be important for principal contractors in Victoria, to reduce cost and increase productivity. Traffic control plans could also be a significant practice as there are various local regulations about traffic such as Road Safety (Traffic Management) Regulations 2009 that could influence building projects' performance.

Fangel (1984) recommended preparation of a project management manual that contains project start-up details. The author also suggested project start-up meetings prior to commencing a construction project. Kerzner (2010) proposed project kick-off meetings as one of the best practices that should be included in the project start-up process. Nasir (2013) confirmed that project start-up and completion plans, and new technologies are the best practices to enhance productivity in infrastructure projects. In the context of building projects in Victoria, various sub-contractors finish their works at different times and a principal contractor should plan when to receive certificates of the completed works by each sub-contractor. Thus, completion plans could be a significant practice during handover of a building project to the client. New technologies might also be important. For instance, to detect clashes between different services in a building, different software could be used.

Research methodology

The research context

The construction sector in Victoria, Australia is dominated by a few large contractors that engage numerous small companies. In 2015, the proportion of companies involved in building construction were 0.06%,0.78% and 99.15% for firms employing over 200 workers, 20-199 workers, and 0-19 workers respectively (Australian Bureau of Statistics, 2016). The local construction industry is characterized by the presence of a strong Construction, Forestry, Mining and Energy Union that prepares a calendar for construction sites (CFMEU, 2016). The Union signs an enterprise bargaining agreement in which minimum payments and other working conditions are agreed between contractor and Union. Regulatory bodies such as the Fair Work Commission stipulate minimum wages, working hours, overtime payments, penalty rates and other employment conditions in building construction projects. Accordingly, the ordinary number of working hours is 38 per week between 7:00am and 6:00pm (Fair Work Commission, 2016). In addition, Environment Protection Authority Victoria (EPA) has a guideline to control noise from building projects. Accordingly, normal working hours are restricted to 7:00 am to 6:00 pm during weekdays and 7:00 am to 1:00 pm on Saturdays (EPA, 2016). Most construction materials are imported from overseas due to increasing investment costs in the manufacturing sector (Wheeldon, 2012). Prefabricated construction systems are increasing at about 5% per year (PrefabAUS, 2014).

Measurement of management practices for construction methods and construction projects' productivity

Management practices are measured by using validated standard questionnaires. Bloom and Van Reenen (2007) developed a technique to measure management practices in the manufacturing, education, and health sectors. The authors validated their survey tool by collecting data from 732 firms operating in Germany, France, UK and US. In the construction industry, management practices questionnaires have been developed by the Construction Industry Institute (CII) through the collaboration of researchers and industry practitioners. The tool has been validated by collecting data from various projects in North America. This research uses CII Survey Tool (Appendix- 1B2) after conducting validation by discussing with local experts, and collecting productivity data from various building projects.

Construction projects' productivity can be expressed in either absolute or relative terms. In absolute term, the units of measure of both output and input are shown in the productivity value. The relative measure or Productivity Factor (PF) refers to the ratio of actual to planned productivity. Actual productivity is computed using project value as output and actual completion time as input. Planned productivity is calculated using project value as output and planned time as input. Productivity factor (PF) is a more useful measure to compare the productivity of different construction projects than the absolute measure (Nasir, 2013).Thus; PF is used in this research.

Data collection

This study was conducted in two phases. In phase 1, qualitative data was collected using in-depth interviews that took an average of one and half hours. The objective of this stage was to identify the best practices for construction methods using knowledge and experience of local construction experts. Nineteen professionals who have been working with the prequalified principal contractors in Victoria, Australia and having experience ranging from five to forty years were interviewed (Table 1). The experts have been working as general manager, construction manager, project manager, project coordinator, project engineer, site engineer, contract administrator, supervisor and cost manager. Snowballing technique was used to select the participants for interviews. Moreover, the experts were selected based on their experience in working with exemplar contractors. The exemplars were principal contractors that had the capacity to deliver numerous projects within a fiscal year. They were chosen based on the companies information provided in May 2015, IBIS World Report. Semi-structured questions were prepared for the interview. The questions included: Does this practice exist? How is it practiced by local contractors? Is this practice best for improving the productivity of building projects? What other practices enhance the productivity of building projects? The interviews were conducted until the data analysis reached saturation point. Saturation refers to the point where similar reasons for accepting or rejecting a particular best practice were given by the participants.

Table 1: Interviewees' years of experience in construction industry

Experience	**Number**
0-5	0
5-10	6
10-15	5
15-20	2
20+	6
Total	**19**

In phase 2, an industry-wide questionnaire survey was conducted (Appendix-1). The objective of this stage was to prioritize best practices for construction methods; develop a scoring tool and a logistic regression model. Thirty-nine pre-qualified principal contractors, based on their managerial capability, financial capacity, expertise and experience, were selected as the units of analysis (Department of Treasury and Finance, 2015). Victorian construction industry is comprised of a few principal contractors, all of whom were considered in this study. After identification of the unit of analysis, professionals who have been involved in the construction of building projects were contacted to respond to the questionnaires. General Managers, construction directors, construction managers and project managers, project coordinators and site managers with an average of fifteen years of experience participated in the survey that was administered using face-to-face interviews in which the researchers clarified the questions and took notes. The experts were asked to rate the relative importance of each element in improving productivity of building construction projects based on their experience in the industry using a 1 to 5 response scale(Appendix-1A). Moreover, they were requested to indicate the level of implementation of the best practices for construction methods on a particular building project that had been completed within the previous five years (Appendix-1B).

Mixed methods were used in this study. Since management practices could vary from country to country and from project to project, interviews were used to investigate the context-specific best practices during Phase I. A constructivist paradigm was adopted during stage I as there is no single best management practice. Different construction industries have their own best practices and no single best practice exists. Thus, context-specific best practices for construction methods should be investigated prior to conducting industry-wide questionnaire survey and analysing data objectively. This aspect of the research makes it different from previous similar studies that entirely used a positivist paradigm.

Data analysis

Qualitative data analysis consists of three concurrent flows of activity: data reduction, data display, and conclusion drawing (Rose, Spinks and Canhoto, 2015). Data reduction is a form of analysis that sharpens sorts, focuses, discards, and organizes data in a way that final conclusions can be drawn (Miles and Huberman, 1994). Writing summaries, coding, and making clusters are common methods used in data reduction process. The latter two methods are more suitable when the research is entirely inductive in nature. In this study, writing summaries was used as a technique to reduce the transcribed interviews. The reduced data is displayed using matrices, graphs, charts and networks. In this research, matrix technique is used as it is suitable to display the summaries of the responses in matrix boxes. Once the data is displayed, the conclusion is drawn by either noticing the patterns of similarities and differences between categories and/or processes, clustering, making contrasts and comparisons and noting relations between concepts (Rose, Spinks and Canhoto, 2015). The latter three strategies for conclusion drawing are more appropriate if the study is entirely qualitative in nature. Qualitative data was analysed and used as input to the quantitative phase in this research context. Identifying the pattern of similarity between the responses was used to draw a conclusion.

To analyse the data collected during phase I, the audiotaped interviews were first transcribed, and a matrix was prepared in Excel spreadsheet to match the responses of an expert and management practices. A summary of each interview result was written in a matrix box and conclusion was drawn for each practice. Similar iterative procedures were used for all the interview results. The similarity between the successive summaries was observed to find saturation point. After analysing the outcome of the fifteenth interview, similar explanations for management practices was observed. Although the saturation point was reached at the fifteenth interviewee, more interviews were conducted until the nineteenth participant, for the sake of confirmation. Finally, the best practices that were described as applicable to building projects by all participants were included in the list for the industry-wide survey.

To prioritize the best practices, Relative Importance Index (RII) was computed by using the equation below, and weights were assigned to the best practices (Enshassi et al., 2007). Furthermore, Friedman's and Wilcoxon's tests were conducted to check whether there were significant differences among the best practices.

$$RII = \frac{5(n_5)+4(n_4)+3(n_3)+2(n_2)+n_1)}{5(n_1+n_2+n_3+n_4+n_5)} *100$$

The number of respondents who selected 1 for not important, 2 for slightly important, 3 for somewhat important, 4 for very important, and 5 for extremely important practice to improve productivity in building projects are shown as n_1, n_2, n_3, n_4, and n_5 respectively.

To develop a scoring tool for the best practices, the weight of each practice was distributed proportionally from Level B to Level F, and Level A was assigned 0. The results are shown in the Findings and Discussion section, and Appendix-2. One-way ANOVA test was conducted to check if there was a significant difference between projects having higher score and lower score, and to validate the tool used to measure the best practices. Correlation analysis was conducted to check the relationship among best practices for construction methods, project delays, project costs, company size, experience of construction firms and annual turnover.

Logistic regression analysis was conducted to develop a model, to predict probability with respect to baseline productivity factor, based on a project's construction methods score. The model was validated by dividing the data obtained from 39 companies randomly into two (Zayed and Halpin, 2005). Thirty-one data points were used to build a model and the remaining data sets were used for validation purpose. The rule of thumb for sample size for logistic regression analysis states that the number of "Events Per Variable (EPV)" should be greater than 10 (Peduzzi et al., 1996). Some authors argue that the minimum of 10 events per predictor is conservative (Vittinghoff and McCulloch, 2007). In this research context, there were 18 projects with productivity factors greater than baseline PF = 0.97 (positive events) and there is one predictor (construction methods). EPV = 18>10 and logistic regression analysis can be conducted. Moreover, to increase the reliability of the model, bootstrapping was conducted. Before developing the final model, six alternative models were developed by varying the baseline PF. Using validation datasets, probabilities were predicted, Receiver Operating Characteristic (ROC) curves were drawn and Area under Curve (AUC) was computed.

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Findings and discussion

Identification of best practices for construction methods in building projects

Ten best practices for construction methods were identified. These are integrated schedule, work schedule strategies, schedule execution and management, dynamic site layout plan, traffic control plan, site security plan, machinery positioning strategy, project start-up plan, project completion plan, and innovations and new technologies. For the sake of brevity, a summary of the findings of only two best practices is indicated in Table 2.

Construction schedule that integrates work, materials procurement and delivery, machinery, sub-contractors, financial and other schedules have positive impact on the productivity of building projects. If work schedule is integrated with material and machinery schedules then the project teams are aware of when a particular activity needs to be done, what type of machinery should be hired, how much material and manpower should be deployed, and thus track the delivery of materials. The research participants described that the best-performing principal contractors link all the schedules together.

Developing a suitable working-hours strategy is also found to be another important management practice that increases productivity. There are working hour restrictions imposed by city councils, and contractors are required to develop a strategy to reduce project delays. Most commercial contractors in Victoria follow the calendar prepared by Construction, Forestry, Mining and Energy Union, which is typically 36 working hours per week. They schedule to work either four, five or six days a week and sign contracts with their subcontractors accordingly. Some respondents described that on Saturdays they reduce the working hours to 50%. They described that most workers are not productive on Saturday, Sunday, and rostered days off. Moreover, the participants indicated that it is expensive to work on Sundays and after hours, as the rates provided in the Enterprise Bargaining Agreement are high.

Table 2: Summary of interview results

Construction Methods	**Summary**	**Conclusion**
Integrated schedule	Linking various programs together is essential. Most principal contractors try to link materials procurement, lead time, work status, main work program and other issues such as the schedule for FFE (Fittings, Fixture, and Equipment) together.	applicable
Dynamic site layout plan	The site plan is constantly changing for the sake of productivity. The gates in and out, for instance, might be changed throughout the construction period. They could be changed after completion of excavation, during superstructure and landscaping works. The site layout is also planned by considering materials delivery and the requirement of temporary facilities at various stages of the project.	applicable

Changing a site plan based on phases of a construction project also improves productivity. The interviewees described that although the practice of adopting dynamic site layout is important, it should be planned ahead to be effective. They indicated that experienced contractors include their site logistics plan in a tender document. The changes in a plan that is based on the stages of construction are clearly shown in the tender document so that sub-contractors are aware of the future changes in the site layout. Moreover, the respondents described that integration of traffic control and site layout plans is of paramount importance in reducing the loss of productivity.

Construction machinery positioning strategy is also an important practice that influences productivity in the construction of building projects. The critical machine for these projects is a tower crane and its location on a site is planned by considering the weight to be loaded, distance from the street from which materials are lifted, the area of a building under construction and distance from existing buildings. The respondents described that careful analysis of the position of a crane using either 2D drawings or 3D models is an important practice.

Relative importance of the best practices for construction methods

Based on the results of RII analysis, the five most critical practices that have the potential to improve the productivity in building projects (Table 3) are traffic control plan, project start-up plan, machinery positioning strategy, project completion plan, and dynamic site layout plan. The finding of this study confirmed that best practices that are given top priority in other project types cannot directly be used for building projects. Traffic control plan was found to be the most significant practice that could enhance the productivity of building projects. However, for infrastructure projects the practice is not given top priority, and for the industrial projects traffic control plan is not included in the list of best practices (CII, 2013a; b). In Victoria, regulations oblige contractors that use public roads during construction periods, to prepare traffic management plans. Failure to prepare such plans will result in financial penalty and could lead to suspension of works if accidents occur. According to Road Safety (Traffic Management) Regulations (2009), any person conducting an activity on a road or road related areas must maintain a copy of the traffic management plan on the worksite at all times when the work is undertaken, and it should be available for inspection on request by an authorized person. The absence of the plan is an offense against the Regulation. Therefore, to reduce project delay and related penalty, principal contractors considered traffic control planning as the most important practice.

Project start-up planning is also considered among crucial practices that should be given priority in building projects. The finding of this study suggests that principal contractors in Victoria, Australia attempt to reduce the initial project delay by using a project start-up plan which could be used as a checklist to remind the project team regarding the information that is required to commence a project. In the plan, the pre-commencement meeting dates, resource requirements, and any other information which could be forgotten during commencement date are included. As per the plan, the principal contractor conducts meetings with its sub-contractors and resolves matters such as interference among subcontractors which could be one of the causes of the delays during project start-up.

Table 3: Relative importance of the best practices

Elements	**Weight (%)**	**Rank**
Traffic Control Plan	86	1
Project start-up plan	86	1
Machinery Positioning Strategy	83	3
Project Completion Plan	82	4
Dynamic Site Layout Plan	82	5
Schedule Execution and	77	6
Work Schedule Strategies	73	7
Site Security Plan	73	7

Integrated Schedule	66	9
Innovations and New Technologies	64	10

Similarly, machinery positioning strategy is considered to be the most significant practice for building projects. However, the practice is rated as having less importance for infrastructure projects and as an intermediate significance for industrial projects. Since the critical machinery for high-rise building projects is a tower crane, its location should be carefully analysed for the sake of productivity. The construction systems in Victoria, such as the use of heavy precast concrete panels in building projects, could influence the location of cranes. If the machine is not positioned in a suitable location, these concrete elements could not be placed in accordance with the scheduled time. The contractor might change the design of the panels to reduce their weights or look for other alternatives to place them. Moreover, since most multi-story building projects are in the city of Melbourne where there are restricted spaces, machinery positioning strategy is the crucial practice to improve productivity.

In Table 4, the results of Friedman test are presented. As the p-value (<0.001) is much less than 0.05, the null hypothesis which states the mean of all the best practices is equal should be rejected. Therefore, there is a statistically significant difference between the best practices. To identify where such difference lies, Wilcoxon Test was conducted.

Table 4: Outputs of the Friedman test

Elements	**Mean Rank**
Integrated Schedule	3.72
Work Schedule Strategies	4.76
Schedule Execution and Management	5.49
Dynamic Site Layout Plan	6.24
Traffic Control Plan	6.76
Site Security Plan	4.86
Machinery and Equipment Positioning	6.29
Project start-up plan	6.82
Project Completion Plan	6.59
Innovations and New Technologies	3.47
df	9
χ^2 approximation	74.73
p-value	<0.001

The results of Wilcoxon test are shown in Table 5. Accordingly, from forty-five possible combinations, statistically significant differences exist among twenty-nine of them (Table 5). Ten possible combinations among the top five best practices were found to be statistically insignificant at the 5% significance level. This shows that there is no major difference among the top five best practices. Therefore, traffic control plan, project start-up plan, machinery positioning strategy, project completion plan and dynamic site layout plan are equally important to improve productivity in building projects.

Table 5: P-values obtained using Wilcoxon analysis

	IS	**WSS**	**SEM**	**DSLP**	**TCP**	**SSP**	**MPS**	**PSP**	**PCP**	**INT**
IS		.013	.001	<.001	<.001	.040	<.001	<.001	<.001	.557
WSS			.046	.014	<.001	1.00	.028	.002	.013	.003
SEM				.242	.023	.158	.252	.036	.140	<.001
DSLP					.159	.009	.950	.162	.947	<.001
TCP						.001	.233	.917	.414	<.001
SSP							.023	.002	.025	.004

MPS								.339	.836	<.001
PSP									.446	<.001
PCP										<.001
INT										

Legend: IS=Integrated Schedule, WSS= Work Schedule Strategies, SEM=Schedule Execution and Management, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies.

Best practices for construction methods scoring tool and validation

To develop the Scoring Tool (Appendix-2) for best practices, the weight obtained using RII analysis was proportionally distributed. For instance, the weight for the practice integrated schedule is 0.66, and the proportions are Level A=0; Level B=1/5*(0.66)=0.13; Level C=2/5*(0.66)=0.26; Level D=3/5*(0.66)=0.40; Level E=4/5*(0.66)=0.53; and Level F=0.66 (Table 6). Similarly, the scoring tools for other best practices were developed. In Table 6, the score of the practice "integrated schedule" for one of the projects is shown in the last column. Since the respondent of that particular project ticked Level C, the equivalent score for "integrated schedule" is 0.26. The total construction methods score for a project is computed by adding the scores of the ten best practices. All the thirty-nine survey data was converted to scores of the best practices for construction methods. Overall there are 390 (39*10) best practices scores.

Table 6: Integrated schedule score

Survey Data Collected using Standard Tool (CII, 2013b)		**Distributed Weights**	**Score**
Level A	The use of an integrated schedule using CPM is not applicable.	0	**0.26**
Level B	The use of an integrated schedule using CPM has not been addressed	0.13	
Level C	Developing a schedule with no resources present and managing schedule status via duration or remaining duration but no link to earned percent complete progress from associated deliverables per activity.	0.26	
Level D	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity.	0.40	
Level E	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity. Resources are updated to reflect current work content or quantity adjustments.	0.53	
Level F	Continuation of Level E and updated to include quantity adjustments. Earned progress for the activity is based on measured or assessed work completed per deliverables per activity. Progress measurement performed in application adapted specifically for each deliverable.	0.66	

One-way ANOVA was conducted, to test the hypothesis that building projects with higher scores of the best practices for construction methods have also higher productivity. The projects were grouped based on the baseline mean score of 4.84. Projects with scores less than the mean value were classified under Group 1(low score) and those having scores greater than the baseline were classified under Group 2 (high score). In Table 7, the descriptive statistics and ANOVA results are presented. The mean productivity factor of Group 1 and Group 2 are 0.88 and 1.01 respectively. The p-value (0.004) is less than 0.05 indicating that there is statistically significant difference between the two groups. The finding implies that building projects with a higher level of implementation of the best practices for construction methods also have higher productivity. Therefore, the tool developed to measure the best practices is valid. The tool is shown in Appendix-2.

Table 7: One-way ANOVA for PF and construction methods score

Descriptive					ANOVA					
			95% CI for Mean							
	N	Mean	Lower Bound	Upper Bound		Sum of Squares	df.	Mean Square	F	Sig.
Group	18	0.882	0.808	0.955	Between	0.161	1	0.161	9.643	0.004
Group	21	1.012	0.960	1.061	Within Groups	0.617	37	0.017		
Total	39	0.951	0.905	0.998	Total	0.777	38			

Relationship between project delay and best practices

Correlation analysis was conducted to investigate the relation between project delay and the best practices and the results are indicated in Table 8.

Table 8: Spearman correlation coefficients for project delay

		PF	**IS**	**WSS**	**SEM**	**DSLP**	**TCP**	**SSP**	**MPS**	**PSP**	**PCP**	**INT**	**CM**
Delay	Coeff.	-.940	-.470	-.204	-.195	-.262	-.177	-.011	-.349	-.524	-.366	-.079	-.425
	Sig.	<.001	.003	.213	.234	.107	.280	.949	.030	.001	.022	.635	.007

Legend: PF= Productivity Factor, IS=Integrated Schedule, WSS= Work Schedule Strategies, SEM=Schedule Execution and Management, DSLP= Dynamic Site Layout Plan, TCP=Traffic Control Plan, SSP=Site Security Plan, MPS=Machinery Positioning Strategy, PSP=Project Start-up Plan, PCP= Project Completion Plan, INT=Innovation and new Technologies, CM= Construction Methods.

There is statistically significant negative correlation between integrated schedule, machinery positioning strategy, project start-up plan, project completion plan, and project delay. The results show that high levels of implementation of the best practices are associated with low project delay.

Correlation analysis was also conducted to check if implementation levels of the best practices vary based on project cost, annual turnover of companies, experience of companies, and company sizes. The results of the analysis are shown in Table 9. Statistically significant correlation between project cost and construction methods ($p=0.001<0.05$) was found. Thus, one of the main reasons for variations in the level of implementation of the best practices could be the change in project costs. As the project costs increase due to increment in the scope of works, the levels of implementation also increase. Although there is a positive correlation between construction methods and annual turnover, experience, and company size, the p-values are not statistically significant. This shows that larger and experienced companies may not fully implement the best practices if the scope of a project is small.

Table 9: Spearman correlation coefficients of company profile and project cost

		Construction Methods	Annual Turnover	Company Experience	Company Size	Project Cost
Annual Turnover	Coeff.	0.119				
	Sig.	0.570				
Company Experience	Coeff.	0.224	0.062			
	Sig.	0.176	0.769			
Company Size	Coeff.	0.261		0.520		
	Sig.	0.109		0.001		
Project Cost	Coeff.	0.538	0.356	0.547	0.488	1.00
	Sig.	0.001	0.081	0.001	0.002	

Logistic regression model building and validation

Binary logistic regression model was developed to predict the probability of exceeding the baseline productivity factor of 0.97 which is the mean PF value. Some of the results are shown in Table 10. For the sake of brevity all the outputs are not presented in this paper. The model's Omnibus Test indicates significance value of $0.016<0.05$; Hosmer and Lemeshow Test shows a p-value of $0.172>0.05$ indicating the strength of the model. Furthermore, the model's overall p-value is $0.029<0.050$ and it is acceptable. The model in Block-0 during the analysis indicates the predictive capacity of 58.1% whereas the final model has a predictive capacity of 74.2%. Thus, the selected model is good. Moreover, the coefficient of the variable after bootstrapping using 1000 samples is statistically significant ($p=0.01<0.05$).

Using the coefficients indicated in Table 10, the final model is $\text{Log}\ (p/1\text{-}p) = 0.749{*}CM\text{-}3.366$. To compute probabilities, the model's equation is simplified as follows. Let $L=B_o+B_1{*}CM$, then $P=e^L/\ (1+e^L)$. By using this formula, probabilities are predicted and the sigmoid graph is drawn as shown in Figure 1. Users can compute their projects' CM score using the scoring technique (Appendix-2) developed in this research and read the probability from the graph. For instance, if a project manager computes the construction methods score of 4.0 then the probability that a project's PF exceeding 0.97 is 40%. Thus, the actual productivity could be less than planned productivity and the possibility of occurrence of project delay is high. However, the project manager can increase the chance of completing a project on or before the contract date by increasing the level of implementation of the best practices. The tools developed in this study have paramount significance for assisting building project teams to carry out such predictions.

The model was validated by predicting the probabilities of the validation datasets. Receiver Operating Characteristic (ROC) Curve was drawn (Figure 2) and Area under the Curve (AUC) was computed to be 0.833. Thus, the model is valid as AUC is greater than 0.5 and close to 1.0.

Table 10: Summary of the outputs from logistic regression analysis

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Construction Methods (CM)	0.749	0.343	4.785	1	0.029	2.116	1.081	4.141
Constant	-3.366	1.724	3.809	1	0.050	0.035		

Bootstrap for Variables in the Equation

					Bootstrap	
					95% Confidence Interval	
	B	Bias	S.E	Sig.	Lower	Upper
Construction Methods (CM)	0.749	0.120	0.465	0.013	0.156	1.995
Constant	-3.366	-0.548	2.243	0.031	-9.286	-0.448

Classification Table

Observed		Predicted		
		PF		Percentage Correct
PF	0	0	1	61.5
	1	8	5	83.3
		3	15	74.2

The cut value is 0.500

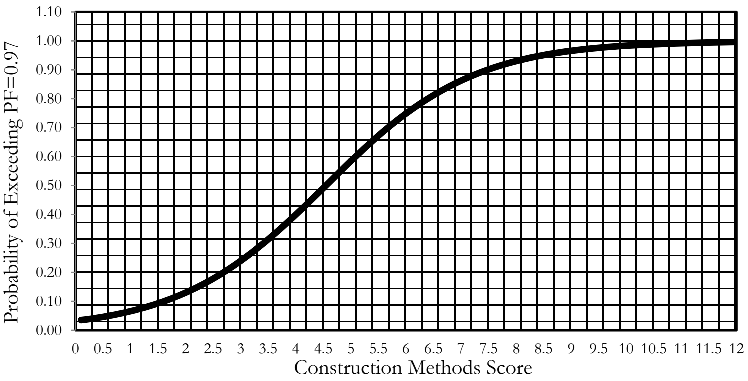

Figure 1: Probability plot of construction methods

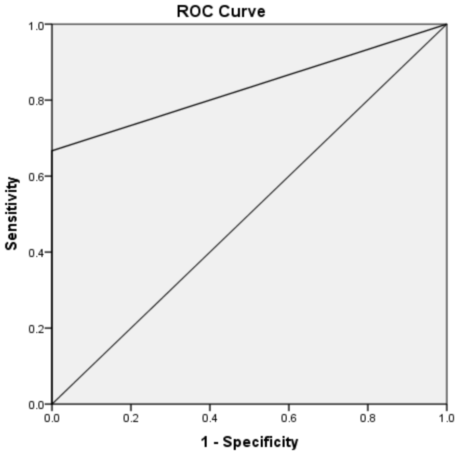

Figure 2: ROC curve

Conclusion

Ten best practices for construction methods were identified and prioritized for building projects in Victoria, Australia. Among the ten best practices, traffic control plan, project start-up plan, machinery positioning strategy, project completion plan, and dynamic site layout plan were found to be the top five most important best practices. The study revealed that high levels of implementation of best practices are associated with low project delays. The levels of implementation of best practices increase as project costs increase. Positive correlation between company's annual turnover, company size, company experience, and best practices were found. However, these relationships are not statistically significant. Logistic regression model was developed to predict probability based on the best practices score.

This study has implications for both contractors and future researchers. The principal contractors involved in the construction of building projects in Victoria, Australia can implement the identified best practices to improve the productivity of their projects. They can also score the construction methods and use the logistic regression model to predict the probability of exceeding a baseline productivity factor. Based on the predicted productivity, contractors can implement corrective actions to achieve the desired level of productivity. Contractors in other countries can also use these practices to enhance the productivity of their building projects, but the best practices should be adapted to local context as they could vary from country to country. Furthermore, sub-contractors both in Australia and other countries might not enhance their building projects' productivity by implementing the identified best practices as this study focuses on the management practices of principal contractors only. Future researchers can use this study as a background to investigate best practices for construction methods that could enhance construction productivity from sub-contractors' perspectives. Furthermore, researchers in other countries can also use the best practices identified in this research to validate their suitability in a particular environment and to identify the most critical practices.

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Appendix-1

Questionnaire

A. Relative Importance of the Management Practices for Construction Methods

Please rate the following elements based on their degree of importance in improving productivity in building construction projects on the scale of 1 to 5.

Best Practices for Construction Methods	**Level of Importance**				
	Not important (1)	Slightly important (2)	Somewhat important (3)	Very important (4)	Extremely important (5)

1. Integrated Schedule					
2. Work Schedule Strategies					
3. Schedule Execution and Management					
4. Dynamic Site Layout Plan					
5. Traffic Control Plan					
6. Site Security Plan					
7. Machinery & Equipment Positioning Strategy					
8. Project start-up plan					
9. Project Completion Plan					
10. Innovations & New Technologies					

B. Data Collection Tool from Building Projects

B1. Project Characteristics

Project type (residential, commercial etc.)	
Project value	
Floor area	
Project start date:	
Planned completion date:	
Actual completion date:	

B2. Best Practices for Construction Methods Survey Tool(unweighted) (adapted from (CII, 2013b)) Please check (√) one box per element in space provided in front of the level of implementation of the management practice. Please do not leave any elements blank.

1.Integrated Schedule	
Level A	The use of an integrated schedule using CPM is not applicable.
Level B	The use of an integrated schedule using CPM has not been addressed.
Level C	Developing a schedule with no resources present and managing schedule status via duration or remaining duration but not linked to earned percent complete progress from associated deliverables per activity.
Level D	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity.
Level E	Developing a schedule with resources present but not linked to earned percent complete progress from associated deliverables per activity. Resources are updated to reflect current work content or quantity adjustments.
Level F	Continuation of Level E and updated to include quantity adjustments. Earned progress for the activity is based on measured or assessed work completed per deliverables per activity. Progress measurement performed in application adapted specifically for each deliverable.

2. Work Schedule Strategies	
Level A	The development of a work schedule strategy is not applicable
Level B	The development of a work schedule strategy has not been addressed
Level C	The strategy is based on a single work schedule be it either a straight time such as 36 hours per week schedule, overtime, or other work schedule strategies.
Level D	Strategy considers multiple work schedules considering critical and near critical activity sequences.
Level E	Continuation of Level D, plus strategies considers the potential impact on worker fatigue, supervision, safety, and absenteeism.
Level F	Continuation of Level E, plus each potential strategy's impact is analysed for manpower density and congestion at an area or sub-area level.

3. Schedule Execution and Management	
Level A	The development of a schedule compliance plan is not applicable
Level B	The development of a schedule compliance plan has not been addressed
Level C	Consistent follow-up to monitor the following tasks: schedule updated periodically, critical path analysis, and progress narrative prepared as required and effective team participation in schedule updates.
Level D	Continuation of Level C, plus quantity reports are regularly performed. Upon request, or as the project requires, may include any of the following: change management analysis, risks assessment scenarios/analysis, date variance analysis to approved baseline or previous update period, start / finish percent achieved ratio analysis, communication with material suppliers to ensure material will arrive on site when planned.
Level E	Continuation of Level D, plus monitor the following: schedule rigorously updated based on manual input of quantity reports, critical and near critical path analysis, progress narrative prepared and effective team participation in schedule updates. Quantity reports rigorously done by trained individual(s). Material suppliers routinely contacted to track the status of material delivery dates.

Level F	Continuation of Level E, plus will consistently include all of the following, based on project requirements and observed schedule status conditions: change management analysis, risks assessment scenarios/analysis, date variance analysis to approved baseline or previous update period, start / finish percent achieved ratio analysis; also included progress tracking using 3D imaging and other techniques.
4. Dynamic Site Layout Plan	
Level A	Site layout plan is not applicable for the project.
Level B	A site layout plan has not been addressed.
Level C	The project team examines the project schedule and assesses when Temporary Facilities (TF) will be brought in.
Level D	Continuation of Level C, plus what sizes will be needed prior to the start of the project. No consideration is given to the addition and removal of TFs at different stages of the project. No analysis is done in regards to the layout of the project to optimize locations of the TFs to limit travel time to and from.
Level E	Continuation of Level D, plus consideration is given to the addition and removal of TFs at different stages of the project.
Level F	Continuation of Level E, plus the team analyses the layout of the project including where the different parties will be working and place their TFs in the optimum location in order to limit travel time to and from TFs.
5. Traffic Control Plan	
Level A	Traffic control plans are not applicable for the project.
Level B	Traffic control plans have not been addressed for the project.
Level C	The project has some traffic control plans and is used on a reactive basis.
Level D	The project has a traffic control plan, equipment, and an arrangement for daylight traffic control only and has no trained traffic control persons.
Level E	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control.
Level F	Continuation of level E, plus a trained traffic control supervisor. It has an approved contingency plan in place to accommodate unexpected situations, and has designed and constructed alternate arrangements for traffic such as detours, flyovers, etc.
6. Site Security Plan	
Level A	Site security plan is not applicable for the project.
Level B	The site does not institute security in regards to entry to the site, securing commodities, or tools and equipment.
Level C	The site controls entry and exit from the site, but does not have any other formal security throughout the site.
Level D	The site has established security procedures including visitor sign in and sign out procedure and security guards at every gate. The site has implemented security measures to ensure the preservation of company assets. Protocols have been identified for searches of individuals and their personal property. Searches are conducted randomly.
Level E	Continuation of Level D, plus the site has ensured that material is not leaving the job site by instituting "lock-ups" for items that are prone to theft.
Level F	Continuation of Level E, plus the use of electronic security such as security cameras has been implemented.
7. Machinery Positioning Strategy	
Level A	Machinery positioning strategy is not applicable.
Level B	There is no strategy for positioning of machinery at the project site.
Level C	Heavy rigging and lifting studies are accomplished on all critical lifts including evaluation of the machinery, rigging selection, and crane location.
Level D	Continuation of Level C, plus planning includes the use of 2D layout and studies to aid in constructability for locating and utilizing machinery.
Level E	Continuation of Level D, plus some 3D modelling studies to aid in constructability for locating and utilizing machinery.
Level F	Continuation of Level E, plus planning includes the use of 3D layout studies and 3D modelling/visualization to aid in constructability for locating and utilizing machinery.
8. Project Start-up Plan	
Level A	No start-up plan exists.
Level B	A partial start-up plan has been prepared; the plan has not been communicated to the concerned stakeholders.
Level C	A basic start-up plan has been developed with input from the project participants, but the plan has not been implemented.
Level D	Continuation of Level C, plus with considerations for interfaces among sub-contractors or project participants. A start-up plan has been developed that identifies the duties and responsibilities of each stakeholder.
Level E	Continuation of Level D, plus with consideration for cost analysis and detailed scheduling components. The plan is well communicated to all the stakeholders.

Level F	Continuation of Level E, plus with the plan being implemented on the project by incorporating feedbacks from the stakeholders or project participants.
9. Project Completion Plan	
Level A	The project completion requirement or handover procedure is not applicable.
Level B	The project completion requirement or handover procedure has not been identified.
Level C	The project has a handover procedure that defines the parameters of project completion and delineates the requirements for the handover.
Level D	The project has a formal handover process that defines the necessary documentation, parameters of completion and other issues to assure proper handover of a project.
Level E	Continuation of Level D, plus the procedure has been reviewed and agreed by the stakeholders.
Level F	Continuation of Level E plus the plan is approved by project management team and is reviewed for applicability during all phases of the handover process.
10. Innovations and New Technologies	
Level A	Innovation in new materials, equipment, information systems is not applicable.
Level B	Innovations and new technologies investigation is not addressed.
Level C	The project does not have a formal program for the investigation of innovations and new technologies. Implementation of innovations and new systems will only occur after the industry-wide implementation.
Level D	The organization has an informal program for the investigation of innovations, and they will investigate the feasibility of the new technologies on a regular basis.
Level E	Continuation of Level D, plus the program is formal to investigate new systems and they will investigate the feasibility of the new technologies on a regular basis.
Level F	Continuation of Level E, plus they investigate all new technologies using a formal system of rating the new technology.

Appendix-2

Best Practices for Construction Methods Scoring Tool (Weighted) for Building Projects

1.Integrated Schedule		**Weights**
Level A	The use of an integrated schedule using CPM is not applicable.	0.00
Level B	The use of an integrated schedule using CPM has not been addressed	0.13
Level C	Developing a schedule with no resources present and managing schedule status via duration or remaining duration but no link to earned percent complete progress from associated deliverables per activity.	0.26
Level D	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity.	0.40
Level E	Developing a schedule with resources present but no link to earned percent complete progress from associated deliverables per activity. Resources are updated to reflect current work content or quantity adjustments.	0.53
Level F	Continuation of Level E and updated to include quantity adjustments. Earned progress for the activity is based on measured or assessed work completed per deliverables per activity. Progress measurement performed in application adapted specifically for each deliverable.	0.66
2. Work Schedule Strategies		
Level A	The development of a work schedule strategy is not applicable	0.00
Level B	The development of a work schedule strategy has not been addressed	0.15
Level C	The strategy is based on a single work schedule be it either a straight time such as 36 hours per week schedule, overtime, or other work schedule strategies.	0.29
Level D	Strategy considers multiple work schedules considering critical and near critical activity sequences.	0.44
Level E	Continuation of Level D, plus strategies considers the potential impact on worker fatigue, supervision, safety, and absenteeism.	0.58
Level F	Continuation of Level E, plus each potential strategy’s impact is analysed for manpower density and congestion at an area or sub-area level.	0.73
3. Schedule Execution and Management		
Level A	The development of a schedule compliance plan is not applicable	0.00
Level B	The development of a schedule compliance plan has not been addressed	0.15
Level C	Consistent follow-up to monitor the following tasks: schedule updated periodically, critical path analysis, and progress narrative prepared as required and effective team participation in schedule updates.	0.31

Level D	Continuation of Level C, plus quantity reports are regularly performed. Upon request, or as the project requires, may include any of the following: change management analysis, risks assessment scenarios/analysis, date variance analysis to approved baseline or previous update period, start / finish percent achieved ratio analysis, communication with material suppliers to ensure material will arrive on site when planned.	0.46
Level E	Continuation of Level D, plus monitor the following: schedule rigorously updated based on manual input of quantity reports, critical and near critical path analysis, progress narrative prepared and effective team participation in schedule updates. Quantity reports rigorously done by trained individual(s). Material suppliers routinely contacted to track the status of material delivery dates.	0.62
Level F	Continuation of Level E, plus will consistently include all of the following, based on project requirements and observed schedule status conditions: change management analysis, risks assessment scenarios/analysis, date variance analysis to approved baseline or previous update period, start / finish percent achieved ratio analysis; also included progress tracking using 3D imaging and other techniques.	0.77
4. Dynamic Site Layout Plan		
Level A	Site layout plan is not applicable for the project.	0.00
Level B	A site layout plan has not been addressed.	0.16
Level C	The project team examines the project schedule and assesses when Temporary Facilities (TF) will be brought in.	0.33
Level D	Continuation of Level C, plus what sizes will be needed prior to the start of the project. No consideration is given to the addition and removal of TFs at different stages of the project. No analysis is done in regards to the layout of the project to optimize locations of the TFs to limit travel time.	0.49
Level E	Continuation of Level D, plus consideration is given to the addition and removal of TFs at different stages of the project.	0.65
Level F	Continuation of Level E, plus the team analyses the layout of the project including where the different parties will be working and place their TFs in the optimum location in order to limit travel time to and from TFs.	0.82
5. Traffic Control Plan		
Level A	Traffic control plans are not applicable for the project.	0.00
Level B	Traffic control plans have not been addressed for the project.	0.17
Level C	The project has some traffic control plans and is used on a reactive basis.	0.34
Level D	The project has a traffic control plan, equipment, and an arrangement for daylight traffic control only and has no trained traffic control persons.	0.511
Level E	The project has a traffic control plan and equipment for all times of the day including trained persons for traffic control.	0.68
Level F	Continuation of level E, plus a trained traffic control supervisor. It has an approved contingency plan in place to accommodate unexpected situations and has designed and constructed alternate arrangements for traffic such as detours, flyovers, etc.	0.85
6. Site Security Plan		
Level A	Site security plan is not applicable for the project.	0.00
Level B	The site does not institute security in regards to entry to the site, securing commodities, or tools and equipment.	0.15
Level C	The site controls entry and exit from the site, but does not have any other formal security throughout the site.	0.29
Level D	The site has established security procedures including visitor sign in and sign out procedure and security guards at every gate. The site has implemented security measures to ensure the preservation of company assets. Protocols have been identified for searches of individuals and their personal property. Searches are conducted randomly.	0.44
Level E	Continuation of Level D, plus the site has ensured that material is not leaving the job site by instituting "lock-ups" for items that are prone to theft.	0.59
Level F	Continuation of Level E, plus the use of electronic security such as security cameras has been implemented.	0.73
7.Machinery Positioning Strategy		
Level A	Machinery positioning strategy is not applicable.	0.00
Level B	There is no strategy for positioning of machinery at the project site.	0.16
Level C	Heavy rigging and lifting studies are accomplished on all critical lifts including evaluation of the machinery, rigging selection, and crane location.	0.33
Level D	Continuation of Level C, plus planning includes the use of 2D layout and studies to aid in constructability for locating and utilizing machinery.	0.49
Level E	Continuation of Level D, plus some 3D modelling studies to aid in constructability for locating and utilizing machinery.	0.65

Level F	Continuation of Level E, plus planning includes the use of 3D layout studies and 3D modelling/visualization to aid in constructability for locating and utilizing machinery.	0.82
8.Project Start-up Plan		
Level A	No start-up plan exists.	0.00
Level B	A partial start-up plan has been prepared; the plan has not been communicated to the concerned stakeholders.	0.17
Level C	A basic start-up plan has been developed with input from the project participants, but the plan has not been implemented.	0.34
Level D	Continuation of Level C, plus with considerations for interfaces among sub-contractors or project participants. A start-up plan has been developed that identifies the duties and responsibilities of each stakeholder.	0.51
Level E	Continuation of Level D, plus with consideration for cost analysis and detailed scheduling components. The plan is well communicated to all the stakeholders.	0.68
Level F	Continuation of Level E, plus with the plan being implemented on the project by incorporating feedbacks from the stakeholders or project participants.	0.85
9.Project Completion Plan		
Level A	The project completion requirement or handover procedure is not applicable.	0.00
Level B	The project completion requirement or handover procedure has not been identified.	0.17
Level C	The project has a handover procedure that defines the parameters of project completion and delineates the requirements for the handover.	0.33
Level D	The project has a formal handover process that defines the necessary documentation, parameters of completion and other issues to assure proper handover of a project.	0.50
Level E	Continuation of Level D, plus the procedure has been reviewed and agreed by the stakeholders.	0.66
Level F	Continuation of Level E plus the plan is approved by project management team and is reviewed for applicability during all phases of the handover process.	0.83
10.Innovations and New Technologies		
Level A	Innovation in new materials, equipment, information systems is not applicable.	0.00
Level B	Innovations and new technologies investigation is not addressed.	0.13
Level C	The project does not have a formal program for the investigation of innovations and new technologies. Implementation of innovations and new systems will only occur after the industry-wide implementation.	0.25
Level D	The organization has an informal program for the investigation of innovations, and they will investigate the feasibility of the new technologies on a regular basis.	0.38
Level E	Continuation of Level D, plus the program is formal to investigate new systems and they will investigate the feasibility of the new technologies on a regular basis.	0.51
Level F	Continuation of Level E, plus they investigate all new technologies using a formal system of rating the new technology.	0.64

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