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PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE &  
REHABILITATION PROJECTS: PERSPECTIVES OF NEW  
ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS  
AND IMPROVEMENT MEASURES

2023

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REHABILITATION PROJECTS: PERSPECTIVES OF NEW  
ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS  
AND IMPROVEMENT MEASURES

A thesis submitted in fulfilment of the requirements for the degree of  
Doctor of Philosophy (PhD)  
in  
Construction

School of Built Environment  
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Albany  
New Zealand

Saeed Haji Karimian  
2023

## **STATEMENT OF ORIGINALITY**

I declare that this thesis is my work, except where due acknowledgement is made, and that it has not been previously included in a thesis, dissertation or report submitted to this University or to any other institution for a degree or any other qualification.

Saeed Haji Karimian

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## **LIST OF ABBREVIATIONS**

RMRC - Road Maintenance and Rehabilitation Contractors

NZ- New Zealand

IPEO - Input-Process-Environment-Output

MUHEC - Massey University Human Ethics Committee

NZTA – New Zealand Transport Agency

CSPP - Construction Systems Productivity Partnership

RMRP - Road Maintenance and Rehabilitation Process

GDP - Gross Domestic Product

RAMM - Roading Assessment & Maintenance Management

TLA - Territorial Legal Authorities

FTN - Fast Transit Network

LCN - Local Connector Network

PKRA - Principal's Key Result Areas

NZdTIMS - New Zealand version of Deighton's Total Infrastructure Management System

PCA - Principal Component Analysis

MR- Mean Rating

KMO - Kaiser-Meyer-Olkin

SME – Subject Matter Expert

## ABSTRACT OF RESEARCH

Road Maintenance and Rehabilitation contractors (RMRCs) – and indeed all contractors handling public sector projects – face the challenge of performance-based rewards, which seek to maximise tax dollars by ensuring whole-of-life best value in the project delivery process. To be successful, a contractor's productivity and performance should remain high and resilient to internal and external constraints in the project environment. There is a lack of research on a practical approach to modelling and prioritising performance constraints in the roading sector.

This study aimed to investigate the priority constraints RMRCs face in New Zealand (NZ) as well as strategies for improvement. The thesis presents the final findings of interview-based qualitative surveys of medium- to large-sized roading contractors in NZ, followed by a questionnaire survey (quantitative) to prioritise the constraints found during the first stage of the research. Empirical data then were analysed using descriptive statistics and SPSS-based principal component analysis.

The results showed - in diminishing order of influence - the following four principal items extracted from the initial 68 constraints identified from the interviews: process, operating environment; input; and output constraint groups. The most influential constraints in the four groups are inclement weather, frequency of design changes, inadequate supply or high cost of required resources, and post-construction defective or non-compliant work.

The findings contribute to the relevant body of knowledge by revealing critical factors constraining the productivity performance of NZ RMRCs and associated improvement measures. The Input-Process-Environment-Output (IPEO) constraint model is seen as being more practical and easy-to-follow by industry stakeholders than the internal-external risk approach reported in the literature; it presents new and more enriching perspectives into how contractors could leverage their limited resources to address key constraints.

**Keywords:** Contractors, efficiency, performance, productivity, road pavement, road maintenance & rehabilitation.

## **ETHICAL APPROVAL**

In order to ensure compliance with the ethical standards of Massey University, a research ethics application was submitted to the Massey University Human Ethics Committee (MUHEC). MUHEC granted 'Low-Risk Notification' to this research project on 18 July 2016.

The confirmation letter has been attached as Appendix A to this thesis.

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# CHAPTER 1: INTRODUCTION

## 1.1 Background

It has been acknowledged that a soundly-constructed, well-operated and routinely-maintained road network is the critical enabler of economic growth (NZTA, 2019). This is because a well-maintained road network enhances and sustains national and regional communications in a more effective, efficient and safe manner which, in turn, helps to support and sustain a thriving New Zealand economy when considering that New Zealand's population growth has been high by historical and international standards in recent years (NZTA, 2019). An efficient road network is not only critical for the economic well-being of a country; it also carries a tremendous social impact like providing access to health and educational services and generating employment opportunities.

A recent study commissioned by the New Zealand Transport Agency (NZTA, 2019) found that the agency's annual expenditure on the operation, maintenance and rehabilitation of the state highway network and local roads, including road safety improvement projects, is around \$2.91 billion. Around 70 per cent of this annual expenditure budget is allocated to general maintenance -reseal and pavement rehabilitation works - to provide an acceptable level of service to road users and counter the rapid pavement deterioration rate (NZTA, 2019).

According to New Zealand Transport Agency, the current net worth of New Zealand road network assets is valued at approximately \$51.1 billion (NZTA, 2019). Given this considerable asset value, one of the most significant challenges faced by policy- and decision-makers in the New Zealand roading industry is how to ensure that every dollar invested in road infrastructure development, operation and maintenance maximizes its value for the taxpayers' money. This results in extensive pressure for the service providers. They are expected to do much work with so few resources. Consequently, road pavement contractors responsible for designing, constructing, and maintaining the road infrastructure networks are put under enormous pressure to optimise their work to maximise value delivery in the process.

However, contractors at the forefront of road infrastructure asset development face enormous constraints that hinder their productivity and performance – and, resultantly, the extent of value they can deliver. The productivity constraints have resulted in several issues in delivering infrastructure projects, such as cost overruns, delays, and poor quality of work (Pell et al., 2015).

Importantly, to ease the challenges roading contractors face and help them improve their productivity within the available resources, it is imperative to provide them with information on the constraints they may face in their day-to-day project implementation role. It is also essential to equip them with practical ways of mitigating these constraints. This is more so because a bit of improvement in productivity through mitigation of the constraints has a multiplier effect on the cost savings. For instance, the World Economic Forum (2016) noted that a 1% increase in productivity within the global engineering and construction industry could save \$100 billion in a year. The productivity of New Zealand's construction industry is considered to be very low compared to other countries with similar conditions and challenges (Scofield, 2009). I. C. Page (2010) reports that the productivity of the New Zealand construction industry is continuously declining. Also, the New Zealand Construction Strategy Group reports that the New Zealand Construction industry has meagre productivity rates compared to Australia and some other Commonwealth countries (ConstructionStrategyGroup, 2017). The Construction Systems Productivity Partnership (CSPP, 2013) notes that increasing building and construction productivity by 10% could result in a corresponding lift of 1% in the aggregate Gross Domestic Product (GDP) of New Zealand. Also, Construction Strategy Group (2017) reports that every 5 per cent lift in productivity in New Zealand can bring an annual saving of 1.5 billion dollars to the NZ economy, which means better outcomes for infrastructure projects.

Several studies have looked at the challenges faced by contractors in infrastructure asset delivery and maintenance. For instance, the UK's Network Rail (2018) identified issues such as capacity limitations, poor performance management and progress tracking, poor safety management, unproductive organizational culture, and weather and climate as some of the constraints faced by service providers in infrastructure asset development and maintenance. Other issues included poor asset strategic planning and policies and communication, as well as supply chain limitations (Assaf & Al-Hejji, 2006). While investigating a risk-management approach to a successful infrastructure project, Beckers et al. (2013) found that a significant problem for contractors at the tendering and contract signing stage is that they take on higher risks that are disproportionate to their reward in the contract, and this often results in serious resource constraints during the implementation phase. The Controller and Auditor General's Office (2011) identified New Zealand-specific challenges in public infrastructure asset development and management to include issues such as acute skills shortage, unrealistic public expectations, the fiscally constrained environment within which an

infrastructure asset is procured and managed, and the type of procurement and contracting strategies adopted for infrastructure development which are not necessarily the most appropriate for collaborative relationships and successful project delivery.

While the challenges facing roading contractors as identified in some overseas studies could generally be applicable across countries, the unique socio-cultural, economic and regulatory environment within which the New Zealand roading maintenance contractors operate may require the investigation of the unique constraints and challenges they face, as challenges identified in the overseas countries, may not be fully applicable in the New Zealand context. Mbachu, Egbelakin, Rasheed, Shahzad, et al. (2017) corroborated this uniqueness by arguing that effective and enduring solutions are found when specific needs of organisations are articulated from key stakeholder viewpoints, ensuring that the solutions are in strategic alignment with their specific contexts such as their unique operational environments, regulatory frameworks, cultures, values, capabilities and capacities.

This study aimed to contribute to bridging the existing information gap in what is currently known about the challenges contractors face in the New Zealand roading sector. Empirical data comprised structured interview-based feedback provided by experienced roading contractors involved in road pavement design, construction, and maintenance and rehabilitation projects.

## **1.2 Research Problem statement**

The investment made in New Zealand by the New Zealand Transport Agency in operation, maintenance and rehabilitation of only state highway networks amounts to about \$500 million per year (NZTA, 2020). Given the reported poor productivity (ProductivityCommission, 2020) and construction industry performance, the New Zealand government tasked every service provider around 2012 to find ways of improving their sector's productivity by 20% by 2020 (ProductivityCommission, 2012). However, it was never achieved (Ayodele et al., 2021). Research done by the New Zealand Productivity Commission (Patrick Nolan, 2019) presented that New Zealand is one of the small numbers of OECD countries that have had low levels for both growth and labour productivity - around 40% below the average of the top half of the OCED since 1996 which means a low level of average income and comes at an actual cost to living standards.

Therefore, the New Zealand Productivity Commission suggests that rather than suddenly increasing the productivity rate and setting the same target for all different industries, New Zealand can successfully lift its productivity performance if it chooses a different path to success compared with other larger or more central economies. The NZPC is of the opinion that New Zealand's path to success will require consistent and focused effort over many fronts and for many years and that this is only possible with consistently researching and finding the real risks and causes of the low productivity rates within each different industry in New Zealand (Patrick Nolan, 2019).

The New Zealand Transport Agency (NZTA) targeted a 4% saving each year in the annual road maintenance budget spend (NZTA, 2014a). The NZTA has also developed a proposed maintenance and renewals programme for 2015-2018 and beyond to bank efficiency gains made to date and aggressively pursue new opportunities due to the increasing cost of maintenance and rehabilitation projects. NZTA has chosen seven critical areas of focus to achieve its targeted efficiencies and savings. The main focus area within each key area is finding risks and risk mitigation factors as well as finding new opportunities that can lead to a greater productivity rate and consequently improve efficiencies resulting in a targeted 4% saving rate (NZTA, 2014d). Nevertheless, achieving this goal would be impossible without properly understanding the issues road contractors are facing and how to resolve these issues to improve current productivity and performance levels.

The key areas of focus are listed below:

- 1- Having sound network conditions,
- 2- Network Outcome Contracts,
- 3- Data acquisition, analysis and use,
- 4- Working the asset,
- 5- Condition monitoring,
- 6- Infrastructure asset management plan,
- 7- Cost-effectiveness of state highway maintenance & renewals.

Several studies have been undertaken to understand the challenges faced by contractors in the infrastructure asset - delivery and maintenance (Rail, 2014); (Beckers et al., 2013); (Controller and Auditor General, (2011)). However, there is a lack of prioritisation of these challenges in the context of New Zealand's roading sector. Some pertinent questions need to be answered: Are the

challenges identified in overseas countries applicable in a New Zealand context? What are some specific constraints New Zealand contractors face in road maintenance and rehabilitation projects? What are mitigation measures specifically applicable to the New Zealand roading sector context?

While overseas studies are robust in regard to addressing some of these questions and should generally be applicable across countries, the unique socio-cultural, economic and regulatory environment within which the New Zealand roading maintenance contractors operate may require the investigation of the unique constraints and challenges they face. Challenges identified in the overseas countries may not be fully applicable in the New Zealand context. Also, there is a lack of empirical study in the New Zealand context. This study aimed to bridge the existing information gap in what is currently known about the challenges contractors face in the New Zealand roading sector.

### **1.3 Rationale for the study**

In the above section, a short review of the research background and existing problems have been summarised. However, four (4) more theoretical issues need to be studied and understood in order to increase the possibility of successfully implementing the research outcomes in real-life projects.

Firstly, the low productivity performance of infrastructure construction projects in New Zealand, compared to the other developed countries, shows that the existing practices are insufficient and adequate to achieve the NZTA's target of saving 4% of the budget each year.

Secondly, there are not enough empirical studies regarding the improvement in the construction projects' productivity, especially related to the New Zealand road maintenance industry, to rate the level of impact of existing constraints on the New Zealand road construction and maintenance industry. Obviously, without having a clear understanding of the level of impact of existing productivity improvement constraints, it will not be possible to tackle the constraints to improve productivity and achieve NZTA's targeted goal.

Thirdly, there is a lack of quality research on mitigation measures. This limits the construction industry to improve its productivity to be able to achieve the highest possible level of productivity.

Finally, there are not enough approaches to prove a model of improving productivity that the industry can adopt to improve productivity outcomes. An efficient model that can indicate the

importance of adopting appropriate mitigation measures can accelerate the success rate in achieving productivity improvement goals.

The main factors that motivated this study are the above-identified four (4) theoretical and contextual issues related to the knowledge-implementation gaps that exist within the New Zealand roading sector.

## **1.4 Research aim, questions and objectives**

### **1.4.1 Research aim**

The study aimed to investigate, explore and prioritise the constraints that are hindering the productivity and performance of roading contractors who are performing road maintenance and rehabilitation projects in New Zealand, as well as finding practical and innovative ways for mitigating the identified productivity constraints which can facilitate improving the productivity rate within a road maintenance and rehabilitation project. The main reason that has driven this research is a demand from roading contractors to improve their performance and project outcome by improving their productivity rate (NZTA, 2014d; ProductivityCommission, 2020).

### **1.4.2 Research questions**

The key research questions driving the research design, empirical data gathering, and analyses were formulated as follows to achieve the aim of the study:

- 1) What priority constraints do contractors' productivity performance in the road maintenance and rehabilitation process (RMR) in New Zealand?
- 2) What measures could be used to mitigate the identified priority constraints with a view to improving efficiency and productivity performance in the RMR?
- 3) How could the key stakeholders involved in the RMR be guided to improve productivity in their daily operations and final project outcome?

### **1.4.3 Research objectives**

The key objectives of this research study were framed to guide inquiry for the answers to address the research questions as follows:

- 1) To identify and prioritise the factors that constrain contractors' productivity performance in the road maintenance and rehabilitation process (RMR) in New Zealand.
- 2) To explore the measures for mitigating the identified constraints, focusing on improving the efficiency and productivity in the road maintenance and rehabilitation process (RMR) project delivery process.
- 3) To develop and validate a conceptual model of the identified productivity constraints and mitigation measures as a toolkit for guiding stakeholders' productivity improvement in the RMR process.

### **1.5 Research propositions**

Based on literature insights, the following propositions have been formulated to guide the research design: data gathering, data analysis, and interpretation of results for meeting the research objectives. The propositions were re-formulated as hypotheses to be tested using appropriate statistical tests of significance.

- 1) Poor project management is the most influential factor constraining contractors' productivity performance in the road maintenance and rehabilitation process (RMR) in New Zealand (ConstructionStrategyGroup, 2017; NZTA, 2014a)
- 2) Proper planning and progress monitoring are the most effective ways to mitigate the identified constraints and improve efficiency and productivity in the RMR project delivery process (Lee et al., 2002; Mohammadi et al., 2020).
- 3) Consensus the opinion among roading experts on their perceptions of the practical usefulness of the conceptual model developed as a toolkit for guiding stakeholders' productivity improvement in the RMR process.

## **1.6 Scope of research**

The scope of this research is limited to the investigation of productivity issues in the New Zealand roading maintenance projects only as the collected feedback are from research participants who are practising only in road maintenance and rehabilitation projects. It therefore only presents roading maintenance and rehabilitation projects and only New Zealand roading.

The research domain, unit of analysis and geographical coverage for soliciting empirical data are discussed below.

### **1.6.1 Domain investigation**

The research focuses on medium to large contractors who are working all around New Zealand. Therefore, experienced people who were working in all parts of New Zealand were also invited to participate in the research. The list of contractors that participated in the study was acquired from the NZTA register of pre-qualified contractors (NZTA, 2017). Moreover, based on the nature of this research and feedback received from contractors, the research scope focused on productivity issues related to the operational process of a project.

### **1.6.2 Unit of analysis**

This research was conducted from the perspective of New Zealand's main roading contractors and some other experienced firms who are involved in roading projects from the start to the day-to-day operations to project handover. The reasons for targeting and focusing on this group of contractors were:

- 1- They are the leading group that are familiar with the existing challenges in the New Zealand construction industry.
- 2- Achieving the productivity goals will not be possible without properly understanding the issues road contractors are facing.
- 3- Understanding and aiming at how to resolve the existing constraints, as faced by the main contractors and the whole industry in the first place, can successfully lead the roading industry to improve their productivity and performance.

### **1.6.3 Geographical coverage**

This study focused on all road types defined by the NZTA as arterial and non-arterial networks and which were built with asphalt or chip seal pavement material in the North Shore area, Auckland. However, the researcher welcomed other experienced professionals and individuals who decided to participate and contribute to the research findings.

## **1.7 Significance of the research**

The primary beneficiaries are roading contractors that specialise in road maintenance, rehabilitation and pavement construction projects. The research outcomes may also be beneficial to consultants responsible for supervision and performance appraisal of the contractors on behalf of the roading clients, notably NZTA and, finally, other project stakeholders, especially government and taxpayers.

### **1.7.1 Practical significance and unique contribution of the research**

The most significant contribution to this research mainly goes to the roading contractors in New Zealand. The research outcome helps them understand the existing constraints in their day-to-day operational processes and the level of impact of each constraint on their productivity outcome. This research also presents the existing mitigation measures that roading contractors can use to tackle existing obstacles to improve their productivity and performance.

### **1.7.2 Theoretical significance**

The theoretical significance of this research is to fill the existing knowledge gap in the literature related to the New Zealand road maintenance and construction industry. Moreover, this study has bridged the existing international literature and New Zealand-related roading industry literature by investigating the relevance of broader international literature and New Zealand's roading industry research contexts in the field of road construction and maintenance project productivity improvement. This is also achieved by integrating the existing international theoretical knowledge and New Zealand's existing theoretical knowledge. At the same time, a more extensive range of variables was included, which were recognised during each phase of this research, such as recognised existing productivity constraints, the level of impact of each constraint, and the

mitigation measures essential for tackling existing constraints improve productivity outcomes. This study also provided a framework that offers a theoretical and practical method and guidance to researchers to seek new ways to enable roading project contractors to improve their productivity and enhance their project expected outcomes.

## **1.8 Structure of the thesis**

This thesis has been structured into seven chapters which are outlined below:

**Chapter 1 (Introduction):** Introduces the research background, statement of the research problem, study objectives, research motivation, research propositions, the scope of research work and the importance of research findings.

**Chapter 2 (Literature Review):** Presents the review of existing literature related to the subject area; this chapter puts the work in the context of previous studies. The chapter also provides contextual definitions of the key concepts embodied in the thesis title. It will review the extent to which previous studies have addressed the key research objectives and what knowledge gaps exist. This chapter ends with a summary subsection highlighting how this research has contributed to filling the identified gaps in the literature.

**Chapter 3 (Methodology):** Appraises the various research methodologies and discusses the methodology employed in this study. Key sections include discussions on the data collection approach, selection of sampling frames, sampling techniques, a method of data analysis, triangulation of findings and ethical approval sought for this research from Massey University Human Ethics Committee (MUHEC).

**Chapter 4 (Data Analysis & Presentation):** This chapter presents the data collected for this study. Additionally, the results of data analysis and relevant discussion concerning the study objectives are presented in this chapter.

**Chapter 5 (Developed Model Reliability & Validity):** Discusses the hypothesis testing. Statistical tests of significance carried out to examine reliability and validity issues related to the findings and their practical application in the industry are presented in this chapter.

**Chapter 6** (Conclusion & Recommendations): Concludes the study by providing a comprehensive conclusion and recommendations for future research. The chapter also highlights the study's contributions to the body of knowledge.

**Chapter 7** (Publications): Extracts from this research are presented in the attached publication, aiming to summarise the research findings and do the research finding a practical and easy-to-use toolkit for all New Zealand Roothing contractors in real-life projects.

The report also includes appendices. These appendices comprise documents used during data gathering, tables used for data presentations and analyses, proposition testing, and a summary of the study's key findings.

## **1.9 Generalisation**

This study aims to generalise this research study for Australia and New Zealand; however, it can also be generalised to other countries with similarities in their environment, population, and policies. Also, the aim is that the developed toolkit can be used as a base tool by contractors in different countries with similar situations for improving their productivity and performance and final project outcome.

## **CHAPTER 2: LITERATURE REVIEW**

### **2.1 Overview**

This chapter reviews the background of the roading maintenance and rehabilitation methods with an overview on how to improve productivity. This section also provides an overview of the key concepts of the research topic. It also examines the extent to which the research objectives have been addressed, in whole or in part, in previous studies by reviewing related international- and New Zealand-related literature. Overviews are provided on productivity, road pavement maintenance and rehabilitation, and typical constraints in road pavement maintenance and rehabilitation and improvement measures in order to understand how stakeholders can make different choices to improve productivity in roading projects. This chapter also focuses on reviewing the existing literature and summarising the recognised constraints that main contractors are facing in day-to-day operations during a roading project in New Zealand. Finally, the section concludes with a subsection that summarises gaps in existing knowledge about the topic and how the research will contribute to filling the identified gaps.

### **2.2 Productivity in context**

Depending on the purpose, different methods are available for explaining productivity and depending on the context, and the objectives sought, ‘productivity’ as a complex concept can be interpreted in a variety of ways. Generally, productivity can be explained, “as a measure of how well resources are leveraged to achieve a set of objectives or desired output” (Durdyev, 2011). p20 Schreyer (2001) explained productivity from an economist’s perspective. He stated that productivity is the ratio of a measure of output to a measure of resource input. From a production system perspective, Bjork (2003) and Al-Kofahi et al. (2020), defined productivity as the ability of a system to convert input resources into outputs. This efficiency perspective of productivity expresses the concept as a quantitative relationship between the output and the input. It does not address the effectiveness criterion. Unfortunately, this efficiency perspective is widely adopted by economists. For instance, Günter and Gopp (2021) while relaying the economists’ perspective of the concept, defined it as the ratio of a measure of output to a measure of resource input which is a easy understandable concept.

The economist's or efficiency perspective of productivity is not entirely helpful to the construction industry stakeholders in terms of being used as a quantitative tool for measuring and benchmarking project performance. Statistics New Zealand (2016) corroborated the inadequacies of the efficiency-only perspective of the concept and its lack of effectiveness focus by noting that the economist's perspective of the concept (i.e., the output to input ratio measure) is not a measure of effectiveness because it reflects only how much extra output is produced per unit of input, not whether that input has a productive outcome. To provide a more relevant definition consistent with the industry's project performance measurement and benchmarking needs, several authors have come up with some definitions. Productivity can also be explained as a measured rate of successful delivery of the main project objectives with a high level of cost-effectiveness which is commonly used for economic resilience investigations (Dormady et al., 2022). The main project objectives in this field can be the rate of achieving the targeted schedule, the rate of the project cost-effectiveness, and the level of achieved quality. For instance, Chan and Chan (2004), and then Meng (2012) defined the concept as a measure of the extent of achievement of project objectives, namely, time, cost, quality and scope accomplishments. However, there could be other perspectives of the concept as used in the roading sector, such as a measure of achievement of the pre-established performance assessment criteria, which may encompass a broader scope beyond cost, time and quality expectations.

### **2.3 Productivity in the context of road maintenance and rehabilitation**

Road Maintenance, in general, is a set of activities that are performed to keep a road network in a condition where traffic can operate without any interruption. Moreover, due to the enormous amount of investment required to maintain ageing infrastructure, especially infrastructure such as roads, productivity in Road Pavement Maintenance and Rehabilitation (RPMR) is fast becoming a priority issue. As Abdul Kadir et al. (2005) described, a significant portion of the road network in most developed countries, such as the United States, have exceeded their design life of 20 years and started seriously deteriorating and, as it is evident, expensive maintenance is required to overcome the rapid rate of deterioration.

Based on a working paper by UK-based economist Geoff Mason (2013) New Zealand's productivity levels were about 22% lower than Australia across 24 industries and especially the

construction industry which is still continued as described by more recent studies such as Conway (2018), and also considering lack of adequate research attention, in terms of productivity, in the context of road maintenance and rehabilitation management (NZTA, 2014c), therefore, New Zealand Transport Agency has proposed topics related to improving productivity and performance on road maintenance and rehabilitation to improve productivity in the road maintenance industry.

Existing definitions of ‘productivity’ in the road pavement construction sub-sector express the concept as output quantity per unit of time. For instance, Aziz et al. (2017) defined productivity in the road surfacing operation as the quantity of asphalt (in tons) laid per hour. Also, Rebholz et al. (2004) defined productivity in road pavement construction as the paved length (in metres) per hour. These definitions reflect the effectiveness or strategic perspective of the concept. Though the definitions are in alignment with the performance measurement approach commonly used in the construction sector (Chia et al., 2018), they are not helpful in the way they are expressed. To be useful, the measures need to be benchmarked against targeted outcomes, e.g. actual versus targeted outputs. This is important because a productivity measure is meaningless unless it is expressed in a comparative sense – such as across teams, historical performance data, or industry benchmarks (Tsolas, 2013).

Productivity measurement for the purposes of interim progress monitoring and control is usually carried out in-house by the contractor; the aim is to ensure the achievement of the primary project objective of completing the project on time, within budget and to the specified quality standards. Qasim (2018) argued that achieving the primary project objectives would result in the achievement of the secondary objectives such as profit margin, client satisfaction and re-use intentions.

The second purpose for productivity measurement in the road pavement maintenance and rehabilitation project and in general productivity concept is to benchmark the performance of the service providers against contractual thresholds (Holzer & Callahan, 2019). The contractor usually carries this out to benchmark the performance of subcontractors or the client’s project manager to benchmark the performance of the contractors. The assessment rubrics, in this instance, are geared towards establishing performance scores as indicators of the levels of achievement of the specified performance assessment criteria. The performance scores help establish ‘stellar’, ‘standard’ or

‘substandard’ performance levels. The assessment outcome may have implications for retention or exclusion of service providers in future contracts (Tsolas, 2013).

In the context of the New Zealand road pavement maintenance and rehabilitation projects, the New Zealand Transport Agency (NZTA, 2021c) measures the interim and end-of-project productivity performance of the contractors based on their levels of achievement of the performance assessment criteria specified for the work category they are prequalified to undertake. The current productivity assessment criteria as set out in the modified Manual for Performance Evaluation of Maintenance Contractors (NZTA, 2021c) are as follows:

1. *Project Management* (weighted 20%): comprising the following subcomponents:
  - a. Skill level and competency (5%)
  - b. Risk management (5%)
  - c. Responsiveness (5%)
  - d. Quality assurance (5%).
2. *Production* (weighted 45%): comprising the following:
  - a. Contractor’s programme (5%)
  - b. Ability to meet programme (5%)
  - c. Achieves the specified standard (10%)
  - d. Defect management system (10%)
  - e. Achievement: timely completion of cyclic maintenance and unit rate work items (10%)
  - f. Network condition and service level (5%)
3. *Health & Safety* (20%); comprising the following:
  - a. Safe work practices (10%)
  - b. Traffic management control (10%).
4. *Administration* (15%): comprising the following:
  - a. Financial: management of project budget, cash flow and invoicing (5%)
  - b. Handling of variations (5%)
  - c. Reporting (5%)

## **2.4 Productivity in the context of this research**

A review of extant literature to date shows that performance measurement is a widely accepted definition of productivity, especially among construction industry stakeholders (Martinez-Budria et al., 2011); (Hu & Liu, 2018). In the performance measurement context, productivity is expressed as a measure of how well resources are leveraged to achieve set targets or desired outputs (Durdyev & Mbachu, 2011a; Holzer & Callahan, 2019). This study aimed to focus on productivity by recognizing how a set of three objectives have been achieved on a project. As described by Mbachu and Seadon (2013) and Carson and Abbott (2012), these three main productivity objectives are 'efficiency', 'effectiveness' and 'sundry measures'. Therefore, this definition of productivity is adopted in this study as it is consistent with the research objectives.

## **2.5 Productivity constraints and improvement measures**

Productivity is a concept that often has been defined as a ratio of output that it produces to the input. Productivity also has been used often as a tool for measuring the performance of a firm or project outcome.

Productivity in the context of the construction industry, in recent years, has been the centre of concern and attention. Because the construction industry is highly competitive, and firms that are participating in such an environment must improve their outcome constantly through increasing their productivity and performance, many firms have tried to establish a definition of productivity that can help them to achieve better outcomes by improving their productivity (ConstructionStrategyGroup, 2017; Park et al., 2005; Zhan & Pan, 2020).

The most common and straightforward explanation for productivity is  $\text{Productivity} = \text{Outputs} / \text{Inputs}$ , and this simple formula is used only when output is achieved, using an input. However, when the process is getting complex, more inputs are involved, as are many other factors can impact the process and the final output. These factors can be positive factors that can improve productivity rates or negative ones that can hinder the productivity rate hugely; they are often called 'productivity constraints' (Bernold & AbouRizk, 2010; Serdarurdyev & M Reza Hosseini, 2019; Lessing et al., 2017).

To find effective methods to achieve desired construction productivity, it is important to recognise all constraints factors that impact productivity during a project's lifecycle (Zhan & Pan, 2020), (Serdar Durdyev & M. Reza Hosseini, 2019).

### **2.5.1 Typical productivity constraints in the construction industry**

There are different types of constraints in every work that needs to be dealt with; however, the constraints can be hidden, and we may be unaware of possible constraints which can cause low productivity rates and even increase the risk of project failure. Several studies have investigated different aspects of productivity constraints in the construction industry, such as Javed et al. (2018). For instance, Intergraph (2018) & an older study such as Lau and Kong (2006) identified many workforce-related social constraint factors such as morale and attitude, fatigue, poor wages, poor health, lack of clarity of role and task description, lack of skill, and relationship issues. Intergraph (2018) also identified construction industry characteristics such as the fact that no two construction projects are the same due to variations in design, size, location, stakeholders and other issues, which make it difficult to apply lessons learnt in previous jobs to new ones; other construction industry-related constraints to productivity include poor supply chain management, 'patch protection', lack of transparency, lack of integration between design and construction phases, and the lowest price approach to competitive tender awards.

Mbachu, Egbelakin, Rasheed, Shahzad, et al. (2017) identified further productivity constraining factors to include design-related issues such as errors and omissions in drawings and specifications, buildability, insufficient detailing, and design not aligning with Building Code and actual site conditions.

Lessing et al. (2017) also identified that one of the significant productivity constraints within the construction industry is project delays. However, the project delay itself can happen due to other productivity constraints, such as constraints related to the design stage.

#### ***Summarized review of typical constraints to productivity in the construction industry***

Thematic analysis of the literature insights on typical constraints to productivity in the construction industry shows several themes and their underlying subcomponents, as presented in Table 1.

**Table 1:** Summary of typical constraints to productivity in the construction industry (Source: Varied sources)

	<b>Major constrain factors</b>	<b>Subfactors</b>	<b>Source</b>
1	Site/ project characteristics		
a)		Confined or congested workspace	(Intergraph, 2018), (Rahal & Khoury, 2019)
b)		Hazardous work area	(Intergraph, 2018), (Van Tam et al., 2018)
c)		Variability in subsoil properties and inconsistency with design assumptions	Mbachu, Egbelakin, Rasheed, Shahzad, et al. (2017)
d)		Access issue and high traffic volume	(Chan et al., 2001; Dunston et al., 2000; Wang, 2021), (Lee et al., 2007)
2	Project management		
a)		Poor scheduling and coordination of work packages	(Mbachu, 2008b)
b)		Poor leadership	(Mohammadi et al., 2020)
c)		Lack of sufficient planning from the start leading to design changes later on during the construction phase	(Alinaitwe et al., 2007), (Rasel, 2016) (Derek Gill & James Zuccollo, 2012)
d)		Lack of effective communication/ clarifications of expectations	(Hasan et al., 2018) (Vaux & Kirk, 2018) (Hamza et al., 2019)
3	Environmental		
a)		Inclement weather conditions	Intergraph, (2018), (Hasan et al., 2018) (Alinaitwe et al., 2007)
b)		Shorter daylight hours	Intergraph, (2018)

c)		Location and specific environmental condition such as ground condition	(Lau & Kong, 2006) (Van Staveren, 2018)
d)		Environment preservation	(Hasan et al., 2018) (Lau & Kong, 2006)
4	Legal constraints		
a)		Regulations that rule the construction project include legal constraints related to work law, safety regulation, etc.	(Hasan et al., 2018) (Lau & Kong, 2006) (Lau & Kong, 2006), (Alinaitwe et al., 2007),
b)		Local authority Bylaw	(Walsh, 2010), (Frost, 2001)
c)		Health & Safety Act	(Gurmu & Aibinu, 2018)
5	Technical constraints		
a)		Frequency of design changes/ change orders/ late changes	(Yates & Hardcastle, 2002), (Alinaitwe et al., 2007), (Hwang et al., 2017), (Lessing et al., 2017)
b)		Lack of technical knowledge when developing the design which leads to design change and defects during the construction phase	(Li et al., 2022) (Karim et al., 2013), (Haji Karimian, 2014), (Hwang et al., 2017)
c)		The complex design which is challenging to implement	(Jarkas, 2015), (Jarkas & Bitar, 2011)
d)		Lack of new technologies	(Mbachu & Seadon, 2013), (Kuroshi & Lawal, 2014)
6	Workforce related constraint		
a)		Lack of leadership with management capability	(Durdyev, 2011), (Alinaitwe et al., 2007)
b)		Workforce fatigue due to long working hours leading to workforce absentees	(Damiani et al., 2016), (A Enshassi et al., 2007)

c)		Low level of commitment and motivation	(Aynur Kazaz et al., 2008), (A. Kazaz et al., 2008), (Kazaz et al., 2012)
d)		Lack of adequate training	(Adnan Enshassi et al., 2007) (Mbachu & Seadon, 2013), (ConstructionStrategyGroup, 2017)
7	Project finance issues		
a)		Inaccurate estimate, high cost of needed resources & construction phase defective or non-compliance work	(Martinez-Budria et al., 2011), (Mahamid, 2013)

### 2.5.2 Typical productivity improvement measures in the construction industry

Given the importance of productivity, several authors have investigated its improvement measures in the construction industry. For instance, Durdyev and Mbachu (2018) recommended using a Project Risk Register to correctly identify and assess potential risk sources at the onset that may constrain the achievement of the project objectives and provide adequate contingency measures for addressing the risks if and when they occur. The authors also recommended good leadership as an effective way of inspiring and bringing out the best in the workforce, which is the critical engine for revamping productivity in the workplace.

From a resource point of view, Intergraph (2018) recommended adequate cash flow as a means of resourcing the project implementation process and ensuring as-planned progress on the job.

On the other hand, Mbachu, Egbelakin, Rasheed, Shahzad, et al. (2017) advocated that productivity could be significantly improved if the project planning process is well formulated to account for the key variables that affect the scope of work and if proper monitoring and control measures are in place to accurately compare actual against planned outputs with corrections applied on time to anomalies to ensure that the project is nudged back on track.

#### *Summarized review of typical productivity improvement measures in the construction industry*

Thematic analysis of the literature insights on common productivity improvement measures in the

construction industry shows several themes and their underlying subcomponents, as presented in Table 2.

**Table 2:** Summary of typical measures for improving productivity in the construction industry (Source: Varied sources)

	Major constrain factors	Subfactors	Source
1	Site/ project characteristics		
a)		Better planning from outset to reduce subcontractors working at the same area of the project	(Dai et al., 2009); Intergraph (2018), (Liberda et al., 2003), (Mohammadi et al., 2020)
b)		Efficient and effective health & safety management can reduce work-related accidents	Intergraph, (2018)
c)		Better project feasibility studies from start to avoid locations where risks of unpredictable ground conditions are high	(Durdyev & Mbachu, 2018),
d)		Well organised & effective traffic management plan to reduce risk of access issues at high trafficable areas	(Lee et al., 2007), (Chan et al., 2001), (Dunston et al., 2000)
2	Project management		
a)		Proper scheduling and coordination of work packages	(Durdyev et al., 2018)
b)		Experienced leadership	(Mahamid, 2013)
c)		Early contractor involvement in early design stages	(Alinaitwe et al., 2007), (Rasel, 2016), (Derek Gill & James Zuccollo, 2012), (Yates & Hardcastle, 2002)
3	Environmental		
a)		Better location study - and specific	(Lau & Kong, 2006)

		environmental conditions such as ground condition and locations near to preserved environment	Intergraph, (2018), (Zakeri et al., 2001), (Alinaitwe et al., 2007)
4	Legal constraints		
a)		Better management of regulations that rule the construction project, such as legal constraints related to work law, safety regulation, & etc.	(Mbachu, Egbelakin, Rasheed, Shahzad, et al., 2017), (Alinaitwe et al., 2007), (Shahzad, 2011), (Howe- Walsh, 2010), (Frost, 2001)
5	Technical constraint		
a)		Accurate design from outset to prevent design changes during construction	(Yates & Hardcastle, 2002), (Arashpour & Arashpour, 2015), (Karim et al., 2013), (Hwang et al., 2016), (Jarkas & Bitar, 2011), (Jarkas, 2015), (Lessing et al., 2017), (Serdar Durdyev & M Reza Hosseini, 2019)
b)		Leveraging technologies to improve efficiency	Intergraph (2018), (Serdar Durdyev & M Reza Hosseini, 2019)
c)		Use of modern work methods and new technologies	(Mbachu & Seadon, 2013), (Kuroshi & Lawal, 2014), Intergraph (2018)
d)		Provide enough training to reduce resistance against using new technologies	(Durdyev & Mbachu, 2018)
6	Workforce-related constraints		
a)		Fair wage payment to increase workforce motivation	(Durdyev & Mbachu, 2011a), (Mbachu, Egbelakin, Rasheed, Shahzad, et al., 2017), (Aynur Kazaz et al., 2008), Intergraph (2018)

b)		Involving workers in decisions affecting them	(Damiani et al., 2016), (Adnan Enshassi et al., 2007)
c)		Clear job description and role clarification	(Mbachu, Egbelakin, Rasheed, Shahzad, et al., 2017)  (Durdyev & Ismail, 2012)
d)		Workforce empowerment through proper training and upskilling	(Adnan Enshassi et al., 2007)
7	Project finance issues		
a)		We have accurate estimates and accurate project budgeting and cost tracking through the whole life cycle of a project.	(Mbachu & Seadon, 2013), (Martinez-Budria et al., 2011)
b)		Low-interest rate finance	(López-Salido et al., 2021)
c)		Increase project quality which will lead to decreasing quality defects and cost of remedial work at the end of the project	(Porntepkasemsant & Charoenpornpattana, 2015), (Takim & Akintoye, 2002)

## 2.6 NZTA's Type of contract for major Infrastructure Projects

The types of Contract required for its capital infrastructure projects has been explained on NZTA (2021a) website as follow:

**Traditional Method:** This method mainly relies on how well the scope of the work is identified.

**Alliancing (Full delivery method):** Comprises a single contract from design to completion. However, different organisations will make special arrangements when considering risk/ reward arrangements.

**Design contract (DC) method:** This approach is usually better when a project is in the feasibility stage. However, it still may be used if a project is at different stages but with different approaches.

**Early contractor involvement (ECI) method:** NZTA (2021a) is suggesting this method to be considered if one of the below scenarios is happening as “this approach is a quality-based

procurement method. To ensure value for money is achieved, it is required to engage an independent parallel estimate peer review and conduct a reconciliation process”.

“An ECI method should be considered if:

- A company is looking to fast track a project, and the expected estimate is generally under \$50 million
- there is uncertainty around scope, and there could be an opportunity for staged design and construction to occur, allowing an earlier start on some enabling works
- there is a strong probability that there might be a need to add other package(s) of work during the design phase
- it is felt that the involvement of construction expertise in the development of a project could ensure that decision-making in the planning and designing is appropriately balanced with constructability issues (e.g. complicated traffic movements)”. (NZTA, 2021a)

## **2.7 NZTA’s types of maintenance contract**

NZTA contracts project to pre-qualified consultants and contractors within their 25 network management areas around the whole of New Zealand. Therefore, NZTA uses different contract types to ensure the highest service levels are met. In order to be able to achieve this goal, NZTA uses five types of contracts for procuring operations and maintenance: Alliances contract type, Performance-Specified contracts, Hybrid contracts, Traditional contracts, and Network outcome contracts.

“**Alliances**– special arrangements in which groups of organisations combine in partnership and work together. For example, an alliance is currently contracted to operate and maintain the Auckland motorway network in a long-term agreement that began in 2008.

**Performance-specified contracts** are awarded for ten years to single suppliers responsible for providing all services. There are five such contracts operating in New Zealand, including one for maintaining the Auckland Harbour Bridge. Most resurfacing work is also done under performance-specified contracts.

**Hybrid contracts**- are awarded for five years and involve consultants and contractors working in a partnering arrangement to deliver services.

**Traditional contracts-** are awarded for varying terms and involve consultants managing suppliers who deliver physical works on the highway network in a similar way to traditional road engineering construction contracts. Most pavement strengthening works, and bridge repairs are managed through this type of contract.

**Network outcomes contracts-** are a new approach to our maintenance and operations to ensure efficiency and effectiveness through better asset management and service delivery. These contracts are awarded to primary suppliers and are performance-based. This is a new contract model, and the contracts are being phased in over the next two-and-a-half years.”

## **2.8 NZTA’s maintenance requirement specification, maintenance monitoring & identifying maintenance locations**

To achieve the required level of maintenance services that must be achieved for state highways’ maintenance contracts, NZTA manages New Zealand’s roading standards and guidelines on behalf of all 74 road-controlling authorities (Mackenzie, 2011).

Moreover, NZTA collects and stores all information regarding maintenance cost per year and per kilometre via Roading Assessment & Maintenance Management (RAMM) database (Mackenzie, 2011). The data are collected by using RAMM covers:

1-Condition data such as skid resistance under dry & wet conditions, the pavement strength, and pavement defects such as rutting, cracks, potholes, etc.

2- Data related to all assets on the state highways includes road structure (e.g. type of pavement), drains, signs, etc.

3- RAMM also records all routine and unexpected maintenance activities.

4- Future road maintenance programmes and plans show the exact expected maintenance time.

5- Maintenance Location and type of required maintenance regarding their significance. RAMM information helps identify the required maintenance location that may require renewal and strengthening. If costs of renewal or strengthening are less than continually maintaining the road, then renewal becomes a high priority.

By using RAMM, NZTA has the advantage of using consistent national comparison of asset data and conditions that help make accurate decisions on time and type of required maintenance as all local authorities in New Zealand use RAMM to manage the inventory and maintenance of their networks.

## 2.9 NZTA's procedure for assessing contractor's performance

The contractor's productivity performance is evaluated at specified milestones or the end of a road pavement maintenance and rehabilitation project (Duran, 2021). The NZTA's project management consultant evaluates each contractor's overall productivity performance by rating the contractor's productivity performance level achieved in the above sub-categories of assessment criteria. Each sub-criterion in a major category subset has a relative weight (RW); this provides insight on the NZTA's relative importance attached to the assessment criterion. The sum of the relative weights of the sub-criteria under each major category subset provides the weight or importance of the category relative to the others. The sub- and major-category relative weights guide the contractor to focus more intently on the priority criteria to ensure successful and satisfactory project delivery.

The assessment framework used by the NZTA aligns with Tonidandel and LeBreton (2011) multivariate analytical technique as expressed in Equation 1.

Equation 1:

$$PS_T = \sum_{j=1}^m \sum_{i=1}^n PS_i = \sum_{j=1}^m PSc_j$$

Where:

- $PS_T$  = Total performance score achieved in all the sub-criteria.
- $PSc_j$  = Performance score achieved in the  $j^{th}$  major criterion.
- $PS_i$  = Performance score achieved in the  $i^{th}$  sub-criterion under the  $j^{th}$  major subset.
- $n$  = Number of sub-criteria under the  $j^{th}$  major subset.
- $m$  = Number of major criteria (i.e. four) used for the evaluation.

The performance score ( $PS_i$ ) achieved in the  $i^{th}$  sub-criterion in a given major subset is the product of the productivity rating point ( $Rp_i$ ) assigned by the project manager and the relative weight ( $Rw_i$ ) of the sub-criterion; this is expressed in Equation 2.

Equation 2:

$$PS_i = Rp_i \times Rw_i$$

The performance score ( $PS_{c_j}$ ) for each of the major subsets is used to identify where productivity is low at the major category level; this is evaluated using Equation 2. 3.

Equation 3:

$$PS_{c_j} = \sum_{i=1}^n PS_i$$

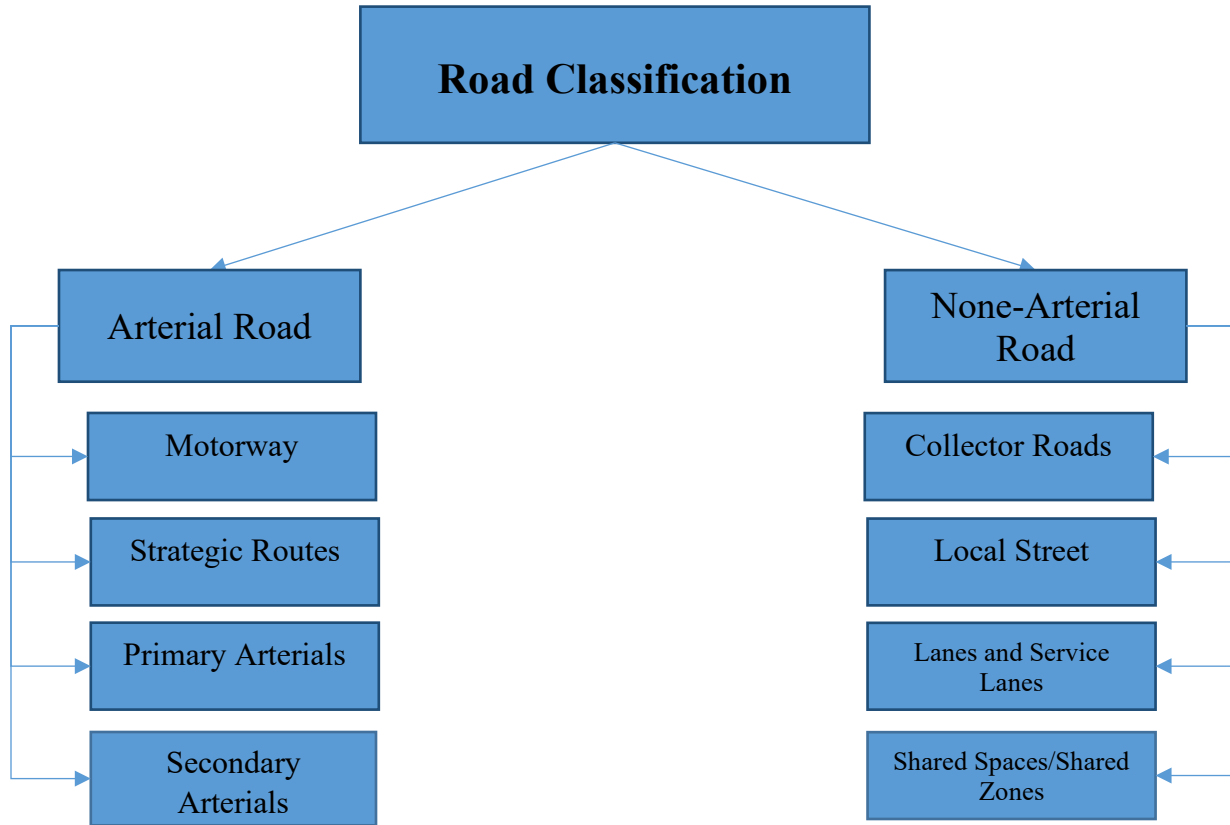
The overall productivity performance score ( $PS_T$ ) and the score for each major category ( $PS_{c_j}$ ) are interpreted in the context of a six-band rating scale to determine the contractor's level of productivity performance out of six possible levels as follows:

- ‘Unsatisfactory Performance’ (i.e.  $PS_T$  or  $PS_{c_j} < 36\%$ ).
- ‘Needs Improvement’ (i.e.  $PS_T$  or  $PS_{c_j}$  within the range 36-49%).
- ‘Acceptable’ (i.e.  $PS_T$  or  $PS_{c_j}$  within the range 50-59%).
- ‘Requirements Fully Met’ (i.e.  $PS_T$  or  $PS_{c_j}$  within the range 60-70%).
- ‘Exceeds Requirements’ (i.e.  $PS_T$  or  $PS_{c_j}$  within the range 71-85%).
- ‘Superlative’ (i.e.  $PS_T$  or  $PS_{c_j}$  within the range 86-100%).

## 2.10 Road classification in New Zealand

New Zealand Transport Agency (NZTA, 2021b) classification system divides NZ's roads, based on traffic volume, locations, and importance into four main categories: 1- High Volume: Primary Collector, 2- National: Secondary Collector, 3- Regional: Access, 4- Arterial: Low Volume.

However, The Auckland Transport Agency has classified all Auckland’s existing roads into two main types: arterial and non-arterial roads. Figure 1 provides a model of the main and sub-types of roads based on this classification (AT, 2013). To help the contractor’s productivity performance, this is evaluated at specified milestones or at the end of a road pavement maintenance and rehabilitation project, which can result in different achievements for different locations, climates,s and types of roads.



**Figure 1:** Road types in New Zealand.

Source: (AT, 2013)

**2.10.1 Arterial road**

Arterial roads are classified by Auckland Transport into four groups: motorways; strategic routes; primary arterials; and secondary arterials (AT, 2013)

***Motorways***

These arterial road types are the highest type of road in the category, which means they are the most crucial type of road. They connect the regions and can be between four and eight lanes, with

traffic volumes generally in excess of 40,000 vehicles per day; they are usually sealed with asphalt. Productivity issues are of critical importance in these road types because they constitute roads of national significance due to the considerable investment in their construction, maintenance, and rehabilitation operations (AT, 2013).

### ***Strategic routes***

Strategic routes are the second type of road in the hierarchy and are intended to carry predominantly through traffic (but many also serve adjacent activities). They connect regions with other regions and connect areas within a region. These types of roads can be between two and six lanes wide and may include significant passenger transport facilities and bus priority measures along the road. Strategic roads generally have over 40,000 vehicles per day traffic, and drivers can drive at moderate to high speeds. These arterial types of routes are comprised of sealed pavement (AT, 2013).

### ***Primary arterials***

Primary arterial roads are intended to carry predominantly through traffic, but many also serve adjacent activities. They connect principal sectors of a region not catered for by strategic routes. They can be designed to have between two and six lanes and may include significant passenger transport facilities and bus priority measures along the road. Traffic volumes may be up to and in excess of 40,000 vehicles per day, and speeds are limited to moderate in urban areas, but in rural areas can be moderate to high. Access to this type of road can be limited or effects controlled by territorial legal authorities (TLA) (AT, 2013). Primary arterial roads are made from the sealed pavement.

### ***Secondary arterials***

This type of arterial road provides movement within the district between key nodes. They connect major nodes within an area and serve adjacent key activities. They form part of either the Fast Transit Network (FTN) or the Local Connector Network (LCN), and they may include significant passenger transport facilities and/or bus priority measures. They can have two to four lanes, and

traffic generally flows up to 25,000 vehicles per day (AT, 2013). They are generally in a moderate speed environment in urban areas and moderate to high speed in rural areas. They may have opposing traffic directions segregated by a flush median, and they all have sealed pavement.

### **2.10.2 Non-Arterial roads**

The NZTA classifies Non-arterials roads into four groups: collector/ connector Roads, local roads/streets; lanes and service lanes; and shared space/shared zones (AT, 2013).

#### ***Collector/ connector roads***

Collector/connector roads collect traffic from local streets in order to connect with arterials. They collect and distribute traffic from local roads to arterials within an area (and vice versa). They also serve adjacent key activities and form part of the FTN, LCN, and/or local services less significant passenger transport facilities. They can be built with two or four lanes and expect traffic flows of typically up to 10,000 vehicles per day. They are generally a moderate speed environment in urban areas and moderate to high speed in rural areas (AT, 2013). They primarily provide access to adjoining properties, and they are generally sealed.

#### ***Local roads/streets***

This type of non-arterial road is a street whose primary role is to serve access to adjacent properties and collect and distribute traffic to/from local properties within an area. They form part of the FTN, LCN, and/or local service, with some limited passenger transport facilities. They are generally built with two lanes and a traffic flow of up to 5,000 vehicles per day. Speed limits in these roads are generally classed as moderate to slow (AT, 2013). They are generally built with a sealed pavement and have significant access to adjoining properties.

#### ***Lanes & service lanes***

These are one-lane roads and provide a side or rear service access or access to a group of dwellings (typically up to 20 lots or dwellings). They primarily provide access to shops, trade units, and high-

density housing of the local street network. Lanes and service lanes are low-speed limit environments and have an expected traffic volume of fewer than 200 vehicles per day (AT, 2013).

### ***Shared space/ shared zones***

A shared space/shared zone is a local street designed to share the road and pavement space between motor vehicles, pedestrians, and cyclists, without indicating a priority for any specific user. These roads have no defined traffic lane(s), and they are in an environment with a very low-speed limit. They are generally sealed and provide access to adjoining properties, where unavoidable (AT, 2013).

### **2.11 Type of road- scope of this research**

This study focused on all road types defined in the NZTA arterial and non-arterial network built with asphalt or chip seal pavement material since the scope of operations for roading contractors was not segregated into road types in the NZTA Register of Pre-Qualified Contractors (NZTA, 2017).

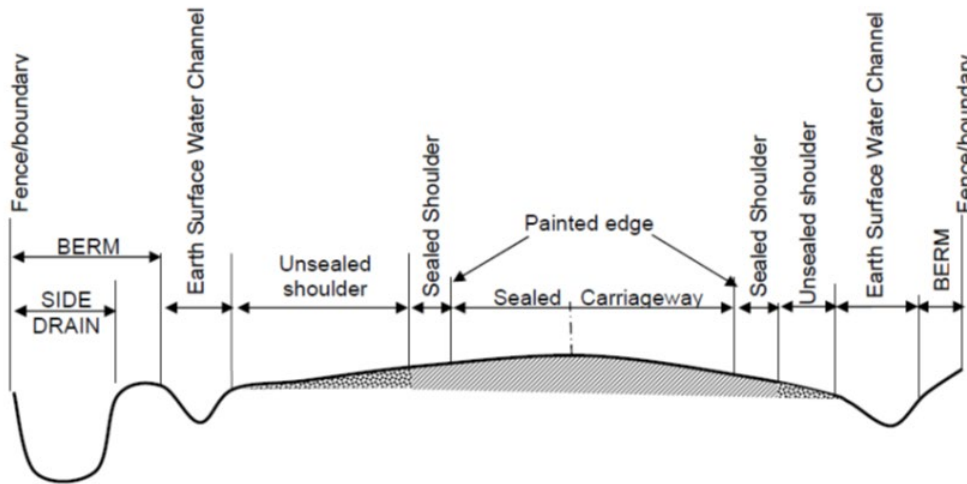
### **2.12 Road pavement maintenance and rehabilitation**

The key factor for pavement preservation is pavement maintenance. However, there are different methods and strategies required to be able to plan successful and productive pavement maintenance or rehabilitation project. As described by Wilde et al. (2014) and a recent study by Mohammadi et al. (2020), the best and, at the same time, effective and productive method of planning a road maintenance project is to consider different strategies and maintenance treatments during the planning process especially applying new approaches such as Lean Construction Principal when planning a road maintenance project. Planning a road maintenance project by considering different strategies and maintenance treatments can ensure the project decision-makers have an effective pavement preservation program that can prevent future defects or delay future required maintenance.

In the following section, road structure has been described briefly to provide informative insights essential for having comprehensive and practical road maintenance and rehabilitation plan that can cover different methods and strategies required to achieve successful project outcomes.

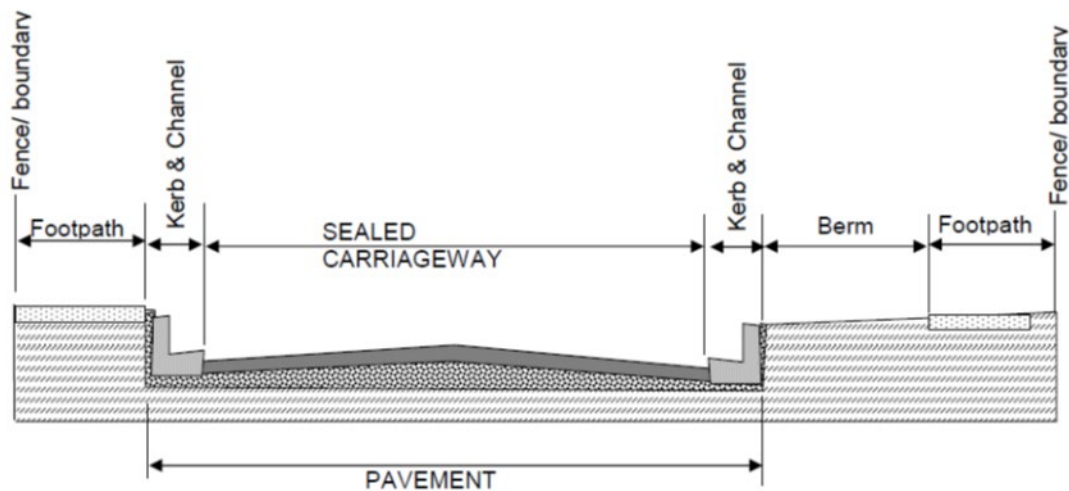
### 2.13 Road pavement: structure/ composition

As described in the Road Assessment and Maintenance Management (RAMM) software manual (RAMM, 1997), for rating road conditions, the road structure needs to be divided into two sections: a road carriageway; and surface water channels and shoulders. Figures 2 and 3 below show typical cross-sections of rural and urban road structures.



**Figure 2:** Cross-section of rural roads

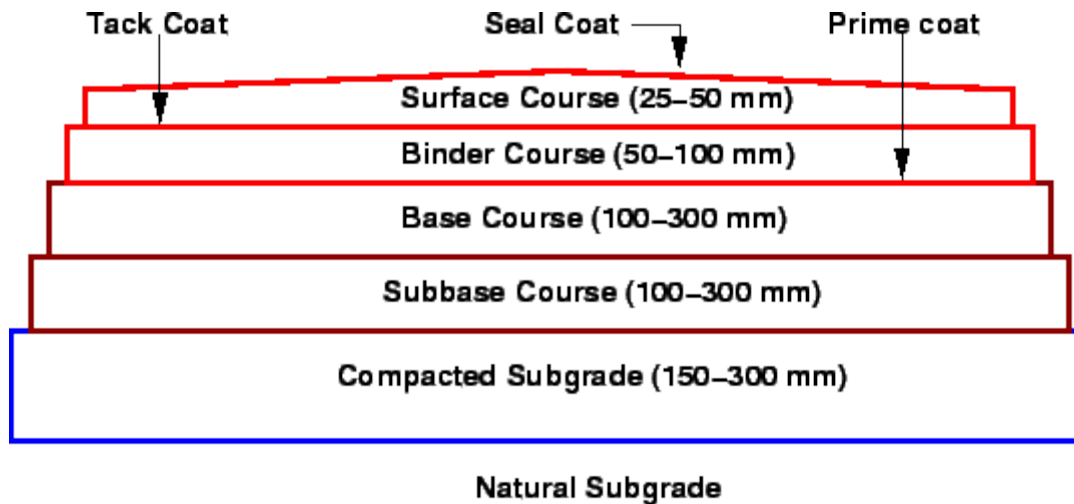
Source: RAMM (1997)



**Figure 3:** Cross-section of urban roads

Source: RAMM (1997)

Figure 4, below, shows a typical asphalt pavement cross-section.



**Figure 4:** Typical cross-section of a flexible sealed pavement (Mathew, 2015)

### ***Relevance***

The above information on the structure, or composition, of typical road pavement design, provides insights into the sources of constraints to productivity in the road pavement maintenance and rehabilitation process from the material, technical, or construction points of view.

### **2.14 Road maintenance management process**

Economic growth is almost impossible unless there is adequate working infrastructure (Pradhan et al., 2018; Thacker et al., 2019). Therefore, an efficient, well-maintained road network is one of the most vital components for robust economic growth (Banerjee et al., 2012). A successful road management system depends on the interaction between three main fundamental components: process, people, and technology (McPherson & Bennett, 2005). A successful collaboration between these components would lead to successful decision-making when managing a road

maintenance or rehabilitation project, leading to a productive outcome for a road maintenance project. Furthermore, well-planned and productive road maintenance will happen when the three components mentioned above interact well. Also it is very important to study and investigate different type of maintenances and their related strategies and their pros & cons well, to be able to plan for a successful and well-planned road maintenance project (Xu et al., 2018).

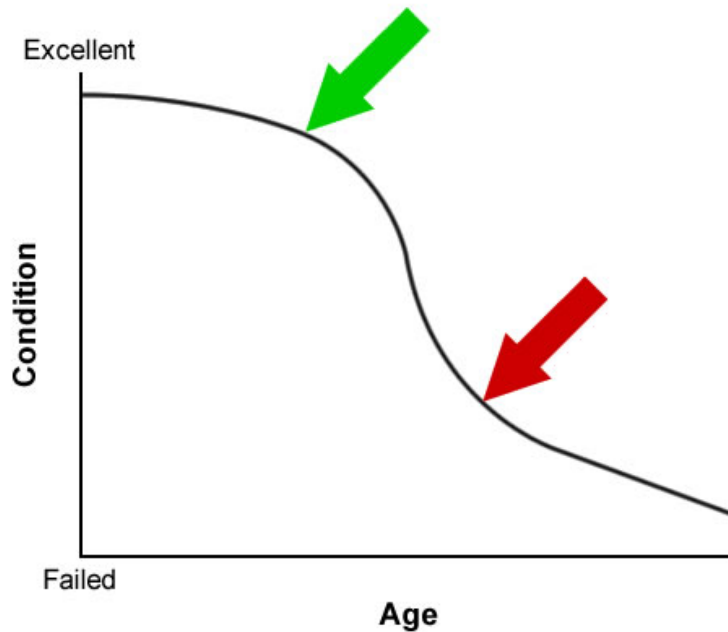
Through regular, productive road maintenance, operators can reduce the rate of pavement deterioration, lower the cost of operating vehicles on the road by improving the running surface, and keep the road open on a continuous basis (France-Mensah & O'Brien, 2019).

Road maintenance can be classified into three types of maintenance. Johanns and Craig (2002) explained these three categories of road maintenance as preventive maintenance corrective maintenance, and the last one, if a road operator ignores the first two types of maintenance, is emergency maintenance or rehabilitation.

### **2.15 Preventive maintenance**

In recent years, road network maintenance methods have been developed & advanced to optimise the quality and effectiveness of road maintenance projects. However, the main principles of all these methods can be summarised in three main phases of road maintenance: preventive maintenance, corrective maintenance, and emergency maintenance.

Preventive maintenance is the essential type of maintenance as it can significantly enhance productivity in road maintenance projects. It is more cost-effective and efficient boosting than other types of maintenance. Applying preventive maintenance during the early stages of road failure can delay costly corrective maintenance or rehabilitation (Wang, 2021). As stated by Wang (2021), the main goal of applying preventive maintenance is to reduce ageing and restore serviceability and durability, not increase capacity or strength.



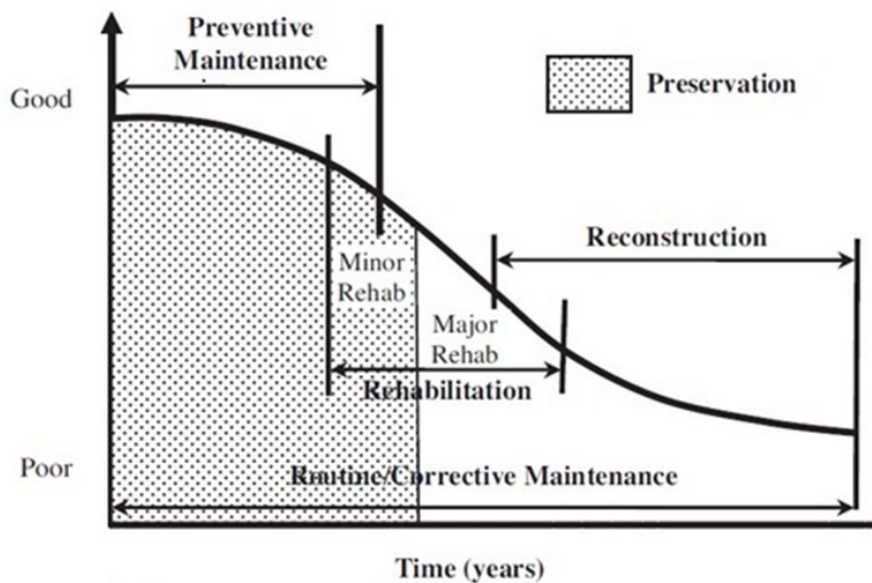
**Figure 5:** Condition vs Age

source: Al-Mansour and Sinha (1994)

“Under most circumstances, the condition of pavement over time can be represented by a curve similar to the one shown in [Figure 5]. The worse its condition gets, the more expensive the treatment required to restore the pavement to good condition, so you want to apply an appropriate treatment in the right general area on this curve.” (Pavement-Inperactive, 2013), (Bahar et al., 2003).

Unfortunately, a lack of appropriate preventive maintenance can decrease the productivity rate by increasing the costs of maintenance projects in the future. Preventive maintenance can stop pavement deterioration at early stages. Basic routine maintenance, such as crack sealing, patching, and basic shoulder maintenance, will slow down the pavement deterioration process, meaning expensive corrective maintenance, such as resurfacing, can be deferred (Giustozzi et al., 2012a; Giustozzi et al., 2012b).

Peshkin et al. (2007) illustrated, in the graph shown in Figure 7 below, how focusing on and applying preventive maintenance is much more effective than corrective maintenance.



Source: Ad

**Figure 6** : Preventive maintenance vs corrective maintenance

Source: (Peshkin et al., 2007)

### 2.16 Corrective maintenance

When road pavement deteriorates to such a level that the serviceability of the road is affected, pavement maintenance is required; this step is called corrective maintenance in road maintenance projects. Corrective maintenance is a chain of tasks to identify, plan and rectify a defect as quickly as possible to ensure that the defective area is restored to an operational condition again. Corrective road pavement maintenance is costlier than preventive maintenance. The scope of corrective pavement maintenance is from pothole repair to full depth mill and fill so that the road can be operational in the shortest possible time (Giustozzi et al., 2012b).

It is important to mention that road pavement performance is closely related to the type of pavement; therefore, the type of corrective maintenance and its associated costs are greatly affected by the type of pavement. As described by Cuelho et al. (2006) and also in a book written by Li et al. (2021), usually the type of preventive maintenance and treatments investigated, planned, managed and implemented by responsible parties through a process include the following three stages:

- 1) Establishing and deciding on choosing the most appropriate preventive maintenance treatment., This stage includes recording the frequency of use of specific preventive treatment methods
- 2) Carefully evaluate the effectiveness of the chosen maintenance treatment method, which helps to choose the most effective treatment method in the future
- 3) Investigate, monitor and report the life-cycle effectiveness of different types of treatments.

### **2.17 Emergency maintenance**

Emergency maintenance is a type of maintenance that is usually required in any natural disaster, such as when earthquakes happen. Johanns and Craig (2002) explained emergency maintenance as:

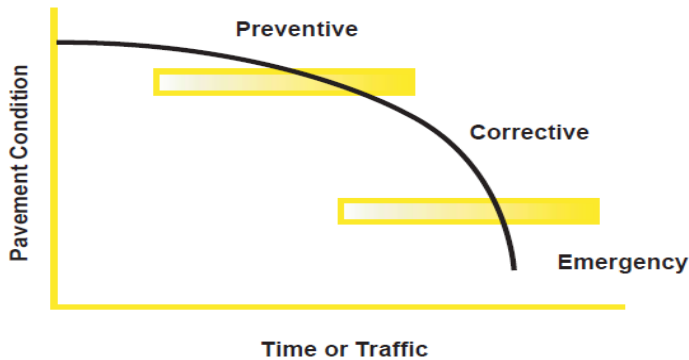
“Emergency maintenance is often related to safety and time, with cost not being a primary consideration. Likewise, materials that may not be acceptable for preventive or corrective maintenance may be the best choice for emergency situations”. (Johanns & Craig, 2002, p. 4)

The frequency of emergency maintenance cannot be estimated accurately in advance, as it is usually required due to a natural disaster or road accident (Garber & Hoel, 2014). Emergency maintenance usually includes clearing a road that has been severely damaged, cut or blocked by clearing debris, preparation for repair or rehabilitation and, finally, pavement maintenance or performing a full repair. As it is socially and economically very important and crucial for affected areas to be connected again to the rest of the roading network urgently, usually associated costs are higher than other maintenance methods because urgent actions need to be executed without considering the associated costs (Amin et al., 2019).

### **2.18 Preventive maintenance versus corrective maintenance and rehabilitation**

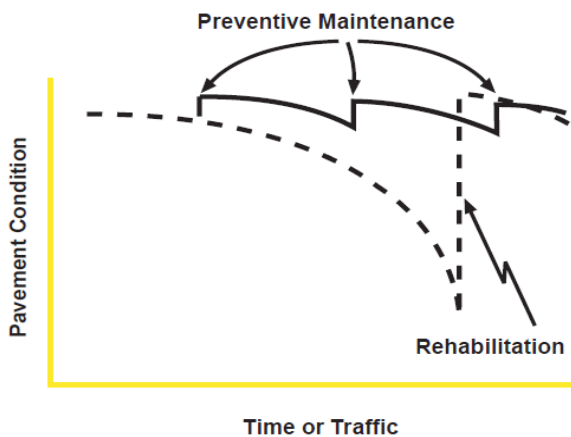
It is evident that the most important type of road pavement maintenance is preventive maintenance, as it has a significant impact on reducing the cost of corrective maintenance or rehabilitation. Pavement preventive maintenance can significantly reduce the cost of corrective maintenance; therefore, it can significantly impact increasing productivity in RPMR.

Johanns and Craig (2002) have shown the time and effect of these different maintenance types (see Figures 7 and 8).



**Figure 7:** Categories of pavement maintenance

Source: Johanns and Craig (2002)



**Figure 8:** Performance of preventive maintenance treatment

Source: Johanns and Craig (2002)

Preventive maintenance has been defined as the “planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without increasing the structural capacity” (Johanns & Craig, 2002, p. 5).

Johanns and Craig (2002) also stated that extending the useful life of airfield asphalt pavements, even by a minimum of 20 per cent, could increase efficiency and save hundreds of millions of dollars in additional maintenance and rehabilitation costs.

All of the aims mentioned above are achievable by having an integrated management process, and, obviously not having an efficient management system can create constraints against improving productivity in RPMR.

A review of international literature on road maintenance management tasks can help inform methods for improving productivity in managing road maintenance projects. To achieve this goal, it is crucial to know the critical tasks for managing road maintenance projects; therefore, it is important to identify the key constraints that exist in each task. Road maintenance management tasks include planning, programming, data collection, preparation, monitoring strategies, performance strategies, cost-benefit analyses, and decision-making.

### **2.19 NZTA contract for road maintenance and rehabilitation**

NZTA contract with roading contractors in relation to road maintenance and rehabilitation is governed by the provisions of the Network Outcomes Contract (NZTA, 2015a). It is a performance-based lump sum and measure and value contract that seeks to reward contractors based on the final product's performance rather than services offered. Mirzahosseinian and Piplani (2011) defined performance-based contracting as a results-oriented contracting method that focuses on the outputs, quality, or outcomes that may tie at least a portion of a contractor's payment, contract extensions, or contract renewals to the achievement of specific, measurable performance standards and requirements.

The contract specifies the desired results or deliverables at milestones or the final stage. A set of performance measures is defined to objectively measure the contractor's performance against the quality desired of the output at the performance stage (Manogaran et al., 2021). The key characteristic of this type of contract is that a set of performance levels is set for the performance measures which guide the contractors on how well they need to perform at each level. A set of payment regimes is provided, which define how much the contractor is being paid for their performance level achieved. Overall, an incentive scheme is administered to reward superior performance and penalise sub-standard performance.

### 2.19.1 Contract outcomes

The Principal's overall objective in the contract is to encourage quality performance outcomes with a particular interest in the following key areas, which constitute the Principal's Key Result Areas (PKRAs) (Manogaran et al., 2021):

- a) **Safety:** This is a measure of achievement and commitment to health and safety outcomes. It aims to encourage opportunities to improve safety outcomes for customers (Wanberg et al., 2013).
- b) **Customer:** Customers' access needs are of prime importance. Contractors are required to respond to customers' requests and manage their expectations while implementing the workflow.
- c) **Sustainability:** Contractors are required to maintain a sustainable and engaged contracting operation. This measure seeks to contribute to a transport system that adds positively to New Zealand's economic, social and environmental welfare by encouraging contractors to adopt good practices and always act in an environmentally responsible manner.
- d) **Quality assurance and value:** Quality outcomes are underpinned by accurate network information and knowledge. Contractors are required to make sound investment recommendations and decisions based on reliable, robust and proven evidence.
- e) **Network performance:** This is a set of physical indicators of service quality. Contractors are required to demonstrate that promises made during tendering add value and are delivered. Network users should be given timely and accurate information to make informed choices and schedule works to minimise disruption.
- f) **The health of the relationship:** The Principal intends to establish a working relationship with the Contractor that fosters open and honest dialogue and feedback, including greater involvement of subcontractors and recognition of their value. By this criterion, contractors' performance is assessed based on the quality of relationships with the key stakeholders, including the subcontractors that work for them and the consultants that supervise their work (Olsen, 2016) (Stankevich et al., 2005).

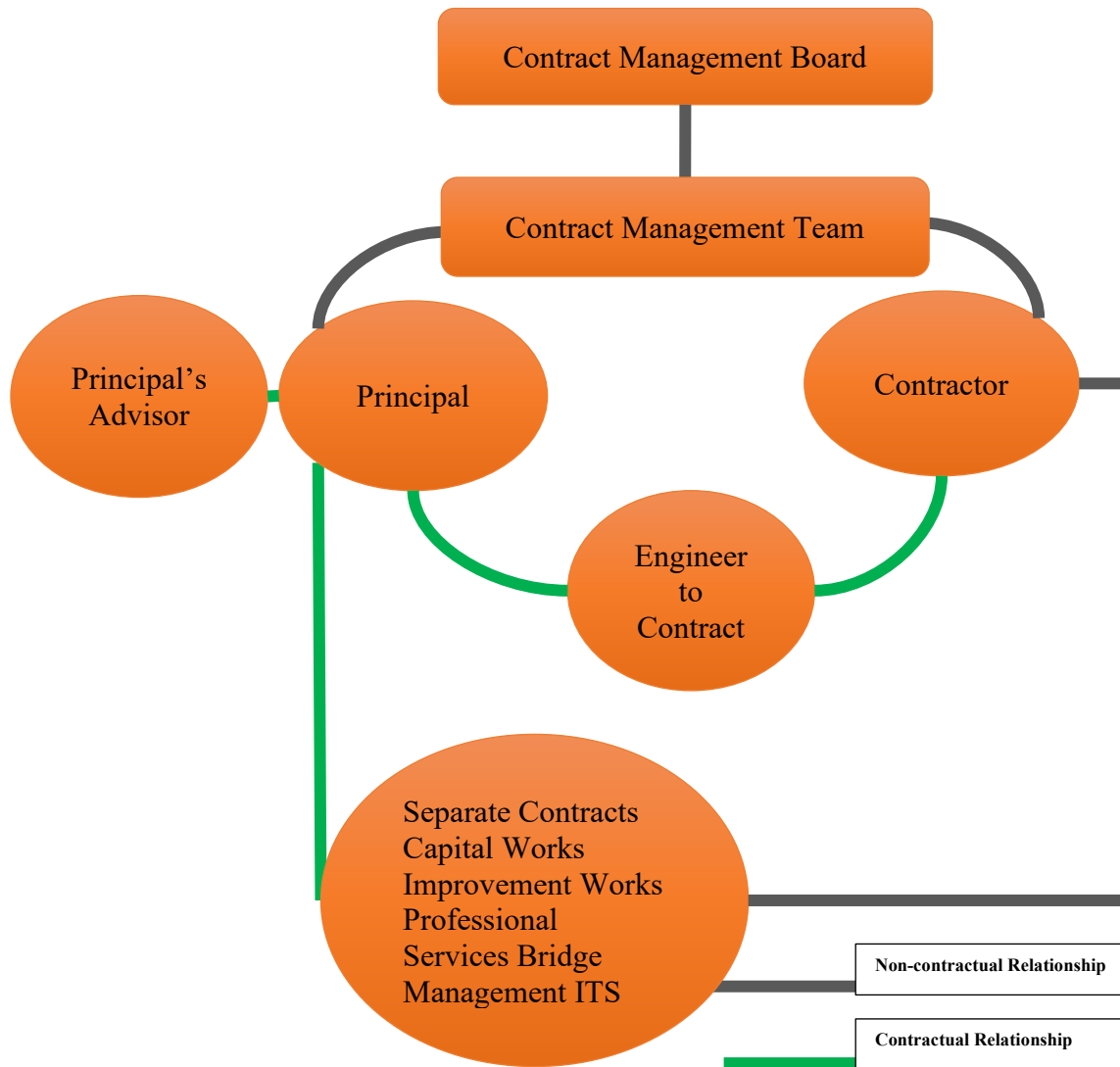
### **2.19.2 Contract outcomes in the context of New Zealand**

As mentioned in the above section, the New Zealand Transport Agency (NZTA, 2015) measures the contractors' interim and end-of-project productivity performance based on their levels of achievement of the performance assessment criteria specified for the work category they are prequalified for, to undertake. In the newly published manual of NZTA (NZTA, 2015a), they have set out four criteria as the main performance-based productivity assessment criteria: Management, Production, Health & Safety, and Administration. The NZTA's project management consultant uses these four main criteria to evaluate each contractor's overall productivity & performance level.

In the following section, roles and responsibilities in the NZTA's network outcome contract have been presented.

### **2.19.3 Contract roles and responsibility relationships**

Figure 9 shows the roles and responsibilities of relationships in the NZTA's Network Outcomes Contract. It understands the roles and responsibilities help to gain insights into how NZTA defines and monitors productivity and performance of the leading contractors and therefore is an important insight into productivity issues in the sector.



**Figure 9:** Roles and responsibility relationship in the NZTA Network Outcomes Contract (NZTA, 2015b)

## 2.20 Constraints in road maintenance and rehabilitation

Identifying key constraints in improving productivity and performance in Road Maintenance and Rehabilitation projects is essential to be able to direct available resources towards eliminating, mitigating, or transferring the risks involved (Aziz et al., 2017; Diewert, 2001; Dunston et al., 2000).

A few studies have been conducted in the past to identify productivity constraints in road maintenance projects. However, within the construction sector, Durdyev (2011) has provided a

holistic model of internal and external productivity constraints that use a global framework, PESTELI (Political, Economic, Socio-Cultural, Technology, Legal/Political, and Industrial constraints). Also, internal constraints can be assessed from the scope of the six Ms of the business process improvement, as explained by Prasad (1999): money/finance; management of the workforce; manpower; machinery; materials; and method process. Also, a study by Chan et al. (2001), with a focus on RPMR, has listed 83 factors related to improving productivity and performance in road pavement maintenance. The study findings showed that focusing on managing these 83 potential delay factors can improve productivity rates. However, none of these studies provided a professional or expert's point of view about how to mitigate these constraints. It needs to be mentioned that the main focus of this study was to compare the findings from literature with professionals' points of view in regards to identifying the existing constraints raised by professionals and experts who work in the road maintenance and rehabilitation industry in New Zealand, which helps to mitigate constraints and improve productivity in RPMR.

### **2.20.1 Challenges in road maintenance and rehabilitation in the context of countries with similar economical & geographical conditions with New Zealand**

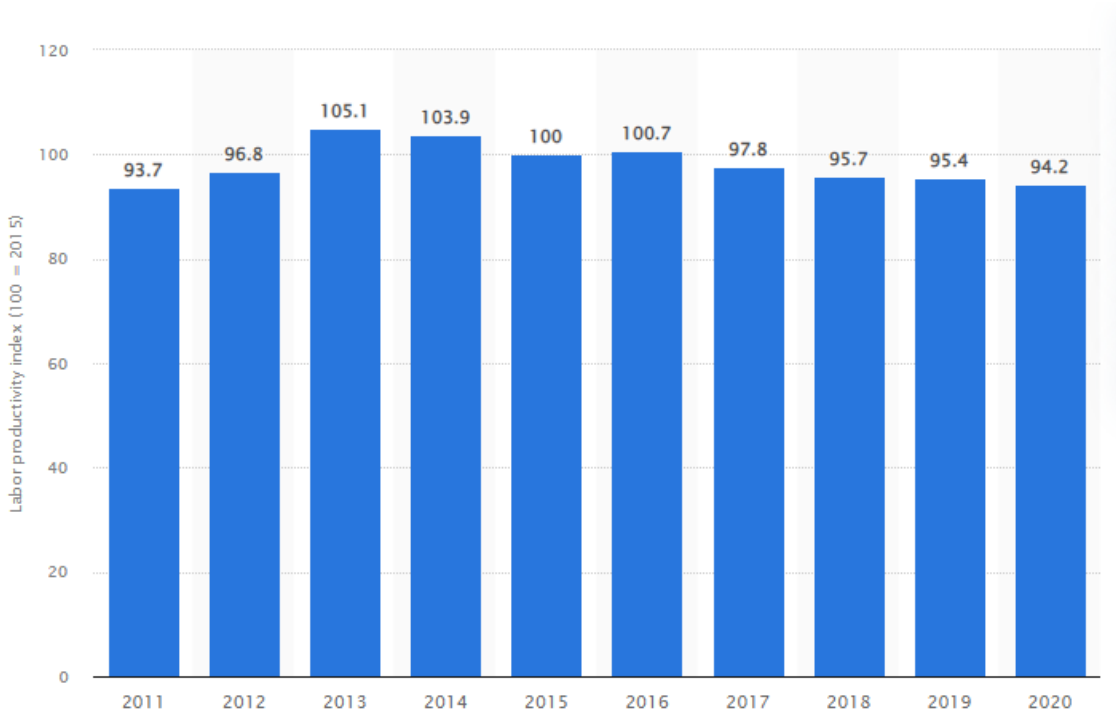
There is little research on the key constraints to contractors' productivity performance in the specific domain of road pavement maintenance and rehabilitation projects in the New Zealand context. However, a review of related literature reveals several studies on the topic in other countries. While the challenges facing roading contractors as identified in some of the overseas studies could apply to some extent in the New Zealand context, investigation of the unique constraints and challenges faced by New Zealand road pavement contractors may be necessary, given the unique socio-cultural, economic and regulatory environment within which the New Zealand roading maintenance contractors operate; these may be different from those shaping outcomes in other countries. Mbachu et al. (2017) corroborated this uniqueness by arguing that effective and enduring solutions are found when specific needs of organisations are articulated from key stakeholder views, ensuring that the solutions are in strategic alignment with their specific contexts such as their unique operational environments, regulatory frameworks, cultures, values, capabilities and capacities. Some of the challenges countries such as Japan or Korea face in maintaining a reasonable productivity rate when doing road maintenance projects which are

similar to New Zealand, are discussed below.

There are many similarities between NZ, Japan and Korea in terms of the geographical conditions, which has led to similar challenges against improving productivity in the construction industry in both Japan and NZ; however, this research explains a couple of them in the below sections.

Japan is one of the examples of an island nation with similar geographical similarities to New Zealand. Japan has had a declining productivity rate in construction mainly due to its ageing workforce, which led to a lack of skilled workers, the same as New Zealand (Popa & Pisaniuc, 2020).

As mentioned above, one of these challenges is Japan's ageing population (Desvaux et al., 2015; Hashiguchi et al., 2020), which has become a key constraint against productivity improvement (Baily et al., 2020). The table below (Popa & Pisaniuc, 2020) shows a declining productivity level in the construction industry in Japan from 2013 to 2020.



**Details:** Japan; Ministry of Internal Affairs and Communications (Japan); 2011 to 2020; figures based on facilities with five or more employees

**Figure 10:** Labor productivity index (LPI) of the construction industry in Japan from 2011 to 2020 (Popa & Pisaniuc, 2020).

It needs to be mentioned that the lack of skilled labourers is also one of the main constraints of productivity in the New Zealand roading industry nowadays (Ghodrati et al., 2018).

Another similar constraint that makes Japan face challenges against improving productivity in roading projects is Japan’s island climate weather conditions & inclement weather, which are very similar to New Zealand (Schuldt et al., 2021).

Korea is another country with geographical conditions with similarities with New Zealand. Such as Japan and New Zealand, one of the main challenges against improving productivity in roading and the general construction industry in Korea is inclement weather (Cho et al., 2021). The other main constraint which hinders productivity in the roading sector is the lack and accurate and certain plans and designs (Kim et al., 2021).

The above discussion was a few similar constraints of productivity improvement between New Zealand and countries like New Zealand; however, in the below chapter, the focus is on constraints hindering productivity in the New Zealand Road Maintenance industry.

**2.20.2 Summary of Constraints in road maintenance and rehabilitation**

A thematic analysis of the key constraint factors found in these studies was carried out and summarised in Table 1. The table shows nine broad constraint categories: finance; workforce; deploying new technologies in the industry; operation process; project characteristics; project management; statutory compliances; industry characteristics/market conditions; other external forces; and external forces related to operational processes.

These are discussed more fully in the following subsections.

**Table 3:** Factors influencing road’s pavement maintenance productivity (source: Varied)

Broad constraint category	Sub-constraints	Authors
	Inaccurate estimate	Kim et al. (2021), Garg and Rawat (2021), Labi and Sinha (2005), Mbachu and Nkado (2007),
	Lack of collaboration between consultant & contractor	

<b>Project Finance Issues</b>	Inadequate supply or high cost of needed resources: money, men, materials & machinery	Alaloul et al. (2021); (Hasan et al., 2018), Mbachu and Seadon (2013), Zakeri et al. (2001), Frost (2001), Reeves and Kapitzke (2001), Chan et al. (2001), Melitz and Ottaviano (2008), Nijkamp and Ubbels (2000), Martinez-Budria et al. (2011), Mbachu (2011), Shahzad (2011), NZTA (2014b), Hastak and Baim (2001), Obodoh and Obodoh (2016)
	Construction-phase defective or non-compliant work	
<b>Workforce</b>	Lack of good leadership/management capability	Kyei and Bamfo-Agyei (2021), Won et al. (2021), Alaloul et al. (2021), Alaloul et al. (2021), Black and Lynch (2001), Gqaji et al. (2016), Pajic et al. (2021), Hasan et al. (2018), Durdyev (2011), Mbachu and Nkado (2007), Mbachu (2008a), Mbachu and Seadon (2013), Zakeri et al. (2001), Durdyev (2011), DBH (2009), Rasel (2016), Damiani et al. (2016), Black and Lynch (2001), Chan et al. (2001), Adnan Enshassi et al. (2007), Fabling and Grimes (2010), Tohidi (2011), Mason et al. (2012), Guthrie (2001), Herzberg (2017), Skipper and Bell (2006b), Skipper and Bell (2006a)
	Low level of motivation/commitment	
	Low level of skill and experience of the workforce	
	Poor monitoring or appraisal of performance	
	Overly long working hours with insufficient rest periods, especially during night work	
<b>Deploying New Technologies in Industry Operation Process</b>	Resistance to accept new technologies in road maintenance projects (include new methods & materials)	Chen and Zheng (2021); (Naseri et al., 2021) Cammeraat et al. (2021), Alaloul et al. (2021), Gulotta et al. (2019), Hasan et al. (2018), Durdyev (2011); (Hasan et al., 2018), Mbachu and Nkado (2007), Mbachu (2008a), Mbachu and Seadon (2013), NZTA (2014a), DBH (2009), Alinaitwe et al. (2007), Abe et al. (2001), Alshibli et al. (2005), Arnold et al. (2009), "Transport Research Laboratory (TRL) Highways Agency Road Research Information System 2 (Harris2)" 2013), Transfund New Zealand, (2009), ( <i>Automated Pavement Cracking Assessment Equipment: State of Art</i> , 2003), Bjork (2003), Chamberlain (2005), Chan et al. (2001), Phillips and Kazmierowski (2010), Tsai et al. (2010), Gambatese and
	Ineffective approach to road maintenance	
	Lack of adequate training on new processes and technologies	
	Inadequate road failure detection system	

		Hallowell (2011), Gavilan et al. (2011), Holloway (2011), Wang et al. (2011), Rogers et al. (2012), Haji Karimian (2014), Roe (2005)
<b>Project Characteristics</b>	Site's location and environmental constraints (e.g. traffic volume, climate, subsoil and topography)	Hamza et al. (2019), Hasan et al. (2018), Lee et al. (2002); Wilinon et al. (2010), Lee and Ibbs (2005), Lee et al. (2006), Alinaitwe et al. (2007), (Ball & Patrick, 2005), Bernard et al. (2000), Chan et al. (2001), Dunston et al. (2000), Ellis Jr and KUMAR (1993), Hancher and Taylor (2001), Mostafavi et al. (2012), (Goodrum et al., 2011), (Sun et al., 2015)
	Planning & logistic issues impacting on continuous workflow (e.g. non-closure period)	
	Un-conductive time frames within which most road works must be carried out	
<b>Project Management/ Project Team Characteristics</b>	The frequency of design changes/ change orders/ late changes	Fashina et al. (2021), Hamza et al. (2019), Hasan et al. (2018), Brooks et al. (1990), Johanns and Craig (2002), Zakeri et al. (2001), Frost (2001), Rasel (2016), Damiani et al. (2016), Black and Lynch (2001), Cottman and Chamala (2001), Alinaitwe et al. (2007), Chan et al. (2001), Chan et al. (2001), Fabling and Grimes (2010), Müller and Turner (2010), Connell (2012), Gill and Zuccollo (2012), Sunitha et al. (2013)
	Lack of sufficient planning from the outset	
	Lack of effective communication/ clarifications of expectations among key stakeholders	
	Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council	
	Lack of organizational learning: Learning from previous projects	
	Client's overt influence on the project process	
<b>Statutory/ Regulatory Compliance</b>	ISO 9001-Quality ISO 14001-Environmental standards	El-Dash et al. (2022), Hasan et al. (2018), Lee et al. (2002); Wilinon et al. (2010), Lee and Ibbs (2005), Lee et al. (2006), Frost (2001), Alinaitwe et al. (2007), Assaf and Al-Hejji (2006), Durdyev and Mbachu (2011a), Shahzad (2011), Walsh (2010)
	Local Authority Bylaws	
<b>Unforeseen Circumstances</b>	Inclement weather	Quezon and Ibanez (2021), Alsharif et al. (2021), Hamza et al. (2019), Zakeri et al. (2001), Assaf and Al-Hejji (2006), Alinaitwe et al. (2007), Baynes (2010), Chan et al. (2001), Dunston et al.
	Unforeseeable ground conditions forcing design revision revisions	
	On-site accidents/ Acts of God	
	Natural disasters	

		(2000), Noyce et al. (2007), Purushothaman and Kumar (2022),
<b>Other External Factors</b>	Market conditions and level of competition in the industry for jobs	Alsharef et al. (2021), (Hasan et al., 2018) Alinaitwe et al. (2007), Chan et al. (2001), Goodwin and Pisano (2003), Thapanont et al. (2018)
	Inflation/ fluctuations in material prices	
	Energy crises/ rising costs	
	Interest rate/ cost of capital	
	Fluctuations in the exchange rate	
<b>Other external forces related to the operation process</b>	Post-construction defective or non-compliant work	Duran (2021), Alaloul et al. (2021), Chan et al. (2001), Ian C Page (2010), Knocke (2003), Hancher (1994), Jia-liang and Qing-hua (2012), Jamal Khattak and Airashidi (2013)
	User/Client value perceptions	
	The durability of completed work within the defect's liability period or warranty/ guarantee	

**2.20.1 Finance-related constraints to productivity in road maintenance and rehabilitation**

The literature review revealed four sub-factors under finance-related constraints: inaccurate estimate; lack of collaboration between consultant and contractors; inadequate supply of high cost, needed resources: money, men, materials and machinery; and under-valued work involved (Hasan et al., 2018). Labi and Sinha (2005) & recent studies such as Alaloul et al. (2021) discussed that maximum cost-effectiveness and the corresponding level of annualised project maintenance are influenced by the pavement functional class and cost components considered. Hasan et al. (2018) and older studies such as Frost (2001) investigated the importance of financial factors and their impact on productive and effective decision-making. He challenged a commonly held view that more investment is needed to arrest the declining state of the road system. He suggested that investments should only be increased when it can be satisfied that the current investment is being spent optimally and productively. Reeves and Kapitzke (2001) emphasised the impact of the budget on choosing the road pavement maintenance method and procurement type.

Hastak and Baim (2001) explained another point of view:

“During the life cycle of any public facility, various risk factors might influence the performance and operating cost of the infrastructure. The risk factors influence the facility's longevity, fitness, and adaptability, dictating the necessity and timing of renewal or rehabilitation. It identifies risk factors that influence the cost-effective management,

operation, and maintenance of bridges, roads and highways, and subway stations as well as how and when in the project life cycle the identified risk factors affect the associated facility costs” (P.1).

However, these studies can all be argued against, as none provides any suggestion or method for tackling existing issues to improve productivity.

## **2.20.2 Workforce-related constraints to productivity in road pavement maintenance and rehabilitation**

Workforce related constraints are rated by many researchers as one of the most critical factors impacting productivity in the workplace. A literature review reveals various ways in which workforce-related issues impact productivity; some of these are discussed in the following subsections.

### ***Lack of good leadership/management capability/ Low level of commitment or motivation***

Khanh and Kim (2022), Durdyev and Mbachu (2018) & Mostafavi et al. (2012) showed that factors such as lack of good leadership or management capability have a negative impact on the productivity of the workforce. This is because the workforce follows the directions and visions of the leadership, and when such visions are not transparent or productive, it will be difficult for the workforce to be inspired to put in their best and achieve high levels of productivity. This is also presented in several recent and older articles written by researchers such as Arifani and Susanti (2020) & Skipper and Bell (2006b) that leadership behaviour highly affects productivity as a skilled and experienced leader can increase an employee’s motivation, making sure they all are following all the systems procedures correctly, thus leading to increased productivity and performance which directly effecting productivity rate of a project.

### ***Low level of skill and experience of the workforce***

Intergraph (2018) found that poor quality and remediation costs increase the resource inputs and, therefore, significantly lower the productivity performance in the workplace. Also, Mbachu, Egbelakin, Rasheed and Shahzad (2017) argued that high productivity levels are underpinned by high levels of skill and experience of the workers; this means that productivity will suffer if the

skill and experience of the workforce are not sufficient for the desired level of quality and productivity for the project.

From a different perspective, some studies such as Hamza et al. (2019) & Gambatese and Hallowell (2011) indicated that workers' low level of skill and experience require closer supervision and resource costs, which could negatively impact productivity at the tasks and project levels.

Poor management, low level of commitment/ motivation, poor workforce monitoring, long working hours, inadequate training, poor resource management, workforce sicknesses and other health issues and subsequent absenteeism, and lack of experience, are the most important productivity constraints in the construction industry. These have been supported by some reports from the Building and Construction Sector Productivity Taskforce (DBH, 2009) & productivity institute (Patrick Nolan, 2019), which emphasised skill shortage as one of the most important factors influencing the low rate of productivity in the construction sector in New Zealand from 1997 to 2019. Need to mention that skill shortage still continues today (Rotimi et al., 2022).

Researchers, such as Damiani et al. (2016), Black and Lynch (2001), and Rasel (2016), have examined the impact of human capital investment on productivity, and their findings revealed the importance of using new methods of labour management. This can improve productivity while using traditional labour management can lower productivity. However, the above findings can be criticised, as there is no explanation for the question of what type of management has had what type of outcome? Alternatively, what regime is being used to compare traditional management styles with new methods?

### **2.20.3 Technology and process-related constraints to productivity in road pavement maintenance and rehabilitation**

***Resistance to accept new technologies in road maintenance projects (include new methods & materials), Ineffective approach to road maintenance, lack of adequate training on new processes and technologies, and Inadequate road failure detection systems.***

As the following research results show, using technology can hugely affect productivity improvement in road pavement maintenance and rehabilitation.

An in-depth literature review revealed that seven types of constraints exist in regard to improving productivity in road pavement maintenance and rehabilitation. These are (i) resistance to accepting new technologies in road maintenance projects (including new methods and materials); (ii) ineffective approaches to road maintenance; (iii) lack of adequate training on new processes and technologies; (iv) inadequate road failure detection systems; (v) inadequate IT infrastructure and application in the road maintenance industry; (vi) suitability or adequacy of the plant and equipment employed; and (vii) insufficient monitoring processes for road failure detection.

NZTA (NZTA, 2014a) research investigated the accuracy and effectiveness of collected data and concluded that it could improve productivity by using a new visual road condition rating system, such as the New Zealand version of Deighton's Total Infrastructure Management System (NZdTIMS) modelling. They suggested that this new technology can be used confidently to support asset management decisions. However, they have not tried to find any related constraints regarding using new technologies. Li et al. (2022), Wang (2021) and some of the older studies, such as Abe et al. (2001), Arnold et al. (2009), and Chamberlain (2005), all recommended using new technologies for measuring pavement texture condition, can increase the accuracy of the decision-making processes.

Also studies by Gulotta et al. (2019) & Li et al. (2021) presented that using new pavement technologies such as using new methods of using recycled materials can not only have positive impact on environmental costs of a pavement project but also have positive impact on road pavement projects productivity rates due to reducing the cost of required materials and maintenance costs.

Several studies such as Black and Lynch (2001) and Bjork (2003) and more recent studies such as Cammeraat et al. (2021) mentioned that productivity is higher in businesses with better-educated workers or greater computer usage by non-managerial employees. This is also applicable to road pavement maintenance projects because having a skilled workforce and management team means new technologies can easily be accepted, leading to higher productivity.

#### **2.20.4 Project characteristics related constraints in road pavement maintenance & rehabilitation**

*Site's location and environmental constraints (e.g. traffic volume, climate, subsoil and topography), Planning & logistic issues impacting continuous workflow (e.g. non-closure period), Un-conductive time frames within which most road works must be carried out.*

Several studies recognised project characteristics as an important factor that can impact productivity. Durdyev and Mbachu (2011b), (2018) explained that project characteristics can be one of the most important constraints against productivity or can improve productivity by making the right decisions at the right time.

Project characteristic constraints can be classified into eight subfactors: (i) site location; (ii) planning; (iii) unconductive time frames; (iv) public notification issues; (v) accepted type of procurement; (vi) the complexity of the project; (vii) maintenance or rehabilitation size; and (viii) type of road in the road hierarchy. A recent study by Li et al. (2022) and an older study by Cottman and Chamala (2001) findings showed that road type and the emerging maintenance environment in different places could and has been significantly impacted productivity. A study by Shan et al. (2020), & Khanh and Kim (2022) also argued that project characteristic-related constraints are one of the important factors for the planning stage. Several studies such as Naseri et al. (2021), Chen and Zheng (2021) and an older study by Ball and Patrick (2005) findings showed the impact of choosing correct strategies during a maintenance project. The research findings revealed that effective resealing strategies could increase seal life and prevent seal layer instability, thereby improving productivity in RPMR. However, none of these studies has suggested any methods for mitigating the project characteristic-related constraints.

#### **2.20.5 Project management-related constraints to productivity in road pavement maintenance and rehabilitation**

*The frequency of design changes/ change orders/ late changes*

The frequency of design changes/ change orders/ late changes are well-known productivity constraints, and as several studies such as Zidane and Andersen (2018) & Kermanshachi et al. (2018) described, they have an actual impact on project productivity on a big scale project because

they are often more significant than expected. Usually, a lack of knowledge, experience, and understanding of the impact of changing design during a construction project and not at early stages of a project can lead to severe impacts on the productivity rates of the project. This finding is also supported by other researchers such as Al-Kofahi et al. (2020) and Kong et al. (2020).

### ***Lack of sufficient planning from the outset***

Lack of enough planning from the outset also has been recognised by many productivity field researchers for many years, such as Olawale and Sun (2010), Mbachu and Taylor (2014) & Hasan et al. (2018) as one of the main important constraints that can result in a lower productivity rate because it creates many unexpected issues such as design changes or quality issues. Lack of sufficient planning can also cause project managers to make wrong decisions, resulting in catastrophic financial loss for the company. This is even more important when planning for road pavement maintenance; it quickly affects public transport, which is very important for road users' safety and the country's economy.

Gill and Zuccollo (2012) argued that the first step to improving productivity is having a standard national performance framework/benchmark that is essential for planning. This is also required to reduce the risk of inappropriate decision-making and to be able to implement a productive managerial decision-making phase. They also offered other measures such as:

- Having common data protocols
- Having agreed on common standards on levels of service
- Improved data infrastructure to enhance data input and user access
- Focus on measuring the effectiveness of road maintenance interventions
- Learning through communities of practices
- Enhancing the capability of people to work in a different way
- Support by leadership, engagement, focus, and commitment.

A study by Chan et al. (2001) suggested that focusing on reactive and proactive repair actions, whilst optimising and prioritising the use of available resources and effective planning and scheduling of projects by contractors, can maintain a high level of productivity in a road pavement maintenance project and subsequently the serviceability of road pavement.

### ***Lack of effective communication/ clarifications of expectations among key stakeholders***

Effective communication with all project stakeholders can result in positive participation and engagement of the main stakeholders to enhance project management culture, which can enhance project productivity and final project outcome. However, ignoring stakeholders and their expectations can become the main reason for failure in a complex project, especially in complex road maintenance and rehabilitation projects which need a clear understanding of expectations (Butt et al., 2016).

There are lots of research around this productivity constraint. Researchers such as Ramsing (2009) and Kerzner (2009) have investigated this productivity constraint and have presented them below flowcharts showing all stages of communicating with stakeholders during a construction or road maintenance project.



**Figure 11.** Communication in the project developed from Ramsing (2009) and Kerzner (2009).

### ***Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council***

Each project consists of many different parties; each one of them may exhibit different subcultures. Together, all these different cultures create a project culture that can result in a positive and productive outcome if managed well. Creating a project culture framework consists of some main components such as goal-oriented, cooperative, flexible behaviour, and people-oriented culture (Zou et al., 2009). It is important to note that if the project culture has not been set up with a clear

framework at the start of the project with an agreed degree of harmony and cooperation between parties, project productivity will be hindered, especially if any project changes happen during a project which may result in conflict between parties. Therefore it is very important to manage relationships between all stakeholders and create trust, cooperation and harmony between contractor, consultant and council. Clearly, it is to the advantage of all parties who are involved in the construction project to communicate clearly as the empathy between parties and especially the main stakeholder of a project will increase the likelihood of project success and project owner satisfaction or, on the other hand, client dissatisfaction (Emmitt & Gorse, 2009).

Moreover, another important factor in relationship management is the relationship between subcontractors and main contractors, which is also a very important factor that will affect the project's overall productivity (Martin & Benson, 2021). As indicated by Martin and Benson (2021), using quality relationship theory which is based on a conceptual triangle of Trust, Satisfaction, and Commitment, can help improve relationship management. Also, the relationship quality can be determined by six key factors: integrity, respect and fairness; prompt payment; willingness to negotiate risk and price; effective communication; concern for worker health, safety and well-being; and opportunities for early involvement in planning and design.

#### ***Lack of organizational learning: Learning from previous projects***

Many non-routine problems may occur during a construction project which requires problem-structuring methods to be able to address the non-routine problem situations (Watad, 2018). One of the problem-structuring methods is the ability to review and learn from previous projects. Therefore, the absence of a culture of reviewing and learning from previous projects can lead to repeating the same mistakes in future projects, affecting project productivity dramatically. This factor is also one of the important productivity constraints that more contractors are becoming aware of and plan to mitigate by changing their company culture.

#### ***Client's overt influence on the project process***

One of the main productivity constraints that are still recognised by many contractors of construction and road maintenance projects is, not surprisingly, client expectation for excellent service and quality for the final project outcome. This can lead to a client overt influence process at every project stage (Durdyev et al., 2018). Therefore, having precise project specifications that

explain all the project details and using methods of mitigating any conflict regarding the project process is crucial during a construction project from start to finish.

#### **2.20.6 Statutory compliance-related constraints to productivity in road pavement maintenance and rehabilitation**

##### ***ISO 9001-Quality/ ISO 14001-Environmental standards, Local Authority Bylaws***

Two factors have been found by reviewing related literature: The Health and Safety Employment Act; the Resource Management Act; local authority bylaws; the Construction Contract Act; the Employment Relations Act; the Consumer Guarantees Act; and the Fair Trading Act. Jacquemin and Janssen (2015) showed that statutory compliance could affect different types of businesses by affecting their processes and outcomes. They recommended that governments should take action to reduce any unwanted constraints raised by different Acts. Durdyev et al. (2018), Mohammadi et al. (2018) and (Hasan et al., 2018) also mentioned the factors mentioned above as important constraints for increasing productivity.

#### **2.20.7 Unforeseen circumstances-related constraints to productivity in road pavement maintenance and rehabilitation**

##### ***Inclement weather, Unforeseeable ground conditions forcing design revision revisions, On-site accidents/ Acts of God, Natural disasters***

Many researchers have observed factors that can delay a project, including hot, cold or rainy weather, unpredictable ground conditions, on-site accidents, and other natural disasters such as recent Covid-19 pandemic (Jayathilaka & Waidyasekara, 2022). In the case of road pavement maintenance, any delay can hugely affect productivity and performance. Thapanont et al. (2018), Zidane and Andersen (2018) , Baynes (2010), and Afrin and Yodo (2020) findings prove that unforeseen events such as an unseen ground condition and some other unforeseen factors that may cause delays such as road traffic congestion can hugely affect the productivity rate in the construction industry and road maintenance projects, based on project conditions.

Moreover, Thapanont et al. (2018), & Habibi and Kermanshachi (2018) mentioned that hot, cold and wet weather effects on construction activities, accidents during road maintenance, and

differing site (ground) conditions are the constraints that can hinder productivity rates during a road maintenance project.

### **2.20.8 External force-related constraints to productivity in road pavement maintenance and rehabilitation**

*Market conditions and level of competition in the industry for jobs, Inflation/ fluctuations in material prices, Energy crises/ rising costs, Interest rate/ cost of capital, Fluctuations in the exchange rate, Post-construction defective or non-compliant work, User/Client value perceptions*

There are several external factors that can impact the productivity rate. Many international and local studies have been reviewed to find the external factors that the contractor cannot control that affect productivity in road pavement maintenance and rehabilitation. After an in-depth review, eight factors were identified as essential constraints against improving productivity. Table 1 shows these eight factors and related literature. The durability of completed work within the defects liability period or warranty/ guarantee is one of the factors which is a common finding in many of these studies, such as Hatamleh et al. (2018), & Baynes (2010).

### **2.21 Summary of review of literature and gap in knowledge**

The above subsections have provided insights into the key concepts that underpin this research and the extent to which the research objectives have been addressed in previous studies. It was found that while several overseas studies have been completed in the research area, such as old studies by Lee et al. (2002) and Mbachu and Seadon (2013), Alinaitwe et al. (2007), and Baynes (2010), and some more recent studies such as Ahmadabadi and Heravi (2019), Thapanont et al. (2018), few studies exist in the New Zealand context, especially in regards to productivity improvement in road maintenance and rehabilitation projects and specifically, road pavement maintenance projects, and that is the reason that NZTA is also suggested more studies to be done in this field to help improving productivity (John Bolland, 2013). The New Zealand roading sector is unique in many respects, such as socio-cultural dynamics, regulations, industry characteristics, and legislation (Purushothaman & Kumar, 2022). Therefore, overseas findings relating to the topic

may not be wholly applicable in the New Zealand context given its unique settings. In addition, the productivity constraints identified in other countries were largely unprioritised.

Presenting New Zealand contractors with recommendations on so many productivity constraints and improvement measures without some form of prioritisation will not be particularly helpful; it will only amount to ‘information overload’.

This study has addressed this knowledge gap by investigating productivity constraints and improvement measures unique to the New Zealand roading sector. In addition, the constraints have been prioritised in order of their relative influence, so contractors can focus their limited resources on addressing those constraint factors and improvement measures having the highest impact on productivity outcomes.

## **CHAPTER 3: RESEARCH METHODOLOGY**

### **3.1 OVERVIEW**

This chapter discusses the methodology adopted in the design and implementation of the research and the underpinning philosophical foundations. The chapter starts with discussions of the philosophical foundations to put in context the ontological, epistemological and axiological bases that define and qualify the methodology adopted. This is followed by discussions of the key aspects of the research methodology employed for the research, including the data collection, sampling methods and data analysis.

### **3.2 Philosophical foundations for the research**

Neuman (2016) argues that research, especially in the social sciences, must define the underpinning philosophical foundation in order to put in proper context what is accepted as new knowledge within a given domain or discipline and the appropriate procedure and guiding principles that inform the research design, implementation and interpretation of the results.

#### ***The ontological position adopted in the research***

‘Ontology’ is concerned with studying the fundamental nature of reality or truth and how it is accepted within a given discipline or knowledge domain (Easterby-Smith et al., 2012). From a slightly different perspective, Converse (2012) opines that ‘ontology’ is a system of belief that guides a researcher’s interpretation of what constitutes a fact or reality.

The need to define the ontological position of a researcher or the ontological foundation of a research undertaking is to put in context what constitutes new knowledge for which the research inquiry is directed at, within the researcher’s professional domain or discipline, as this may be disputed by researchers in other disciplines (Neuman, 2016).

In regards to the ontological position, this research undertaking was guided by ‘relativism/nominalism’ in contrast to realism: Realism-centred ontological position assumes that ‘reality’ or ‘truth’ exists out there independently of people and their perceptions or interpretations

of ‘reality’; while relativism/nominalism assumes that people never directly experience the real world but through their own subjective interpretations of their experiences and facts (Neuman, 2016).

### ***The epistemological position adopted in the research***

‘Epistemology’ refers to the approach to scientific exploration of the truth or reality following an appropriate method of scientific inquiry that is acceptable within a given discipline or field of practice (Dudovskiy, 2016).

Furthermore, Vasilachis (2009) argues that epistemology is the acceptable means of studying or enquiring about ontology or what is acceptable as reality or new knowledge within a specific discipline.

The need to define the epistemological position in a research undertaking is informed by the fact that the *means justify the end* and not the other way around; also that the ‘means’ must be acceptable to the discipline if the ‘end’ is to be accepted as a reliable and valid outcome (Becker & Niehaves, 2007).

Becker and Niehaves (2007) provide that two alternative forms of epistemology align with the two main forms of ontology: ‘empiricism’ and ‘rationalism’. The empiricist’s approach is adopted in the quest for new knowledge where there is a need to design the research to gather the facts or new knowledge without human interpretation; scientists often follow this. On the other hand, the rationalistic approach is adopted where the research is designed to obtain the research data as human interpretations of facts.

In this research, the epistemological position adopted the rationalistic approach to the inquiry process because it resonates better with the relativist ontological position of the research.

### ***The axiological position adopted in the research***

‘Axiology’ is the philosophical study of value and the way it is judged or assessed within a specific knowledge domain or, as described by Lincoln et al. (2011), axiology is also recognised as an

essential consideration concerning a paradigm. The axiological position brings to the fore the newness or value-addition in the ontology that drives the research (i.e. the ‘end’ or outcome that is targeted).

The need to clearly state the axiological position of the research is because, as the name implies, ‘re-search’ means to rediscover new knowledge or new value in the research undertaking without which the inquiry cannot be claimed to be truly a research undertaking. In turn, the axiological position helps formulate the research problem statement, research aim, research questions, and objectives to guide the quest for empirical data.

The way the new knowledge or value is assessed depends on the value system used in the specific domain. Some authors Killam (2013) and Morgan (2007) identify ‘ethics’ and ‘aesthetics’ as the two common value systems for defining the axiological position of a research undertaking, although the ethics and aesthetics terminologies confuse rather than clarify what axiology actually stands for. In simple terms, axiology makes it imperative to clearly specify in the research the gaps that exist in current knowledge about the phenomenon being investigated in the specific knowledge domain.

In this research, the new knew knowledge or value the research aimed to add to existing knowledge has been defined in Section 1.3 - Rationale for the Study. A case was made that there was a lack of clear understanding of the nature and relative levels of impact of productivity improvement constraints within the road pavement maintenance and rehabilitation operations in New Zealand, which makes it challenging to address the constraints with available resources with a view to improving productivity and achieving the NZTA’s targeted goals. Therefore, this axiological statement helped formulate the problem statement, research aim, and objectives in Chapter 3 of the thesis.

The two divisions of axiology align with the associated divisions of epistemology, i.e. empiricist-centered and rationalist-centered axiology. The former defines new knowledge or value as being the expected outcome of experimental research that extends or refutes existing knowledge boundaries following the pre-defined epistemological process. On the other hand, rationalist-centered axiology defines new knowledge or value as the expected subjective feedback of research participants on the research questions posed to produce value-added or new understanding for the phenomenon under study.

The axiological filtering in the research was made possible through external validation of the findings by subject experts, especially in relation to the generalizability of the findings beyond the scope of the study to broader contexts and settings.

### ***Paradigm adopted in the research***

Slade (1991) explained the research paradigm as the mindset or principle that guides the inquiry process about the pre-defined axiology (i.e. the truth or new knowledge being targeted) in the inquiry. Moreover, researchers such as Cho and Trent (2006), Slade (1991) and Daniel and Onwuegbuzie (2002) identified three key aspects of the paradigm:

- the positivist/objectivist paradigm; this aligns with the empiricist epistemological and axiological disposition in the research. It assumes that only experimentation that is guided by the empiricist's mindset, principles, and methodology is acceptable in the research process as the means that justifies the end.
- On the other hand, the constructivist/interpretivist paradigm assumes that observation guided by the rationalist's mindset, principles, and methodology is the only feasible and acceptable approach to be adopted in the research process.
- The pragmatist paradigm may be the hybrid or negation of the positivist and constructivist approaches. It is focused on successfully achieving the goal or required outcome rather than being rigidly focused on the imperatives of the positivist- or constructivist-centred methodology or guiding principles. Thus, the pragmatic approach could combine the essentials of both approaches so long as they would support the achievement of the goal or required outcome.

In the research, the pragmatic paradigm was adopted because of the need to combine both the quantitative methodology of the positivist epistemological and axiological positions and the qualitative methodology of the constructivist/interpretivist epistemology and axiological positions. This, therefore, explained the mixed method of research adopted in the study, which necessitated the hypothetical-deductive reasoning that underpinned the two-stage research approach – i.e. formulating research propositions based on qualitative data and then testing the propositions using quantitative data gathered in the surveys.

The following section explores research methodology, ending with the nature and rationale of the research method adopted for the questionnaire survey. The latter section discusses the questionnaire survey's key elements, including the data collection, the sampling method, the pre-testing, circulation of the questionnaire, and an analysis of the collected data.

This chapter ends with a discussion on the ethical approval sought from and granted by Massey University's Human Ethics Committee (MUHEC) to conduct this research following the university's ethical principles.

### **3.3 Research methodology**

Saunders et al. (2011) explain research as a process of investigating evidence of a fact that can discover or develop new knowledge. Therefore, choosing a proper method that can result in a comprehensive outcome is crucial for creating new knowledge. There are three main categories of research methods for the empirical study of built environment problems or phenomena: qualitative or exploratory; quantitative; or mixed-method (i.e. hybrid of qualitative and quantitative methods) (Creswell, 2013). The methods draw upon the fact that empirical investigation is conducted to develop a theory, test an existing theory, or both (Creswell, 2013). Also, several factors affect research design and methods that are chosen for a research, such as the philosophy of research, the objective chosen for the research, and the nature of the data (Yin, 2003, 2009).

The following subsections provide brief discussions on each method and the selected approach for the study.

#### **3.3.1 Exploratory/ Qualitative research method and philosophy**

Hennink et al. (2010) described qualitative research as a broad umbrella term covering many different techniques and philosophies. The qualitative method, also known as the Exploratory method, has many advantages such as providing a two-way interaction tool between the researcher and other parties involved in research, which will give the freedom to the research participants on the feedback they are willing to provide during research. This method allows us to discover people's experiences in detail, using different techniques such as in-depth interviews, content analysis, group discussion, etc. Therefore, it allows the researcher to explore issues from the

perspective of research participants with more accuracy and relativity to the participants' experience and background (Graue, 2015; Tetnowski, 2015).

The aim of qualitative research is to develop a theory, hypothesis, or proposition as an explanation of an observed phenomenon (Bendassolli, 2013; Pope et al., 2000). The philosophy governing the qualitative research method was explained by Hennink et al. (2010) as involving observer interpretation of his or her impression of the observed qualitative data. This means that the researcher observes the data, examines or analyses it, and interprets it by forming an impression of the meanings that could be teased out of the analysed data, and then reports the impression in a structured, and sometimes quantitative, form. It needs to be mentioned that the research strategies associated with qualitative research involved non-probabilistic sampling of data as the intention is not to achieve representation of a target group.

### **3.3.2 Confirmatory/ Quantitative research method and philosophy**

Many researchers have described the quantitative research method, as a method for objective measurements and the statistical, mathematical, or numerical analysis of data collected through questionnaires and surveys. The quantitative research method is different from qualitative as many researchers describe qualitative research as more flexible than quantitative and explain quantitative method as an inflexible method that gives participants limited choices. However, it is a better option for testing a theory because it can quickly adopt many robust statistical test methods for approving or disapproving a chosen theory (Zikmund, 2012). Creswell (2013) also described the quantitative research method as a method for testing an objective theory by examining and measuring the relationship between variables. Therefore, extracted numbered data can be analysed by using statistical procedures.

### **3.3.3 Mixed method of research and philosophy**

This method is a mix of the two above methods approach toward research. Creswell (2013) described a mixed method of research as a step forward – it utilises the strengths of both quantitative and qualitative research methods by using both methods' advantages, for example, by using a qualitative method which is more flexible on gathering data based on participants' real-life experience and background; the inflexibility of quantitative method will be covered. Also, it will

add the strengths of the quantitative method to the whole research, such as using statistical tests, which is of enormous benefit when a researcher analyses data or tests. He described that using only a quantitative or qualitative method for complex research is inadequate for addressing the complexity of a research subject. Therefore, there is more benefit in using a combination of both methods. Using a mixed-method also helps to achieve an expanded understanding of research problems.

### **3.3.4 Selected research method for the study and philosophy**

A mixed-method of research was adopted, which involved theory development from qualitative data gathered via pilot interviews, theory testing via quantitative data gathered via a questionnaire survey, and model development and testing via a model test survey (Saunders et al., 2011; Saunders et al., 1997). The mixed-method approach is recommended because it is appropriate for the nature of the empirical data (i.e. expert opinions) and the objectives to be achieved (i.e. variable formalized and reduction) (Siegel, 2004).

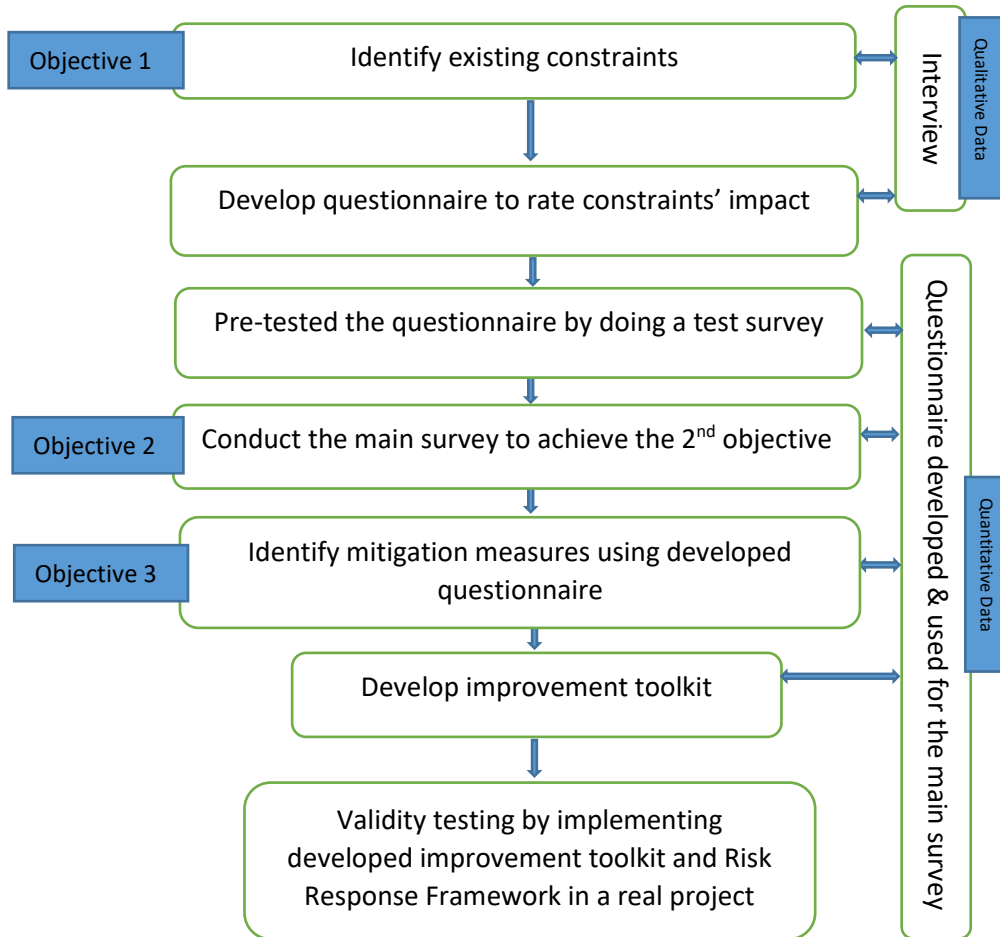
In addition, as McKim (2017) explained, using the two-phased mixed-method helps decrease risks associated with using a single method. It also helps to make sure the findings are comprehensive enough to cover all three objectives and provide a more profound finding related to research objectives.

### **3.4 Research strategy**

A plan used for conducting the research that will define all research stages from start to finish is called research strategy. Having a clear research strategy will provide a clear road map for carrying out comprehensive research and, at the same time, it will minimise the risks which may affect the final quality of the research outcomes because one of the main factors of designing a comprehensive and well-designed research strategy is identifying existing risks (Bryman & Bell, 2015). Yin (2003) argues that a research strategy will not be practical and holistic if it does not include, and is governed by, research objectives, research questions, research theory, and expected outcome and has a clear plan about time and available resources.

Research objectives govern the research strategy which is designed for this research. This means the objectives have been used to design each research phase to achieve the research outcome.

Figure 13 presents a brief description of the research strategy adopted for this research.

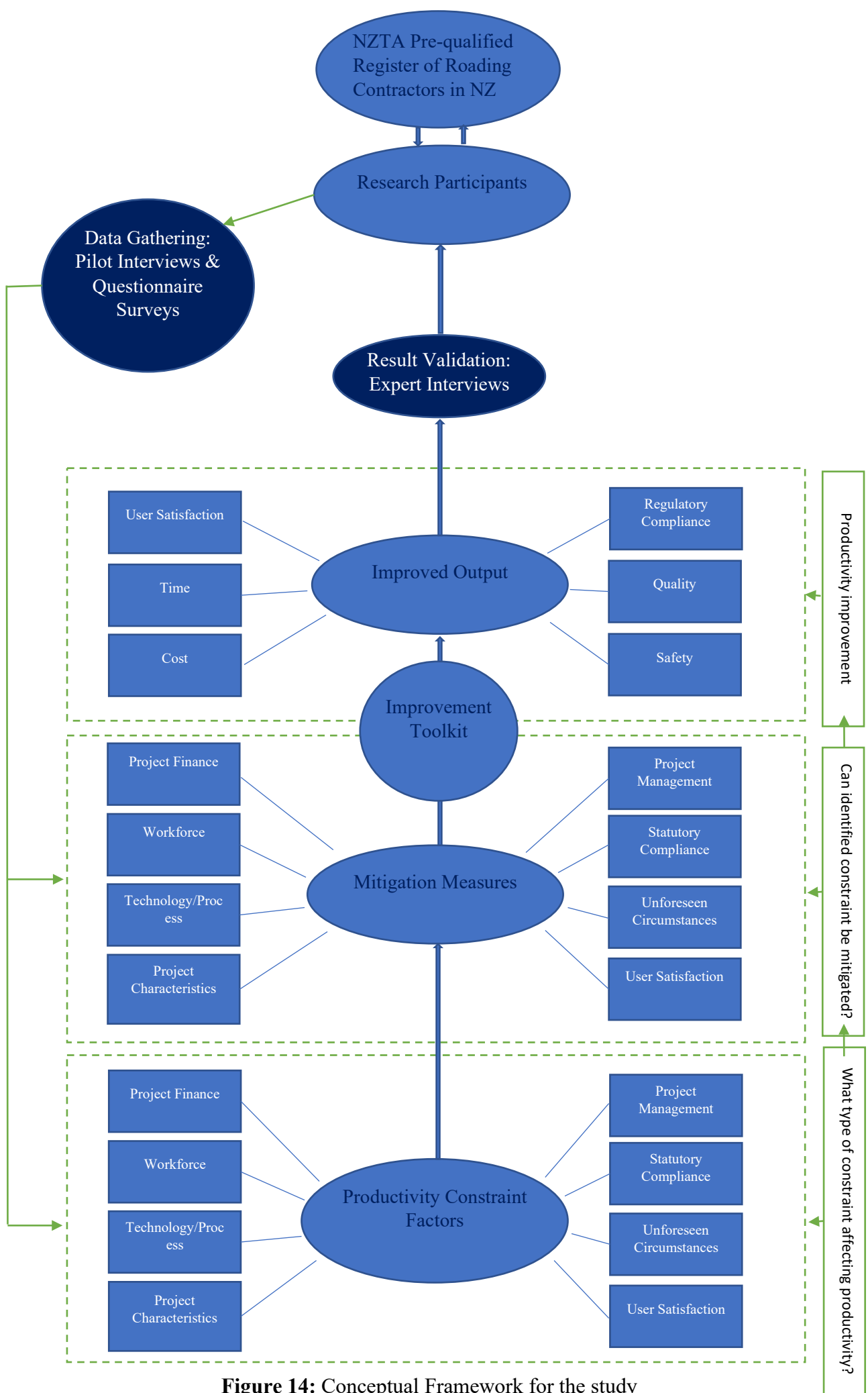


**Figure 12:** Research strategy adopted for this study

### 3.5 Conceptual framework for the study

Durdyev et al. (2014) define ‘conceptual framework’ as a graphical illustration of the key thrusts of the research. The concept draws upon the fact that ‘a picture tells a better story than a thousand words’. The key components of an effective conceptual framework (Mbachu, 2011) comprised the key objectives of the study, the overall goal, sources of primary data and linkage of intents to literature, key variables for analysis, and method for data analysis expected findings. However, to provide a succinct and uncluttered graphic model, including all these attributes in the conceptual framework is not always required. Figure 9 shows a strategic roadmap for the study, while Figure

11 shows the conceptual framework for the study; it illustrates how the empirical data sources, data gathering, and toolkit development relate to each other toward achieving the three objectives of the research.



**Figure 14:** Conceptual Framework for the study

### **3.5.1 Key constraints**

The key constraints to road pavement maintenance and rehabilitation were identified through a review of related literature, as summarised in Table 1. These comprised nine broad categories: management, workforce; project finance; new technologies; project characteristics; statutory compliance; unforeseen circumstances; external factors; and external factors related to the operation process. The literature sources provided starting insight points for the empirical investigations to explore the constraints specific to the New Zealand road pavement maintenance and rehabilitation sector. The empirical data, in this regard, were the subject of the pilot interviews and questionnaire survey carried out at the preliminary stage of the study, and then the main online questionnaire survey was designed by using all the obtained data from previous stages. The main online questionnaire was used to rate the impact of each constraint on productivity and find and rate the mitigation measures. In addition, the open-ended online questionnaires helped to explore new constraints and mitigation measures that were specific to the New Zealand context.

### **3.5.2 Key improvement measures**

In addition, the key measures for improving productivity in road pavement maintenance and rehabilitation have been identified through a review of related literature. As shown in Table 1, these comprised resolutions of the issues identified in the nine broad constraint categories: Management, Workforce, Project Finance, New Technologies, Project Characteristics, Statutory Compliance, Unforeseen Circumstances, External Factors and External Factors Related to Operation Process. The literature sources provided starting points for primary data exploration via pilot interviews and online questionnaire surveys. The main findings then were through the online questionnaire, which provided the final findings related to all three research objectives.

### **3.5.3 Data sources**

The conceptual framework shows that primary data, after literature review, were sourced from pilot interviews and questionnaire surveys. The primary data comprised experienced-based feedback from roading contractors that were registered with the NZTA, as provided in the NZTA's Register of Contractors (NZTA, 2017). As it is presented in conceptual frameworks, the second source of the data gathering was an online and open-ended questionnaire survey that was provided

and required data for achieving the second and third objectives. Using all these data sources helped achieve an expanded understanding of the research problems and resulted in a comprehensive finding that covers a deep insight in relation to each objective.

#### **3.5.4 Hypothesis testing and validity**

A research can be called successful if the outcome is valid and reliable, meaning the industry can use the research. Validity and reliability also need to be part of research design, and a comprehensive research strategy usually includes a validity and reliability measuring tool or strategy (Saunders et al., 2011). In general, the measuring tool does need to measure the overall quality of the research outcome.

##### ***Validity and reliability of the research***

To validate the study's findings, a structured online survey was conducted with experienced roading contractors who did not take part in the previous surveys. The respondents were asked to provide feedback on the practical relevance and ease of applying the research findings. The focus was on the Risk & Constraint Identification Toolkit to be developed as a strategic and methodical approach for identifying and responding to risks & constraints in road pavement maintenance and rehabilitation projects to enhance productivity and achieve successful project delivery. The Risk & Constraint Identification Toolkit then developed based on the research findings, is attached as Appendix D.

#### **3.6 Scope of empirical data gathering**

The empirical data gathering for the study was limited to constraint issues and improvement measures related to road pavement maintenance and rehabilitation of the arterial and non-arterial road network in New Zealand. Johanns and Craig (2002) argued that the pavement part of the non-arterial road network is most prone to rapid deterioration; hence it is subject to the strictest compliance standards. Therefore, it presents the most significant challenge to the productivity and performance of road contractors. The study scope excluded the other road infrastructures such as bridges, wharves, jetties, etc.

Moreover, the scope of data sources was limited to views expressed by experienced and decision-making employees of contracting firms involved in road pavement design, construction, maintenance and rehabilitation in New Zealand as provided in the 30 April 2016 version of the NZTA Register of Prequalified Contractors (NZTA, 2017).

### **3.7 Stages of empirical data gathering**

The following two stages were used for gathering the empirical data for the research.

#### **3.7.1 Qualitative data gathering and analysis**

The first stage of empirical data gathering involved the use of pilot interviews conducted with experienced contractors in the roading industry. As data gathering is one of the most crucial stages of research, it is very important to choose a suitable method for the data gathering stage. Therefore, based on the nature of this research, a selective and purposive sampling method (Bernard, 2011) was used to select convenient samples of interviewees from the sampling frame who were willing to grant approximately one hour for an in-depth interview (Etikan et al., 2016). The reason for choosing this method is that people enable the researcher to choose highly experienced people who are experts in the roading industry; it makes a more positive impact on the quality and reliability of the feedback.

The interviews aimed to explore the key factors constraining productivity performance in road pavement maintenance and rehabilitation projects in New Zealand. In addition, questions were asked about the key improvement measures, which the interviewees believed could enhance the success of delivery of road pavement maintenance and rehabilitation projects.

#### **3.7.2 Quantitative data gathering and analysis**

For gathering quantitative data, a questionnaire survey was used. Questionnaires were developed using the constraints identified at the interviews. The questionnaire, therefore, was categorised into eight broad categories where each category contained related identified productivity constraints.

Prior to administering the questionnaire to the full sampling frame, it was pre-tested among six of the prospective respondents in the study-sampling frame, all of whom were highly experienced in the roading industry. The pre-test helped to ascertain whether there are further constraints to be

captured over and above those identified during the pilot interviews. For this reason, the questionnaire was left open-ended, so respondents could provide additional constraints which were not included in the set of variables to be rated using the Likert Scale method. It was also necessary to avoid bias when preparing and testing the questionnaire; therefore, an additional column was added to the questionnaire where participants could indicate if they were not sure or had no idea about an item. The pre-test captured a few more constraints and categorised the broad categories into two main categories of internal and external factors, rather than having eight main broad categories. The pre-tests also helped to ensure clarity and relevance of the questions and the questionnaire design, with a view to improving the survey response rate during the mainstream questionnaire survey.

### **3.8 Sampling**

Kadam and Bhalerao (2010) described sampling as a method of identifying potential sources of empirical data for research. In this study, participants at the pilot interviews were recruited through a purposive/non-probability sampling method. Creswell (2013) recommended using this approach for exploratory or qualitative data gathering where the aim is only to generate constructs for the purpose of developing theory, rather than a focus on the representation of data.

At the quantitative data gathering stage, a random sampling approach was used to identify representative samples from the sampling frame compiled using the New Zealand Transport Agency's Register of Prequalified Contractors (NZTA, 2017).

#### **3.8.1 Target population**

The target population for the study comprised roading contractors obtained through NZTA's list of prequalified contractors from both North Island and South Island.

#### **3.8.2 Sampling frame**

The NZTA maintains a register of pre-qualified roading contractors in New Zealand. The current version (as of the fieldwork date of 30 April 2017) listed 120 contracting firms. The prequalified list of contractors shows the contractors' geographical locations, the type of projects they are involved with, and their experience classification which is updated around October every year.

The register provided the basis for compiling the sampling frame for the study. The total number of roading contractors in the sampling frame as of 30 April 2017 was 1332 (NZTA, 2017).

The New Zealand Transport Agency's Register of Pre-Qualified Contractors (NZTA, 2017) was used as a basis for compiling the sampling frame for the study. The Register showed 120 pre-qualified contractors as at 30 April 2017. Compiled information on the resources - project management and technical staff - supplied by the contracting firms in their prequalification for Physical Works Application pack (AT, 2013) for work categories related to road pavement design, construction, maintenance and rehabilitation showed that the sampling frame for the study comprised 1332 potential respondents whose official designations in the contracting firms ranged from intermediate, through senior management to director positions. The NZTA maintains this information in the database kept for each company. The Prequalification Manager or the Tender Secretary, NZTA National Office, Wellington, can grant access to the information for research purposes if there is an undertaking to keep the information strictly confidential and without disclosing the names of individuals and company details.

To complement the information provided in the NZTA database of prequalified contractors, the effort was made to reach the individual companies' management and technical staff involved in road pavement maintenance and rehabilitation. This was done by looking up the staff details on the company websites. However, where the companies did not have detailed information about their staff, the secretaries were phoned to provide the information needed.

Compiled information from these sources showed a total number of 1565 technical and managerial staff involved in the road construction and maintenance work. This number was significantly larger than 1332 provided in the NZTA database. The discrepancy could be because the companies do not update their records on the NZTA database except when applying for upgrades to higher categories. Given that the secretaries of the companies would be more helpful in terms of inviting the prospective respondents to participate in the survey, the sampling frame compiled via the individual companies' staff analysis was adopted as the more appropriate sampling frame for the study.

### 3.8.3 Sampling method

The random sampling method was used to draw up a representative number of respondents from the sampling frame for the study, as discussed in the preceding subsection of this section. Random sampling allows all the units of the sampling population to have an equal chance of being selected (Acharya et al., 2013); therefore, the sample will be representative of a large sampling group, thereby reducing any bias around choosing the respondents (Lin, 2018).

### 3.8.4 Sample size

Kothari (2004) noted that determining sample size is crucial for economy, reliability, and validity in research. That is because too large samples may waste time, resources, and money; while too small samples may lead to inaccurate results. Scott M. Smith (2015) provided the expression (i.e. Equation 4) for computing the minimum sample size required in a quantitative survey.

Equation 4:

$$S_m = \frac{Z_{cl}^2 \times \sigma_{cl} \times (1 - \sigma_{cl})}{(\epsilon_{cl})^2}$$

*Where:*

$S_m$  = minimum sample size

$Z_{cl}$  = normal deviate associated with the confidence level (CL) adopted for the study. For 95% CL,  $Z_{0.95} = 1.96$

$\sigma_{cl}$  = standard deviation associated with the confidence level (CL) adopted for the study. For 95% CL,  $\sigma_{0.95} = 0.5$

$\epsilon_{cl}$  = margin of error (MoE) associated with the confidence level (CL) adopted for the study. For 95% CL,  $\epsilon_{0.95} = 0.5$

Therefore, since the confidence interval adopted for the study is the same as used in most built environment research (Amaratunga et al., 2002), the required minimum sample size is 385:  $S_m = ((1.96)^2 \times .5(.5)) / (.05)^2 = 385$ .

### 3.8.5 Representative sample size

Kadam and Bhalerao (2010) provided an expression (i.e. Equation 2) for adjusting the minimum sample size (computed using Equation 1) to reflect the size of the sampling frame for the study as a correction for a finite population.

Equation 5:

$$S_{Rep} = \frac{S_m \times N}{N + (S_m - 1)}$$

Where:

$S_{Rep}$  = representative sample size

$S_m$  = minimum sample size (For confidence level of 95%, std of 0.5, and margin of error of 0.05,  $S_m = 385$ )

$N$  = sampling frame

With a sampling frame ( $N$ ) of 1565, Equation 5 computes the representative sample size to be a minimum of 310, as shown below.

$$S_{Rep} = \frac{385 \times 1565}{1565 + (385 - 1)} = 310$$

### 3.8.6 Census survey

To give all subjects within the sampling frame equal opportunity to participate – and hence minimize response bias – an invitation to participate in the survey was extended to all the prospective respondents as established in section 3.5.5. Pheng and Chuan (2006) noted that survey response rates in the construction industry are very low; this is even worse during the boom phase of a construction cycle, as we are currently experiencing in New Zealand. To improve the response rate, reminders were sent out every month to the respondents, thanking those who had responded while requesting those who had not done so before the cut-off date of 31 June 2018.

It should be noted that the minimum representative sample size, computed using Equation 2, served to check whether or not the responses received by the cut-off date were sufficient to represent the views of all potential respondents within the sampling frame.

There is a need to mention that because the responses received by the cut-off date were less than the representative minimum sample size, a caveat was included as part of the study's limitations - that the findings cannot be generalized across the entire sampling frame and beyond.

### **3.8.7 Data analysis**

Silverman (2006) argued that the choice of the method of statistical analysis depends on five key parameters as follows:

- Type of question to be answered or key purpose of the research; i.e. to understand or describe the nature of the underlying data structure (i.e. requiring descriptive statistic-based analysis), examines the nature of associations among the variables (i.e. requiring analysis of variance method of data analysis for interval data or exploratory factor analysis for ordinal/nominal data), or examine cause and effect relationship between dependent and independent variables (i.e. requiring regression analysis or similar statistical analysis).
- Number of variables; e.g. univariate, bi-variate, or multivariate.
- Scale of measurement; i.e. nominal, ordinal, or ratio/interval
- Nature of the data to be analysed; i.e. subjective data (e.g. opinions) or objective data (e.g. measured parameters);
- Nature of data distribution; e.g. standard or known distribution (i.e. requiring parametric statistical data analysis) or understand distribution (i.e. requiring non-parametric statistical data analysis)

### **3.8.8 Data analysis method used in the study**

The qualitative data obtained during the pilot study phase were analysed using a descriptive statistic technique. As discussed in the above subsection, this approach was taken because the purpose was to understand, or to be able to describe, the variables underlying the major and sub-categories of productivity constraint factors and the associated mitigation measures. The data analysis was essentially by content and/or thematic analysis. This involved frequency counts of

recurring themes and the aggregation of variables into clusters or themes in the feedback given by the interviewees (Willis, 2004).

The SPSS-based factor analysis was used to analyse the quantitative data obtained from the questionnaire survey (Kline, 2014). This approach was chosen because the objective was to examine the nature of associations among the variables and their impact on the phenomenon under study (Kline, 2014; Suhr, 2006). Put in another way, and the objective was to examine the level of correlation among the sets of constraint factors and how they could be further reduced into a smaller number of principal components that could better explain the productivity outcomes in road pavement maintenance and rehabilitation projects.

The principal component analysis (PCA) sub-routine of the factor analysis was therefore used to establish the key broad categories or classifications for the road maintenance and rehabilitation issues and suggested mitigation measures. The choice of this analytical approach was based on the recommendations of a number of authors, such as (Siegel, 2004) and (Mbachu & Nkado, 2006), as the most appropriate for analysing and interpreting patterns in the high dimensional data structure (i.e. large amount of data with multiple variables or dimensions) where the focus is on dimensionality reduction; i.e. reducing the original set of variables to a few key representative orthogonal variables or factors that best describe the patterns in the data set by eliminating redundant dimensions in the data attributes or dimensions whose sum of variances is very low or insignificant. This way, the scarce resources will be more cost-effectively disbursed to address those few key principal factors that account for most of the issues being investigated.

### **3.8.9 Principal Components Analysis (PCA)**

The study's first objective was to identify and prioritise the factors that constrain contractors' productivity performance in the road pavement maintenance and rehabilitation process (RPMR). PCA was used to prioritise the constraints and reduce the 68 factors identified during the pilot interviews into fewer principal components to achieve this objective. The PCA also helped address inter-collinearity and inter-correlation issues among the 68 sub-factors, producing principal components that could uniquely contribute to the productivity issues in the road pavement maintenance and rehabilitation process. This way, contractors could focus on the fewer principal components with their limited resources rather than on the 68 factors.

In the PCA, the focus was to examine variables' relationships or reduce the number of variables in regression and clustering (Blunch, 2012).

Each principal component in the PCA is a linear combination of the set of variables for which it could explain their variances better than any other principal component. For instance, if  $X$  is a matrix for  $n$  observations by  $p$  variables, and the covariance matrix is  $S (= X^T X)$ , then for a linear combination of the associated set of variables, the expression for extracting the first principal component,  $Z_1$  is given by:

Equation 6:

$$Z_1 = \sum_{i=1}^p a_{1i} \times X_i$$

Where:

- $Z_1$  is the first principal component;
- $x_i$  is the  $i_{th}$  variable;
- $a_{1i}$   $i = 1, 2, \dots, p$  are linear combination coefficients for  $z_1$ ; these could be denoted by a column vector  $\mathbf{a}_1$ , and normalised by its covariance matrix,  $\mathbf{a}_1^T \mathbf{a}_1 = 1$ . The variance of  $Z_1$  will be  $\mathbf{a}_1^T S \mathbf{a}_1$ .

The vector  $\mathbf{a}_1$  is found by maximizing the variance.

The second principal component can be found in the same way by maximizing:

$\mathbf{a}_2^T S \mathbf{a}_2$ , subject to the constraints  $\mathbf{a}_2^T \mathbf{a}_2 = 1$  and  $\mathbf{a}_2^T \mathbf{a}_1 = 0$ ; this gives the second principal component that is orthogonal to the first one.

Where several principal components exist, the ones that could be extracted in the same way described above. Usually, the coefficients  $a_1, a_2, \dots, a_p$  can be evaluated as eigenvectors of the transpose matrix,  $S$  (i.e.  $X^T$ ).

### 3.8.10 Cronbach's alpha test for measuring validity and reliability

Henson (2001) stated that Cronbach's alpha is a measure of internal consistency or how closely a set of items relates as a group. Blunch (2012) described it as a measure of scale reliability, i.e.,

whether or not a given scale is measuring what it is supposed to be measuring. In the context of reliability and validity, Cronbach's alpha provides a measure of reliability or consistency of the scale used in the statistical measurement of a multi-variate construct.

Blunch (2012) argued that Cronbach's alpha could be written as a function of the number of test items and the average inter-correlation among the items. Equation 7 provides an expression for computing standardized Cronbach's alpha.

Equation 7:

$$\alpha = \frac{N \times \bar{c}}{\bar{v} + (N-1) \times \bar{c}}$$

Where:

- $\alpha$  is the Cronbach's alpha;
- $N$  is equal to the number of items
- $\bar{c}$  bar is the average inter-item covariance among the items
- $\bar{v}$  bar equals the average variance

Henson (2001) provided a table for interpreting Cronbach's alpha values, as shown in Table 4. The table will help interpret the data analysis results for reliability purposes.

**Table 4:** Cronbach's alpha range

<b>Cronbach's Alpha</b>	<b>Internal Consistency</b>
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

### 3.8.11 Multi-attribute analysis

The multi-attribute method was used to analyse the responses obtained from the pre-test survey. This analytical approach involved the computation of mean rating (MR) as the basis for rank-ordering the items being rated in order of their relative levels of importance. Durdyev and Mbachu

(2011a) provided the expression for the MR as shown in Equation 8.

Equation 8:

$$MR_j = \sum_{K=1}^5 (R_{pjk} * \%R_{jK})$$

Where:

- $MR_j$  = Mean Rating for the  $j^{\text{th}}$  constraint factor;
- $R_{pjk}$  = rating point  $k$ ;  $R_{pjk}$  ranges from rating point 1 to 5 for the 5-point Likert rating scale used;
- $\%R_{jk}$  = Percentage response to rating point  $k$ , for constraint factor  $j$ .

### 3.9 Validating the research findings

A third stage data gathering was conducted with a new set of contractors who had not participated in the initial pilot interviews and the questionnaire survey. The purpose was to validate the results of the analysed feedback from the questionnaire surveys and the efficacy of the developed toolkit for improving the productivity of the roading contractors. The roading contractors were recruited via purposive sampling technique (Fink, 2015; Oppenheim, 2000) in which the participants were selected based on their depth of experience, position in the industry, and strategic decision-making role in their companies.). Ten directors and senior managers of roading contracting companies agreed to participate in the model test structured interviews. They were asked to rate the relative level of influence of the key productivity constraints identified in the previous surveys. They also rated the relative levels of effectiveness of the identified mitigation measures. They were given the opportunity to suggest additional constraints and mitigation measures that were not part of the identified list. Finally, they rated the level of efficacy of the developed toolkit in terms of relevance, practicality, and ease of implementation. Their ratings were compared to those analysed from the questionnaire survey. Spearman's Rank Correlation and Wilcoxon's Matched Pairs tests (Mbachu & Shahzad, 2012; Saunders et al., 2011) were used to examining the extent of congruence or significance level of divergence in the ratings. The results provided a measure of reliability or validity of the survey-based findings.

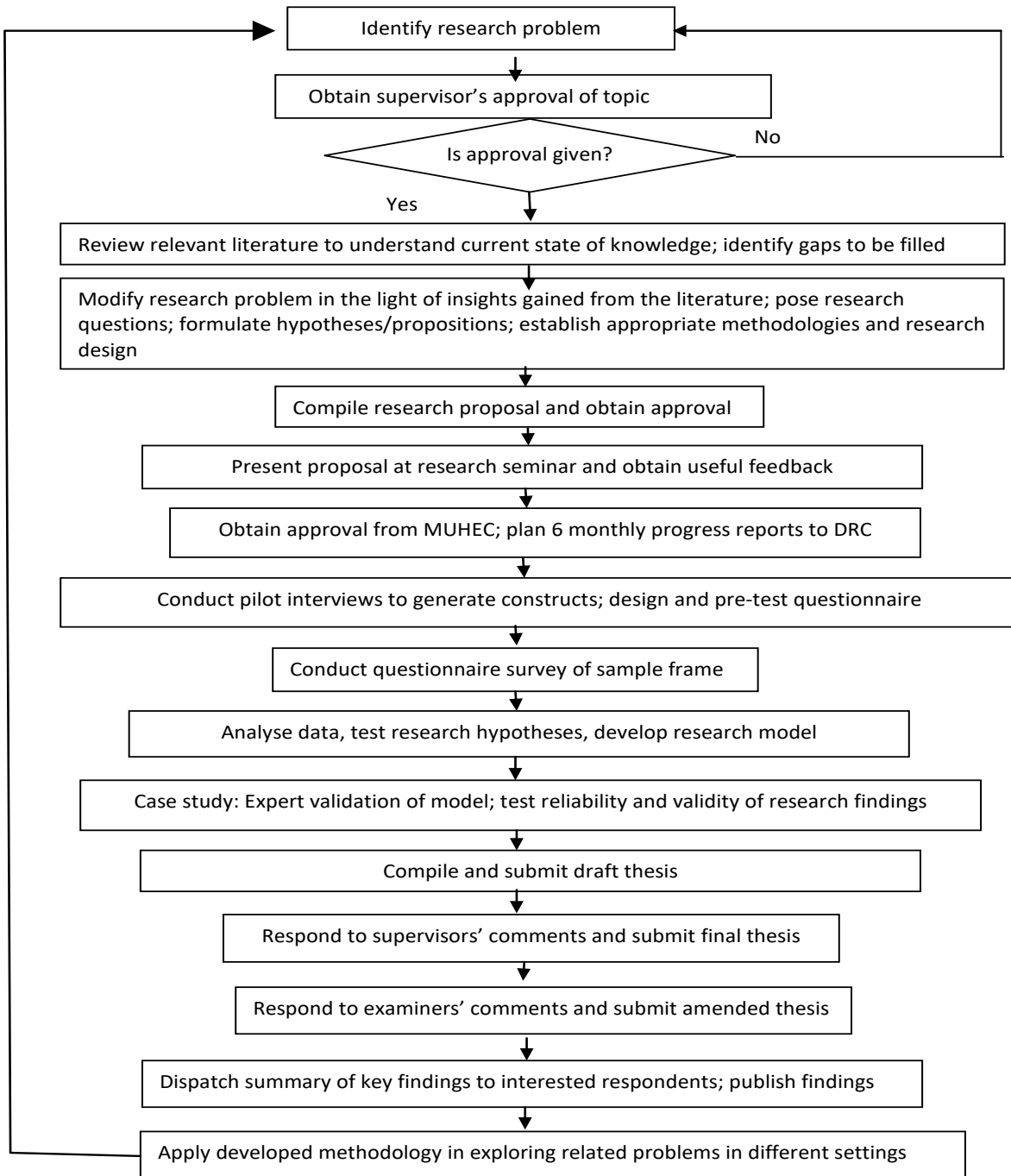
### **3.10 Deliverables**

The key objectives of this research provided the deliverables, the achievement of which marks the completion of the research. These are as follows:

1. Priority productivity constraints that contractors face in road pavement maintenance and rehabilitation (RPMR) projects in New Zealand.
2. Measures for mitigating the identified constraints in order to improve efficiency and productivity in RPMR.
3. Designed Toolkit that industry can use for productivity and constraints risk assessment before entering into any contract.

### **3.11 Research process**

The process being followed for the execution of this research project from conception to conclusion comprises 15 steps, as shown in Figure 14.



**Figure 13:** Research process flow chart

### **3.12 Ethical approval**

Research ethics should remain at the centre of researcher ethics principles as it is important to maintain the best possible behaviour towards research participants or those involved and affected by the research (Mack, 2005; Saunders & Savulescu, 2008). Therefore, to fulfil the ethical requirement for this research, an ethical approval application along with all required and supporting material was submitted to Massey University Human Ethics Committee (MUHEC) before commencing the research. MUHEC approval was granted to this research by rating it as low-risk research. This was then used as permission to go ahead and advance the initial stages of the data collection.

To follow the code of ethics of the MUHEC committee, the required principles were followed strictly. A disclaimer statement also was added in the last section of the survey questionnaire and correspondence with the research participants as a part of the MUHEC code of practice and policy. It assured research participants about the privacy and confidentiality of the research and collected data.

A copy of the obtained ethical approval has been attached to Appendix A.

## **CHAPTER 4: RESULTS AND DISCUSSIONS**

### **4.1 Overview**

This chapter presents the data captured from a questionnaire survey that was sent to targeted participants who were professionals working within companies involved in roading projects, especially road maintenance projects, within New Zealand. A total of 71 participants completed the survey by the final date set for the survey. One survey result was excluded from survey analysis after screening the survey as it was non-responsive and uncompleted. The survey participants were Project Managers, General Managers/ Associate directors, Contract Managers, Project, Site & Design Engineers, Team Leaders, and Supervisors directly involved in roading maintenance projects.

The obtained survey responses confirmed that the constructs generated at the pilot interviews and pre-test survey were robust and provided a comprehensive list of the productivity constraint factors and their mitigation measures accompanied by their level of impact. As the primary survey was also open-ended, it captured some additional factors, especially around mitigation measures. However, the supplied additional factors were largely a rephrase of the constructs in the list provided for rating. In the following sections, each research stage has been described in more detail.

### **4.2 Qualitative data gathering stage: pilot interview & open-ended questionnaire**

As explained in the research methodology section, the first stage of the data-gathering stage for this research was qualitative data gathering through pilot interviews, which were used to create a research hypothesis. This was based on research objectives exploring the existing productivity constraints and benefits of using mitigation measures to improve productivity and preperformance. In addition, to explore more qualitative data, the main survey was also designed as an open-ended questionnaire. This research method is advantageous when a researcher tries to explore facts, information or data which is not easily obtainable through standard data gathering methods such as literature reviews (Creswell, 2013).

Cooper and Emroy (2009) recommended that qualitative data gathering methods are the most appropriate strategy for having an in-depth and comprehensive data gathering from research participants and, in this research, from experienced professionals working in the field of road maintenance and the construction industry.

### **4.3 Quantitative data /confirmatory method**

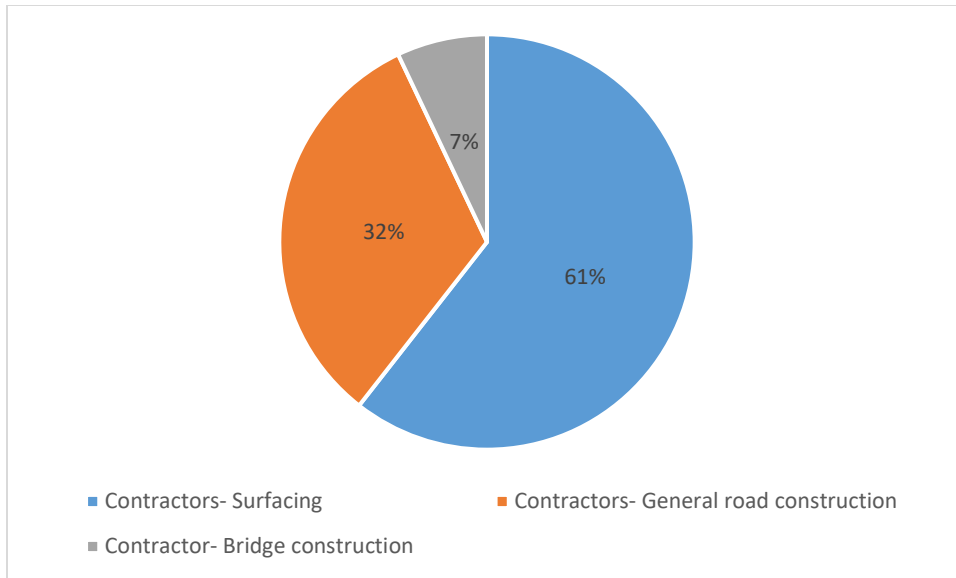
Generally, the quantitative research method is a method that can generate numerical data during research. Numerical data is especially required when a researcher analyses the obtained results and can be used to interpret the data, especially for data obtained during an inflexible close-ended questionnaire with limited choices and limited rating options.

The quantitative research method can also be used to test the research theory as it will allow the researcher to interpret the obtained data and create numerical data using statistical checks (Zikmund, 2012). Using statistical tests can lead to disconfirmation or confirmation of the chosen research theory.

## **4.4 Demographic Profile**

### **4.4.1 NZTA's Prequalification categories of the respondents' firms**

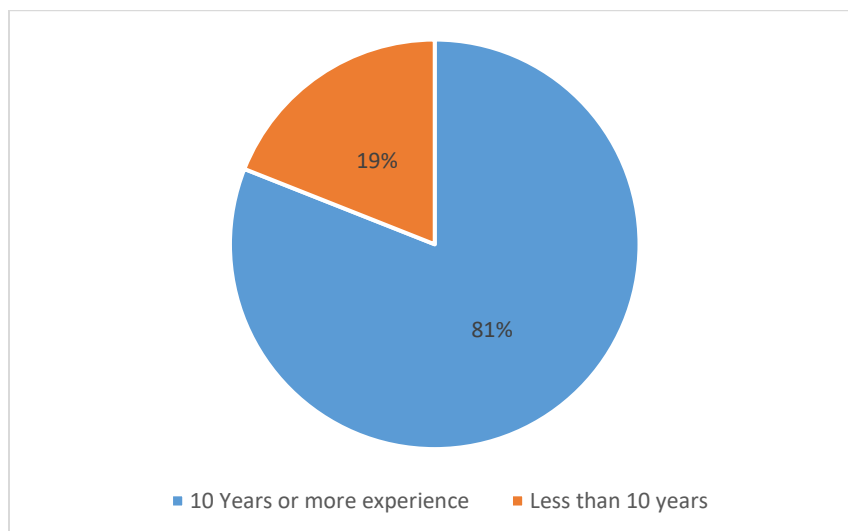
Figure 12 shows the various categories of the respondents' firms in the four categories of NZTA's prequalification contractor levels. The figure indicates that the majority of the participants (i.e. 61%) worked for contracting firms that belonged to the Surfacing work category. Others included general road construction (32%) and bridge construction (7%). None of the respondents' firms belonged to the routine and minor works category. Therefore, the results of this survey were biased towards the opinions of contractors that specialized in road surfacing jobs. The more significant proportion of contractors in this category was a positive outcome, given their direct relevance to the focus of the research.



**Figure 14:** Categories of the respondents' contracting firms in the NZTA's register of prequalified contractors

#### 4.4.2 Length of experience of the respondents

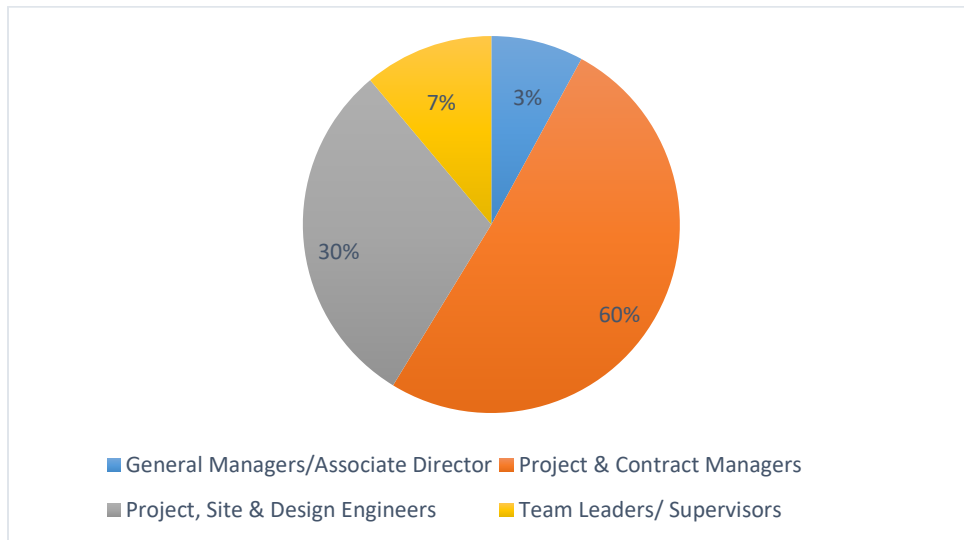
As shown in Figure 13, 81% of the respondents had at least ten years of experience in the roading industry in New Zealand as key members of project teams, and only 19% of the respondents had less than five years' experience. Therefore, feedback from this group enhances the quality of the study findings as professionals with the longest working experience in the industry can correctly recognise and realise the true existing productivity obstacles.



**Figure 15:** Length of experience of the respondents

#### 4.4.3 Status of the respondents in their organisations

Figure 15 shows the status of the participants in their organisations. The majority of respondents occupied the position of Project & Contract Managers 60%, followed by 30% who were Project, Site & Design Engineers, 7% Team Leaders and Supervisors, and 3% General Managers/ Associate Directors.



**Figure 16:** Status of the participants in their organisation

#### 4.5 Implications of the demographic profile for the quality of the research findings

In total, the majority of the respondents occupied leadership or senior leadership positions in their respective organisations. It is assumed that the feedback from those who make strategic decisions about road maintenance and rehabilitations projects have high quality and have added to the reliability of the final study findings and conclusions because these groups are at the forefront of any projects, involved in all stages of all projects and, therefore, their feedbacks are based on their daily real-life experiences. This group of professionals are facing/ resolving most of the productivity obstacles that exist during every phase of a roading project, from start to completion. As explained by Guest and MacQueen (2008), the quality of research is directly related to the length and quality of participants' experience because only the key professionals who are actively involved in road maintenance projects, from the design phase to construction phase, are able to correctly identify and rate the level of influence of productivity constraints.

## **4.6 Findings in relation to the first research objective**

The first objective of this study was to identify and prioritise the factors that constrain contractors' productivity performance in the road pavement maintenance and rehabilitation process (RPMR). The study finding has been explained in the subsections below regarding broad- and sub-categories.

### **4.6.1 Broad- and sub-categories of factors constraining contractors' productivity performance**

Findings from the first phase pilot interviews and open-ended pre-test survey revealed 69 constraint factors, which were aggregated under eight themes: (i) finance, (ii) workforce, (iii) technology/ process, (iv) statutory/regulatory compliance, (v) project characteristics, (vi) project management/project team characteristics, (vii) unforeseen circumstances, and (viii) other/ external factors. The broad categories and the sub-constraint factors are summarised in Table 5, based on feedback from survey participants who responded to the final online survey questionnaire. Therefore, the broad- and sub-constraints under each broad category were prioritised using the multi-attribute analysis of Equation 8. In Table 5, the sub-constraints are listed in decreasing order of their mean ratings (MRs) so that the first factor in the subset achieved the highest mean rating as the most influential in the group in the final survey.

The following subsections present discussions on the findings, in relation to the eight broad categories of constraints highlighted in Table 5.

In addition, section 4.8 describes what analysis method has been used to prioritise the constraints under eight main categories to a possible minimum number of main categories based on the effectiveness and importance of the constraints rated by participants. Also, section five describes how the outcome of the chosen research methodology and using factor analysis methods helped the outcome of the research to categorise eight broad categories into four main groups to achieve IPEO model outcome, which helped develop the final toolkit.

Below is summary of all steps used to categorise the 8 group into four group:

- SPSS-based exploratory factor analysis was used to extract the principal components from the 69 constraints identified in the earlier research phases

- Apply confirmatory tests such as Kaiser- Meyer-Olkin (KMO), Bartlett’s test of Sphericity.
- Apply reliability test for internal consistency such as Cronbach’s alpha test
- And finally present the result by using new findings

**Table 5:** Broad- and sub-categories of factors constraining contractors’ productivity performance in road pavement maintenance and rehabilitation projects in New Zealand

<b>Broad constraint category</b>	<b>Sub-constraints</b>
Workforce	<ol style="list-style-type: none"> <li>1) Lack of good leadership/management capability</li> <li>2) Inadequate skill and experience with current project type</li> <li>3) Low level of motivation/commitment</li> <li>4) Poor monitoring or appraisal of performance</li> <li>5) Poor resource management;</li> <li>6) Inadequate empowerment (training and resourcing) for employees</li> <li>7) Workforce absenteeism</li> <li>8) Unfamiliarity with current project type and project environment</li> <li>9) Long working hours with insufficient rest periods, especially during night work</li> <li>10) Workforce health issues</li> </ol>
Project management/ Project team characteristics	<ol style="list-style-type: none"> <li>1) Frequency of design changes/change orders/late changes</li> <li>2) Poor project management and risk management processes</li> <li>3) Lack of sufficient planning from the outset</li> <li>4) Lack of effective communication/ clarification of expectations among key stakeholders</li> <li>5) Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council</li> <li>6) Experience and competencies of the project team</li> <li>7) Poor supply chain management, especially as it relates to "just-in-time" supply principles</li> <li>8) Lack of proper and regular coordination; supervision; performance monitoring and control</li> <li>9) Lack of project organisational culture that supports high productivity and performance</li> <li>10) Lack of organisational learning: (learning from previous projects)</li> <li>11) Client's overt influence on the project process</li> <li>12) Supplier related issues (delay, inferior goods)</li> </ol>
Unforeseen circumstances	<ol style="list-style-type: none"> <li>1) Inclement weather</li> <li>2) Unforeseeable ground conditions forcing design revisions</li> <li>3) On-site accidents</li> <li>4) Natural disasters/Acts of God</li> </ol>
Project characteristics	<ol style="list-style-type: none"> <li>1) Unfavourable time frames within which most road works must be carried out;</li> <li>2) Sites location and environmental constraints (e.g. traffic volume, climate, subsoil and topography);</li> </ol>

	<ul style="list-style-type: none"> <li>3) Planning &amp; logistic issues impacting on continuous work flow (e.g non-closure period);</li> <li>4) Project complexity: scale, design;</li> <li>5) Public notification issues (e.g. community and environmentalists' resistance to infrastructure development plans)</li> <li>6) Nature and significance of road in the road hierarchy</li> <li>7) Type of procurement adopted</li> <li>8) Relation between rehabilitation or maintenance scale and plant utilisation</li> </ul>
Project Finance Issues	<ul style="list-style-type: none"> <li>1) Inadequate supply or high cost of required resources: funding, labour, materials &amp; machinery</li> <li>2) Lack of collaboration between consultant &amp; contractor;</li> <li>3) Inaccurate estimate (Client, consultant and contractors)</li> <li>4) Under-valued work</li> <li>5) Construction-phase defective or non-compliant work;</li> <li>6) Financial capacity for the scale and complexity of work involved</li> <li>7) Late payments;</li> <li>8) Dispute and litigation costs;</li> <li>9) Lenders' high interest charges</li> </ul>
Technology/ Process	<ul style="list-style-type: none"> <li>1) Ineffective approach to road maintenance</li> <li>2) Resistance to accept new technologies and methods for road maintenance &amp; rehabilitation projects</li> <li>3) Inadequate training on new processes and technologies</li> <li>4) Lack of reliable early road failure detection system</li> <li>5) Insufficient monitoring process for road failure detection</li> <li>6) Suitability or adequacy of the plant &amp; equipment employed</li> <li>7) Inadequate IT infrastructure and application in road maintenance industry</li> </ul>
Statutory/ Regulatory compliance	<ul style="list-style-type: none"> <li>1) Health &amp; Safety in Employment Act</li> <li>2) Resource Management Act</li> <li>3) Statutory Consent Compliance</li> <li>4) Local Authority Bylaws</li> <li>5) Construction Contracts Act</li> <li>6) Employment Relations Act</li> <li>7) Consumer Guarantees Act</li> <li>8) Fair Trading Act</li> </ul>
Other/ external factors	<ul style="list-style-type: none"> <li>1) Market conditions and level of competition in the industry for jobs</li> <li>2) Post-construction defective or non-compliant work</li> <li>3) User/Client value perceptions</li> <li>4) Inflation / fluctuations in material prices;</li> <li>5) Durability of completed work within the defect's liability period or warranty/guarantee</li> <li>6) Frequent changes in government policies/ legislations impacting on construction</li> <li>7) Post completion deterioration rate relating to rough use;</li> <li>8) In-use conditions being at variance with prior production assumption;</li> <li>9) Fluctuations in exchange rate</li> <li>10) Energy crises/rising costs</li> </ul>

### ***Workforce related constraints***

Ten sub-constraints were analysed under the workforce-related broad category. The most influential is the contractor's lack of good leadership/management capability. This finding resonates with the observations of Müller and Turner (2010) that poor project management capability has a huge impact on project outcomes largely due to poor coordination of the various stakeholders' inputs in the project delivery process. This problem might be rooted in the fact that most contractors may have the technical skills but lack leadership and management competencies needed to harness resources and efforts seamlessly towards common goal attainment (Mbachu, Egbelakin, Rasheed, & Shahzad, 2017). Therefore, leadership and management competencies should be part of the upskilling programmes for the road pavement and rehabilitation contractors in New Zealand to boost their productivity.

### ***Project management/ project team characteristics***

Out of the 12 constraints identified under the broad category of project management/project team characteristics, issues relating to the frequency of design changes or late change orders exert the strongest influence. This finding agrees with the conclusions of Alinaitwe et al. (2007) that late change orders – especially at critical stages of the project implementation – could slow down progress; and if the Principal to the contract refuses to accept the changes as a true variation under the contract conditions, the contractor bears the full risks which could constrain the cash flow and completion time. Therefore, fully articulating the needs of the client and the users early at the briefing stage could minimise the amount and frequency of downstream change orders, thereby enhancing progress and productivity outcomes.

### ***Unforeseen circumstances***

Only four constraints were identified under this broad category; inclement weather was rated as the highest influential factor among the four constraints. In the context of construction,

Makulsawatudom et al. (2004) define ‘inclement weather’ as harsh or severe atmospheric conditions that are beyond the level that could be forecast or predicted even by weather experts and which are not conducive for workers to carry on their work unprotected without being exposed to danger. Similarly, the New Zealand Standard 3910 (StandardsNewZealand, 2003) include inclement weather as part of conditions for variation entitlements only if a reasonable contractor is not able to foresee the weather pattern during the weather period of work; however, the variation entitlements are not an option under lump sum fixed-price contracts with no allowance for contract adjustment. The high risk associated with this constraint is due to its prevalence in road pavement maintenance and rehabilitation projects, especially considering the performance-based contracts that are used for the projects, which place most risks on the contractors. Inclement weather and other unforeseeable externalities represent one set of productivity constraints that are beyond human control; mitigation could only be through insurance (where insurable) and adequate contingency allowances.

### ***Project characteristics related constraints***

Table 5 showed that the broad category of project characteristics comprised eight constraints. The most influential in the group relates to unfavourable time frames within which most road works must be carried out. This is consistent with Lee et al. (2002) finding that an unfavourable timeframe can hugely hinder the level of planned productivity and performance, for example, working night shifts that are limited to certain start and finish times.

The second most important factor in this category which was rated with a high level of impact on productivity, is site location and associated environmental constraints such as traffic congestion, climate, subsoil, and topography. This finding is consistent with Lee et al. (2002) statement that location-based construction logistics issues such as road restrictions and traffic volume can significantly influence productivity and performance in road maintenance projects. In addition, Perrier et al. (2006) concluded that subsoil conditions could and indeed do have a high level of impact on productivity rates in road projects.

### *Project finance-related constraints*

Table 5 shows that out of the 11 sub-constraint factors identified under the project finance-related broad category, the most influential constraint to roading contractors' productivity and performance is the problem of inadequate supply or high cost of required resources: funding, labour, materials & machinery. This result agrees with similar findings by Durdyev and Mbachu (2011a) for the building sub-sector. Perhaps this corroborates the submission by the famous British judge – Lord Denning – that “there must be a cash flow in the building trade. It is the very lifeblood of the enterprise” (Cooke & Williams, 2013). This evidence proves the fact that if the flow of adequate resources is constrained at any stage in the contractual supply chain, operations and productivity performance would be seriously constrained.

The second influential factor is the lack of collaboration between consultants and contractors. Ozorhon et al. (2010) found that effective coordination and collaboration among the key stakeholders, notably the client, contractor, consultants and suppliers, is essential for ensuring maximum value delivery in any road pavement project from design through production and construction to the operation and maintenance phases. Therefore, there is empirical evidence supporting the submission that ineffective coordination and collaboration among the key role-players in the road pavement project could constrain cooperative efforts and overall productivity and project outcomes.

The inaccurate estimate was analysed as the third most influential factor under the broad category of project finance-related constraints. This finding is consistent with the conclusion by Peshkin et al. (2009) and Wang and Horner (2007) that contractors themselves cause their problems by not accurately estimating the total costs of work prior to offering a tender figure. Perhaps this problem is prevalent because of the competitive tendering process that is often based on the lowest conforming tender, which is mainly used for public sector contracts (Vassallo & Izquierdo, 2002). To avoid being uncompetitive, contractors may intentionally underestimate, so they can win jobs but with the ulterior motive of making up their profit expectations from anticipated variation claims.

### ***Technology/process related constraints***

Under this broad category, an ineffective approach to road maintenance in the road pavement projects featured as the most influential constraint out of the eight constraints in the group. This is consistent with Giustozzi et al. (2012a) findings that keeping road pavements at high service levels is achievable only through an effective preventive maintenance approach during the pavement service life. This helps to improve road pavement performance and reduces its rapid deterioration rate and costly rehabilitation.

Table 5 also shows that resistance to accepting new technologies and methods for road maintenance and inadequate training on new processes and technologies and rehabilitation projects are the second and third important factors, respectively, under the broad category of Technology/Process constraints. This concurs with the findings of Peshkin et al. (2009) and Peansupap and Walker (2005) that resistance to technology-driven change is prevalent in the roading sector, and it is usually driven by lack of time and resources involved with training on the use of new technologies, or simply because contractors are not convinced that the benefits are worth the investment of time and money. This is largely because of a short-term view of the benefits of technology.

### ***Statutory/ regulatory compliance***

Under this broad category, issues related to compliance with the Health and Safety At Work Act 2015, featured as the most influential out of the nine sub-constraints that were analysed under this heading. This should be expected because of the severe penalties for non-compliance under the new Act. For instance, Work Safe New Zealand (WorkSafeNZ, 2019) advised that Category 1 offence under the new Act attracts the highest penalty for a company (up to \$3 million); for the individual as an officer (\$600,000 or five years in jail or both); and for the individual as a worker (\$300,000 or five years in prison or both). This finding supports the concerns expressed by the New Zealand Productivity Commission (2012) about the over-regulation and high statutory compliance costs in the construction industry of New Zealand and the negative impact on productivity, innovation and housing affordability. Therefore, a strategic reform of the statutory

compliance requirements in the road pavement sector towards a more conducive regulatory environment could enhance productivity in the sector.

### ***Other external factors***

Eleven factors were identified under this grouping, with the highest influencing factor being issues relating to market conditions and the level of competition in the industry. This finding should be expected given that the New Zealand construction industry, in general, is prone to a boom-bust cycle, which has been identified as one of the most significant problems hindering productivity and growth of the industry (ProductivityCommission, 2012). The issues stemmed from cash flow problems associated with under-pricing during periods of stiff competition or resource problems associated with taking on too many jobs beyond the company's resource capacity during the boom phase.

#### **4.6.2 Relative levels of impact of the broad categories of constraint factors on contractors' productivity and performance**

Table 6 presents the result of a multi-attribute analysis of the respondents' ratings of the relative levels of impact of the broad categories of constraint factors on RPMR contractors' productivity and performance. The table shows that out of the eight broad constraint factors, only the workforce-related and Project management/ project team characteristics-related constraints categories were rated as 'High' with a mean rating of 3.79 and 3.69. In diminishing order of impact, the following five constraint categories were rated as being 'Moderate': unforeseen circumstances, project characteristics, project finance, technology/ process, and statutory/ regulatory compliance. Other external factors, such as economic, political, industry, etc., were rated as having a low impact.

In many respects, this result is not consistent with related findings in previous studies. For instance, Wang and Horner (2007), Omopariola et al. (2019) and Kerzner (2017) concluded that cash flow or project finance – being the lifeblood of the business – has the potential to exert the most profound influence on productivity and performance of contractors handling public and private sector projects. Also, statutory/ regulatory compliance issues should have received very high ratings given the increasingly over-regulated environment within which contractors operate in

New Zealand, especially in regards to the new NZ Health and Safety at Work Act (WorkSafeNZ, 2015) which stipulates extremely high fines – up to \$1 million and/ or five-year jail term – for non-compliance.

Also, the World Economic Forum (2016) noted that digitalization, innovative technologies and new construction techniques have vast potential for improving productivity and efficiency in the industry and hence transformation to a more resilient and prosperous future. Inadequate or outdated technology and the process has the opposite effect.

Perhaps the perception that workforce-related issues encapsulate all other issues could contribute to this result. For instance, statutory penalties occur when workers fail to do what they are supposed to do in terms of adhering to the specified compliance standards in work. Cash flow or financial issues arise when workers fail to be prudent in their work processes and are involved in excessive wastage, shoddy work or idleness (Fewings & Henjewele, 2019; Toth & Sebestyen, 2015).

**Table 6:** Relative levels of impact of the broad categories of constraint factors on contractors' productivity and performance

Broad categories of constraint factors	Rating on relative levels of impact					Total Responses	Weighted Average (Mean Rating Eq.5)
	Very Low	Low	Moderate	High	Very High		
2. Workforce	1.59% 1	3.17% 2	33.33% 21	38.10% 24	23.81% 15	63	High 3.79
5. Project management/ project team characteristics	1.61% 1	14.52% 9	25.81% 16	29.03% 18	29.03% 18	62	High 3.69
7. Unforeseen circumstances	4.76% 3	19.05% 12	36.51% 23	26.98% 17	12.70% 8	63	Mod 3.24
4. Project characteristics	1.59% 1	19.05% 12	31.15% 19	26.23% 16	6.35% 4	63	Mod 3.17
1. Project finance	4.92% 3	31.15% 19	30.91% 17	27.27% 15	6.56% 4	61	Mod 2.98
3. Technology/process	1.59% 1	30.16% 19	46.03% 29	19.05% 12	3.17% 2	63	Mod 2.92
6. Statutory/ regulatory compliance	7.94% 5	39.10% 24	38.10% 24	9.52% 6	6.35% 4	63	Mod 2.68
8. Other external factors (economic, political, industry, etc)	17.74% 11	45.16% 28	27.42% 17	8.06% 5	1.61% 1	62	Low 2.31

#### 4.7 Findings in regards to the second objective

The study's second objective was to explore measures for mitigating the identified constraints, intending to improve efficiency and productivity in the road pavement maintenance and rehabilitation (RPMR) project delivery process.

##### 4.7.1 Preventive mitigation measures

Table 7 presents the findings in regards to preventive mitigation measures for addressing the identified constraints with a view to improving productivity and performance. Table 7 shows three factors were rated as the most influential factors out of 19 factors: Early contractor involvement with a rating value of 4.25, Communication with a rating of 4.06, and Planning with a rating of

4.04. This finding is consistent with the findings of Song et al. (2009). As described by Song et al. (2009), the importance of integrating construction knowledge into the design process has long been recognised by the construction industry, and as their research outcome presents, early contractor involvement, especially during early stages such as the design phase, will reduce the project productivity risks and has a significant impact on construction schedule performance. Also, as their research finding suggests, commonly observed benefits of early contractor involvement include improved design quality, material supply and information flow, which all leads to successful project completion with fewer quality defects, as experienced contractors can correctly determine what risks are involved on each project phase from early design stages to project completion. They have also found that early contractor involvement positively affects improving communication which was rated as the second important mitigation measure with a very high impact (4.06) on productivity in road maintenance projects. Song et al. (2009) has described that improving communication facilitates adequate information flow to help prompt decision-making and minimises duplication of efforts due to a communication gap to the 'frontline' people.

The third factor rated as a highly effective mitigation measure on improving productivity in road maintenance projects was planning. Participants rated planning as an influential mitigation measure that minimises unexpected productivity risks. Alinaitwe et al. (2007) suggest that proper planning should be done upfront to establish the benchmarks for downstream performance. Moreover, performance reviews and progress updates are essential for successful planning. He also stated that providing plans for other challenges such as risks for statutory compliance (health and safety, environmental impact, traffic management, etc.) upfront could significantly improve the rate of productivity in any construction project, particularly during road pavement maintenance projects.

Research participants rated proper supervision of the workforce as the fourth highly influential mitigation measure on improving productivity in road maintenance projects that minimises idle time and helps improve productivity and performance of the workforce.

Table 7 also presents that 12 factors were rated with high impact; three factors were rated with moderate impact, and one factor was rated with low impact on productivity and performance in road pavement maintenance productivity. As mentioned above, 12 factors have a high impact on productivity; supervision of the workforce has the highest rating value of 3.93.

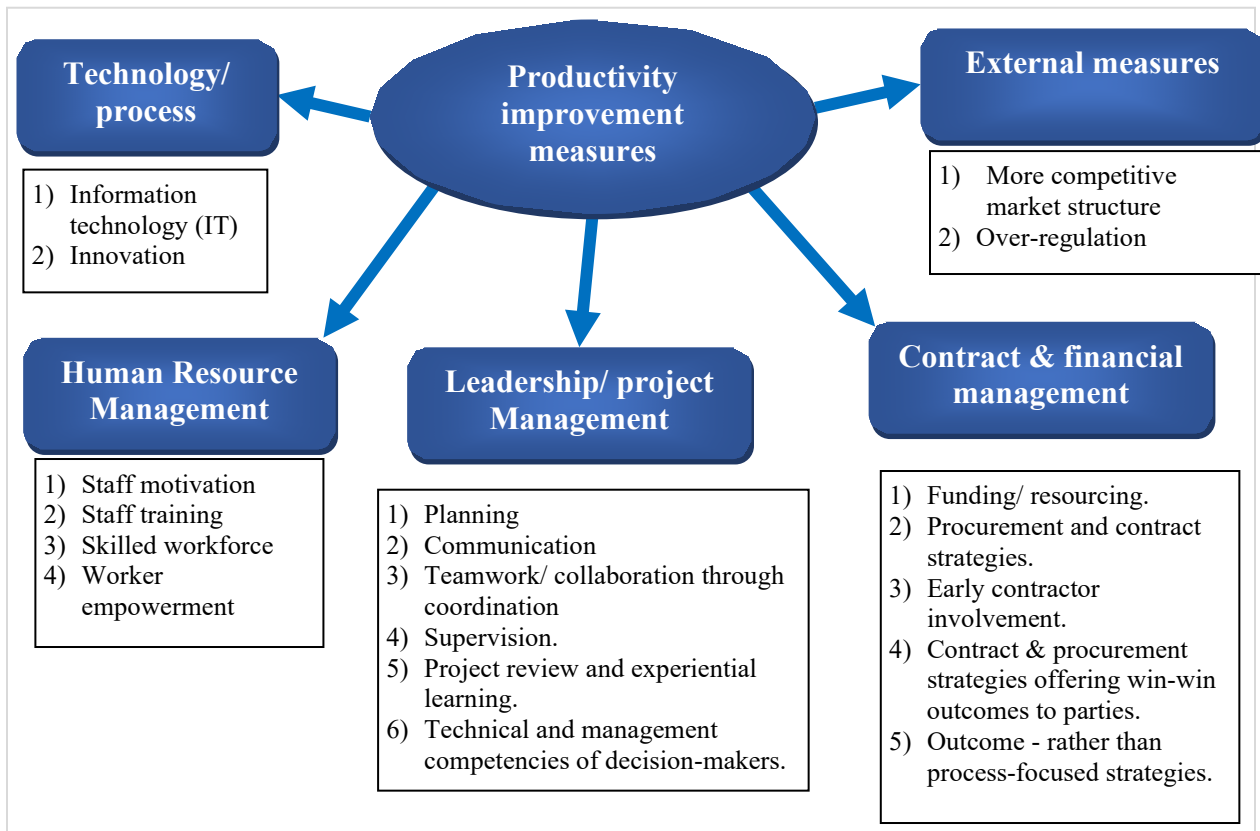
The following preventive mitigating measure with a high impact rating is a skilled workforce. As suggested by research participants, applying this preventive mitigation measure will help contractors achieve high quality and improve productivity by mitigating poor quality of workmanship and serious accidents on site. Several types of research in different countries with similar findings, such as Kazaz et al. (2012) and Crescenzi et al. (2016), show that hiring a skilled workforce is one of the important preventive factors that can help prevent non-conformance accidents which can highly impact a project's productivity.

Improvement Measures	Very Low	Low	Moderate	High	Very High	Total	Weighted Average
<b>Early contractor involvement:</b> Encourage early contractor involvement in the design and planning phase to ensure buildability and more innovation that can reduce costly and time-consuming variation and rework associated with design solutions not aligning with practical site conditions.	0.00%	6.56%	8.20%	39.34%	45.90%	61	Very High
	0	4	5	24	28		4.25
<b>Communication:</b> Ensure effective communication network to permit adequate information flow for clarity and prompt decision-making and to minimise duplication of efforts due to communication gap to the 'frontline' people.	1.61%	3.23%	16.13%	45.16%	33.87%	62	Very High
	1	2	10	28	21		4.06
<b>Planning:</b> Proper planning should be done upfront to establish the benchmarks for downstream performance reviews and progress update; also provide plans for other challenges such as risks for statutory compliance (health and safety, environmental impact, traffic management, etc.)	1.61%	4.84%	16.13%	41.94%	35.48%	62	Very High
	1	3	10	26	22		4.04
<b>Supervision:</b> Ensure proper supervision of the workforce to minimise idle time and poor productivity;	1.64%	4.92%	16.39%	52.46%	24.59%	61	High
	1	3	10	32	15		3.93
<b>Skilled workforce:</b> Ensuring only qualified and experienced workers are employed to mitigate poor quality of workmanship and accidents on sites;	4.84%	6.45%	9.68%	51.61%	27.42%	62	High
	3	4	6	32	17		3.90
<b>Teamwork/ collaboration through coordination:</b> Use good coordination skills to foster collaboration among key stakeholders - client, contractor, consultants, suppliers, etc. - to work collaboratively and ensure maximum value delivery from design through production and construction to operation and maintenance.	1.67%	10.00%	13.33%	55.00%	20.00%	60	High
	1	6	8	33	12		3.82
<b>Staff training:</b> Provide adequate training programme to update and broaden staff skills on current best practices and trends, e.g. new occupational health and safety requirements on site. Up-skill the people making the decisions – i.e. engineers, clients and contractors.	0.00%	3.23%	32.26%	43.55%	20.97%	62	High
	0	2	20	27	13		3.82
<b>Project review and experiential learning:</b> Ensure continuous improvement by debriefing on completed sections or for the whole projects and documenting valuable lessons for the future;	0.00%	4.84%	32.26%	45.16%	17.74%	62	High
	0	3	20	28	11		3.76
<b>Scheduling:</b> Proper scheduling of operations to smoothen peaks and troughs in resource demand in line with resource ceilings/ capacity. Schedule work to minimise impact of weather; e.g. weather affected works should not be planned in winter.	0.00%	11.29%	24.19%	48.39%	16.13%	62	High
	0	7	15	30	10		3.69
<b>Worker empowerment through engagement:</b> Involve all those that will implement the project in the planning and decision-making process, so everyone knows the goals and expectations and can take ownership and commit to overall outcome achievement and, as well, are updated on changes.	1.61%	11.29%	24.19%	45.16%	17.74%	62	High
	1	7	15	28	11		3.66

<b>Technical and management competencies of decision-makers:</b> Improve technical/practical knowledge and management capability of road authority engineers & consultants to align their decisions to practical realities and in line with contractors' innovative processes for optimum productivity and outcomes.	1.61%	12.90%	22.58%	48.39%	14.52%	62	High
	1	8	14	30	9		3.61
<b>Innovation and win-win outcomes:</b> Minimise red tape and bureaucracy in decision-making processes; encourage innovation and share equally any associated rewards for cost and time savings among contributors.	3.33%	8.33%	30.00%	41.67%	16.67%	60	High
	2	5	18	25	10		3.60
<b>Staff motivation:</b> Provide adequate incentives to motivate staff for peak performance;	4.84%	4.84%	30.65%	46.77%	12.90%	62	High
	3	3	19	29	8		3.58
<b>Outcome - rather than process-focused:</b> Focus on outcomes rather than processes to avoid the current practice of missing the goal and 'covering of tracks just in case things might go wrong'	1.64%	9.84%	39.34%	36.07%	13.11%	61	High
	1	6	24	22	8		3.49
<b>Procurement and contract strategies:</b> Clients should rethink preference for lowest price conforming tenders and traditional system approaches to more collaborative procurement and contract strategies that focus on life cycle value and win-win outcomes for all stakeholders.	1.64%	13.11%	34.43%	40.98%	9.84%	61	High
	1	8	21	25	6		3.44
<b>Funding/ resourcing:</b> Provide adequate funding and cash flow to ensure good progress and quality of work; ensure adequate level of resources to suit work demands and optimise efficiency and utilisation (i.e. not too much or too little plant and people resource)	4.84%	24.19%	29.03%	29.03%	12.90%	62	Mod
	3	15	18	18	8		3.21
<b>Information technology (IT):</b> Integration of IT in the work processes to improve efficiencies, productivity and performance, using minimal resource inputs.	0.00%	22.95%	45.90%	26.23%	4.92%	61	Mod
	0	14	28	16	3		3.13
<b>More competitive market structure:</b> Resolve oligopoly to improve efficiencies through fostering competition and innovation. Encourage smaller work packages to enable small to medium competitors to compete for jobs rather than having gigantic projects that only the few big companies have capacity to compete for, which excludes the majority of the SMEs	3.23%	27.42%	38.71%	19.35%	11.29%	62	Mod
	2	17	24	12	7		3.08
<b>Over-regulation:</b> Minimise regulatory and statutory controls that inhibit innovation and creativity towards efficiencies and productivity. The regulators should be in partnership with the service providers, get on-board and work as teams, guiding each other along the way rather than waiting for mistakes and passing on blame.	9.68%	12.90%	45.16%	25.81%	6.45%	62	Low
	6	8	28	16	4		3.06

To present a better overview of all mitigation measures and their level of impact, the 19 sets of constraints summarised in Table 7 were clustered under five broad categories. Figure 16 highlights

the broad categories as technology/ process, human resources management, leadership/ project management, contract and financial management and external measures.



**Figure 17:** Measures for productivity and performance improvement in the road pavement maintenance and rehabilitation projects

#### 4.7.2 Corrective mitigation measures

Participants were reluctant to offer suggestions on corrective mitigation measures because they believed that ‘prevention is better than cure’. They would prefer that preventive measures suggested in the preceding sections were rigidly followed, adding that constraints more often than not result from not implementing the preventive measures adequately. However, a number of the participants provided information on typical problems they encountered and innovative solutions they came up with during project implementation, notwithstanding the preventive measures they had in place. The corrective measures applied to the problems encountered are highlighted under the key clusters as follows.

A) Technology/ process:

- Adopt the new available technologies
- Existing equipment becoming obsolete or inadequate for new standards: Acquire or hire new equipment
- Equipment breakdown: Hire equipment from a new supplier

B) Human resources management:

- Make the road maintenance industry an attractive place to work. Losing skilled staff at crucial stages of the project, e.g. through sickness or secondment: Hire new staff
- Teams need to share the motivation to achieve; it is hard to work towards a common goal where there are competing drivers.
- Good communications between design team, management and field staff with reasonable and realistic expectations of goals and achievements

C) Project management

- More accurate design work and investigation prior to construction. The number one issue on-site that the crew continue to encounter is inaccurate plans, resulting in a failure in attention to detail, inaccurate investigations, or inaccurate surveys in the design phase, which put design management among one of the high priority preventive mitigation measures.
- An agile approach to programming means there is little certainty for contract teams about workload; it is difficult to commit resources and even harder to engage sub-contractors to programs that are subject to change. This is a supply chain flow issue and prevents a team from gaining momentum in continuous improvement.

#### **4.7.3 Extra suggestions**

The comments below relate to extra unedited suggestions freely provided by participants in the open-ended sections of the questionnaire during the research pre-test and main survey. All extra suggestions have been categorised based on research which targeted eight broad categories: project finance, workforce, technology/ process, project characteristics, project management/ project team characteristics, statutory compliance, unforeseen circumstances, and other external factors. It is

important to mention that most of the suggestions are the same as factors that were identified during the qualitative research stage.

***Project finance:***

- 1- *“Cash flow problems arising from clients' reluctance to accept as variation, clients' or consultants' change orders that resulted in the increased scope of work or risks on the grounds that a reasonable contractor ought to have anticipated and priced the increased scope of work at the tender stage, especially in regards to ground conditions and associated design changes.”*
- 2- *“In most of the projects that I have been involved in, any variation requires a massive amount of unnecessary time-consuming communication between all parties due to lack of clarification at the tender phase and not having a detailed BOQ.”*
- 3- *“Across the board realisation that financial difficulties on smaller to medium contractors (i.e. not the big four main contractors in NZ) are reducing actual competition in the industry (which helps the big four). Genuine competition needs to occur, and packages that suit contractors other than the big four need to be considered. Large companies are underbidding maintenance contracts to remove local competition”.*

***Workforce:***

- 4- *“workforce absenteeism is hindering productivity hugely.”*
- 5- *“It has become difficult to hire a suitably skilled workforce.”*
- 6- *“Workers' apathy and resistance to due to lack of proper consultation about project implementation before decisions are taken concerning the work areas, and they are involved in.”*
- 7- *“Engaging people into the workforce that come with the right attitude. It is challenging to teach or change attitude when people are into, say their second or third job. However, if the attitude is already part of someone's personality, then learning new skills and taking on responsibility is easier.”*
- 8- *“Restricted workforce capabilities - no new blood coming into the industry.”*

**Technology/ process:**

- 9- *“All the best equipment in the world is no good if the people employed to drive it cannot operate it with an acceptable level of proficiency. There is no substitute for experience when it comes to machine operation and some good understanding of what is required to achieve a satisfactory level of productivity.”*
- 10- *“Labour-intensive versus technology-driven approaches; mismatch between technology/process and company culture/leadership style.”*
- 11- *“It should be noted that there is a broad range of technology uplift in the sector. Some are very good at it, while others are not.”*
- 12- *“Use of more effective and efficient materials: e.g. use more SBS modified binders in place of current materials; and emulsion-based products in place of current products”.*

**Project characteristics:**

- 13- *“Late client approvals is an issue. These are caused by our supply designs that are not approvable (quality and detail), or our client has an internal process we (and they) do not understand that slow approval. This impacts timing and ability to program work in an ideal way.”*
- 14- *The procurement model drives the contractors' behaviour. The suitable model drives the right outcome.*

**Project management/ project team characteristics:**

- 15- *Lack/poor material supply chain management is hugely affecting productivity.*
- 16- *Poor risk analysis and contingency planning/budget*
- 17- *If the client is micromanaging the project, a lot of time and energy is wasted; try to deal with them rather than the contract delivery itself.*
- 18- *Project teams usually are between jobs or, at times, focused elsewhere. Generally reacting rather than planning*
- 19- *“Currently, jobs must be milled, filled, and finished in one day. That means you need a traffic management team, milling, and paving crew for every site. If you could have*

*independent milling and paving crews, you could double the output. Each crew could mill or pave for 8-10 hours per shift instead of 4-6 hours each. The number of crews could be reduced, and cost per ton laid would be significantly reduced”.*

20- *“Allow for greater disturbance to the public in order to have projects completed more efficiently and cheaper. Timing and availability of road closures are important - if we had full closures, we could complete a whole lot more work”.*

21- *“Use of partnering in the project procurement to achieve win-win outcomes for all”.*

***Statutory compliance:***

22- *“Land Transport Rule - particularly Vehicle Standards Compliance 2002; Land Transport Act 1998; Land Transport (Road User) Rule 2004.”*

23- *“3910 should protect both parties when encountering unforeseeable ground conditions that require a change of scope outside the schedule of works.”*

24- *“Adherence to the 3910 standard and both consultant and contractor not fully understanding their rights and obligations within 3910.”*

***Unforeseen circumstances:***

25- *“Changes in legislation affecting road works, especially seismic resilience and environmental protection.”*

**4.8 Findings related to Objective 3**

The third objective of the study was to develop and validate a conceptual model of the identified constraints and mitigation measures. The model will serve as a toolkit for guiding contractors’ productivity improvement in the RPMR process.

Part of the model development process focuses on the smallest number of key constraint factors that have the greatest influence on the productivity and performance of the RPMR contractors. This marks a departure from existing knowledge where several constraints were provided in the literature with no form of prioritisation. Contractors were not presented with succinct information

on the key constraints so that they could leverage their limited resources to address only those constraints that matter most.

To establish the priority constraints and further reduce the number of constraint categories to as few priority ones as possible, the SPSS-based exploratory factor analysis was used to extract the principal components from the 69 constraints identified in the earlier research phases. Results of the factor analysis are discussed in the following subsections.

#### **4.8.1 SPSS Component transformation matrix (SPSS total variance explained)**

Based on Eigenvalues greater than 0.99, four principal components were extracted from the initial 68 constraint factors used for the exploratory factor analysis. Table 7: The table of total variance shows the total variance explained by the extracted four principal components. The first principal component (i.e. Principal Component 1) explained 78% of the variances in the 68 constraint factors, while the total variance explained by principal components 2, 3 and 4 were 10.6%, 2.6% and 2.1%, respectively. Ideally, only Principal Component 1 should have been extracted since it accounted for approximately 80% of the total variances in the 68 items. However, principal components 2, 3 and 4 were included in the extraction since they have Eigenvalues greater than 0.99 (IBM, 2014), even though their cumulative total variance explained is less than 16%.

#### ***Confirmatory test***

A parallel analysis test results confirmed the initial four factors as having higher eigenvalues, hence justifying their retention.

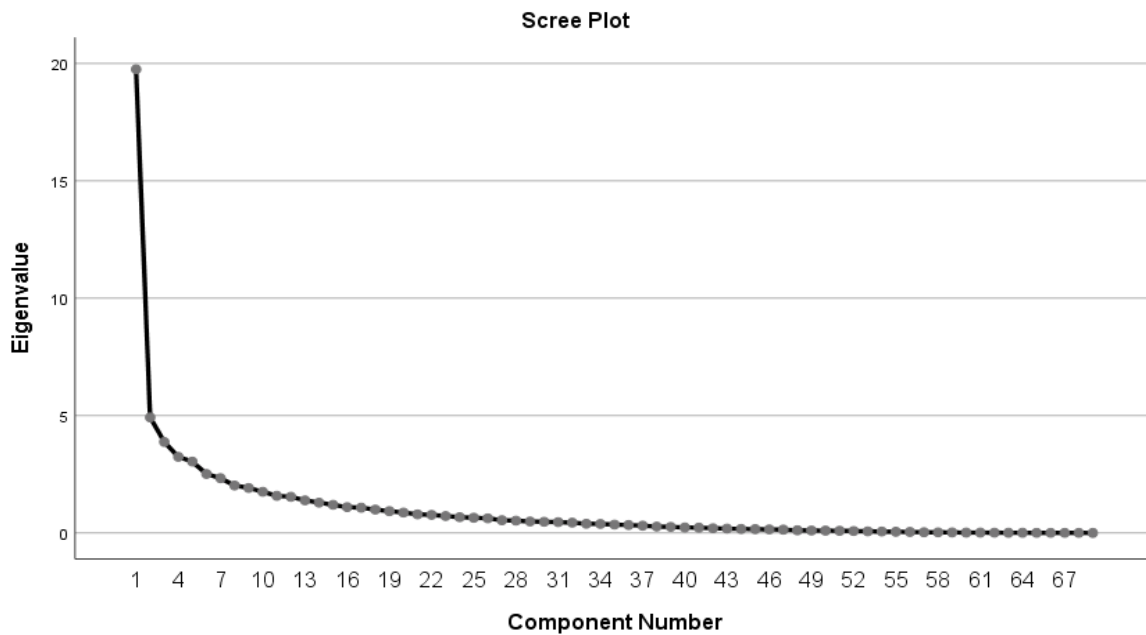
**Table 7:** Table of the total variance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% Of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	53.745	78.08	78.08	53.745	78.08	78.08	28.421	42.225	42.225
2	7.452	10.605	89.885	7.452	10.605	89.885	23.715	35.485	78.377
3	1.812	2.58	92.512	1.812	2.58	92.512	9.816	14.125	93.885
4	1.312	2.059	94.658	1.312	2.059	94.658	1.558	2.245	95.625
5	0.925	1.175	95.753						
6	0.492	0.695	96.658						
7	0.382	0.691	97.348						
..	..								
..	..								
..	..								
..	..								
65	-5.92E-15	-8.78E-15	100						
66	-6.83E-15	-1.15E-14	100						
67	-7.32E-15	-1.21E-14	100						
68	-9.65E-15	-1.52E-14	100						

Extraction Method: Principal Component Analysis

**Scree plot**

As a further confirmatory measure, the SPSS scree plot output in Figure 17: *Scree plot* confirms the Eigenvalues of the four principal components as being more significant than 0.99, though the plot indicates that only principal components 1 and 2 on the cliff of the plot should be retained.



**Figure 18:** Scree plot

#### 4.8.2 Kaiser-Meyer-Olkin (KMO) reliability test on the extraction

The Kaiser-Meyer-Olkin (KMO) test was conducted to measure the level of adequacy of the extraction or sampling of the four principal components from the 68 initial constraint factors. Through its coefficient value, it checks the adequacy of inter-correlations or multi-collinearity among the 68 factors as a measure of reliability or validity of the extraction result. Expressions for the null ( $H_0$ ) and alternative ( $H_A$ ) hypotheses of the KMO test are as follows.

- Null hypothesis:  $H_0: KMO \leq 0.7$  (i.e. insufficient inter-correlations exist among the variables).
- Alternative hypothesis:  $H_A: KMO > 0.7$  (i.e. sufficient inter-correlations exist among the variables)

Table 9 shows a KMO coefficient value of 0.896 achieved in the test. This value is greater than the threshold coefficient of 0.7 (Bryman & Cramer, 2011); it shows a strong measure of sampling adequacy. This result indicated that the partial correlations or multi-collinearity structures among the variables were sufficient to justify furthering the factor analysis procedure to the level of extraction of the principal components from the underlying variables.

**Table 8:** KMO and Bartlett's Test results

<b>Table: KMO and Bartlett's Test Results</b>	
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.896
Bartlett's Test of Sphericity	2445.128
Approx. Chi-Square	300
Degree of Freedom (df)	
P-Value or level of significance	0.001

#### 4.8.3 Bartlett's Test of Sphericity - further reliability test on the extraction

The Bartlett's Test of Sphericity null hypothesis assumed that inter-correlations still existed among the extracted principal components, i.e. there are considerable partial correlations among the principal components (IBM, 2014). Expressions for the null ( $H_0$ ) and alternative ( $H_A$ ) hypotheses of the Bartlett's test are as follows.

- Null hypothesis:  $H_0: p\text{-value} > 0.05$  (i.e.  $p\text{-value}$  is not significant;  $\rightarrow$  significant partial correlations exist among the extracted principal components).
- Alternative hypothesis:  $H_A: p\text{-value} \leq 0.05$  (i.e.  $p\text{-value}$  is significant;  $\rightarrow$  insignificant partial correlations exist among the extracted principal components).

Table 9 shows that the test result indicated a significant  $p\text{-value}$  (i.e.  $< 0.05$  alpha level of the test). Therefore, there was no statistical evidence to accept the null hypothesis, leading to a conclusion that the principal components make distinct and unique contributions to the phenomenon under study, i.e. the contractors' productivity and performance outcomes in the RPMR process. This test result offers an additional layer of reliability and validity to the extraction result, confirming no significant partial correlations exist among the four extracted principal components. It also confirms that the four principal components should not be further reduced, notwithstanding the small amount of total variance explained by the third and fourth principal components.

#### **4.8.4 Item loading on the principal components**

Since the Bartlett's Test of Sphericity result showed no significant partial correlations among the four extracted principal components, the appropriate extraction method in the SPSS factor analysis routine is the Varimax with Kaiser Normalisation rotation method (IBM, 2014). Tables 10 to 13 show how the 68 constraints loaded onto the four principal components.

Table 8 showed that the majority of the items (i.e. 20 out of 68 or 28.6%) loaded onto Principal Component 1. 7.2%, 5.6% and 4.7% of the items loaded onto the remaining Principal Components 2, 3 and 4, respectively. The few items that loaded on to Principal Components 3 and 4 provided sufficient ground to exclude them; however, they were retained since the data were based on pre-test survey responses from only 70 out of the 310 prospective respondents computed as the minimum representative sample size from whom responses will be needed from the study sampling frame during the full-scale survey (see Section 4.9).

**Table 9: Group 1 (Process constraint group) of SPSS rotated component matrix**

Component Matrix			Components			
			Process Operating	Operating Environment	Input	Output
			1	2	3	4
Group 1	1	Insufficient monitoring process for road failure detection	0.964			
	2	Lack of good leadership/ management capability	0.952			
	3	Inadequate empowerment (training and resourcing)	0.944			
	4	Workforce absenteeism	0.928			
	5	Relationship between rehabilitation scale and plant utilisation	0.912			
	6	Frequency of design changes/ change orders/late changes	0.911			
	7	Lack of effective communication/ clarification of expectations among key stakeholders	0.899			
	8	Client's over influence on the project process	0.896			
	9	Supplier related issues (delays, inferior goods)	0.895			
	10	Poor project management and risk management processes	0.894			
	11	Ineffective approach to road maintenance	0.892			
	12	Inadequate road failure detection system	0.889			
	13	Inadequate IT infrastructure and application in road maintenance industry	0.886			
	14	Low level of skill and experience	0.885			
	15	Low level of commitment and motivation	0.845			
	16	Low level of project experience	0.844			
	17	Poor monitoring or appraisal of	0.839			
	18	Overly long working hours	0.822			
	19	Poor resource levelling	0.801			
	20	Lack of experience of current job and operational condition	0.799			
	21	Workforce health issues	0.782			
	22	Planning & logistic issues impacting on continuous work flow(e.g. non-closure period)	0.775			
	23	Un-conducive time frames within which most road works must be carried out	0.769			
	24	Lack of sufficient planning from the outset	0.759			
	25	Relationship management degree of harmony, trust and cooperation between contractor, project owner and other key stakeholders.	0.748			
	26	Lack of organisational learning: (applying lessons learnt from previous projects to solving constraints)	0.732			
	27	Lack of proper and regular coordination; supervision; performance monitoring and controlling	0.731			
	28	Lack of project organisational culture that supports high productivity and performance project outcome	0.725			
	29	Poor collaboration and supply chain management, especially as it relates to "just-in-time"	0.711			
	30	Resistance to accept new technologies in road maintenance projects (include new Methods of repairing road failure)	0.701			
	31	Lack of adequate training on new processes and technologies	0.691			

**Table 10: Group 2 (Operation Environment constraint group) of SPSS rotated component matrix**

Component Matrix			Components			
			Process Operating	Operating Environment	Input	Output
			1	2	3	4
Group 2	1	Site Location		0.988		
	2	Public notification		0.981		
	3	Nature and significance of road in the road hierarchy		0.978		
	4	Health & Safety in Employment Act		0.976		
	5	Resource Management Act		0.971		
	6	Local Authority Bylaws		0.968		
	7	Construction Contracts Act		0.963		
	8	Employment Relations Act		0.958		
	9	Consumer Guarantees Act		0.952		
	10	Fair Trading Act		0.949		
	11	Inclement weather		0.947		
	12	Unforeseeable ground conditions necessitating revisions		0.942		
	13	On-site accidents/ Acts of God		0.939		
	14	Natural disasters		0.938		
	15	Market conditions and level of competitions in the industry for jobs		0.929		
	16	Inflation /fluctuations in material prices		0.924		
	17	Energy crises/rising costs		0.921		
	18	Frequent changes in government policies/ legislations impacting on project		0.919		
	19	Interest rate/cost of capital		0.915		
	20	Fluctuations in exchange rate		0.91		

**Table 11: Group 3 (Input constraint group) of SPSS rotated component matrix**

Component Matrix			Components			
			Process Operating	Operating Environment	Input	Output
			1	2	3	4
Group 3	1	Dispute and legislation costs			0.933	
	2	Lender high interest			0.931	
	3	Financial capacity			0.929	
	4	Project complexity			0.918	
	5	Experience & competency			0.915	
	6	Type of procurement			0.915	
	7	Inaccurate estimate			0.914	
	8	Lack of Collaboration			0.914	
	9	Inadequate Supply			0.91	
	10	Con-Phase Defect			0.909	
	11	Under value works			0.909	
	12	Late Payments			0.906	

**Table 12:** Group 4 (Output constraint group) of SPSS rotated component matrix

Component Matrix			Components			
			Process Operating	Operating Environment	Input	Output
			1	2	3	4
Group 4	1	Durability				0.906
	2	In-use condition				0.901
	3	Post completion				0.9
	4	User/client value perception				0.899
	5	Post-Construction completion				0.897

#### 4.8.5 Reliability test – internal consistency

As explained in Section 3.8.10, Cronbach’s alpha was used as the appropriate statistical tool to test the scale reliability of the items loaded onto the principal components (IBM, 2014). The test aimed to answer the question: Were the scales (i.e. the items that loaded on each principal component) measuring what they were supposed to measure? The question can be rephrased as: Are the items truly internal measures of the principal components, or are there some items that are not consistent with the rest in the set for each principal component?

Subsequently, Cronbach’s alpha test was carried out to screen the items loaded onto each principal component to make sure there are no inconsistent items in the set for each principal component. Two of the following SPSS output tables for Cronbach’s alpha test helped to carry out the item screening:

1. Reliability output table: This table provided the initial Cronbach’s alpha value for each set which is used as the benchmark to compare the Cronbach’s alpha value in the second output table:
2. Item Total Statistics output table: This table provided a column of “Cronbach’s alpha if item removed”. Comparing the initial Cronbach’s alpha value in the first Reliability output table with the value for each item in this table helped to determine which item should be removed (for being inconsistent) or retained (for being truly consistent) with the rest of the items under each principal component. The decision criterion is: Remove an item if its value of ‘Cronbach’s alpha if item removed’ is equal to or higher than the initial Cronbach’s alpha value in the Reliability output table; otherwise, retain the item as being internally consistent as a reliable scale for the principal component in question.

***Internal consistency test for principal component 1 (process)***

Tables 14 and 15 are the reliability and Item Total Statistics output tables of the SPSS Cronbach's alpha test, respectively. Table 14 shows that the initial Cronbach's alpha value for the items in Principal Component 1 is 0.99. As provided in Table 2, this value shows excellent internal consistency among the 31 items that make up the Principal Component 1 (i.e. Process). However, since the aim is to trim the items to the smallest possible size, the SPSS Item Total Statistics output table (i.e. Table 15) was checked to see if any of the 31 items should be removed from the list. As highlighted before, the item to be removed is the one which, if its Cronbach's alpha item is removed, is equal to or higher than the initial Cronbach's alpha value in the Reliability output table. On this basis, the table shows that 14 of the items should be deleted to improve the internal consistency of the group. Therefore, the 31 items are trimmed to 17. Removing these 14 items and re-running the Cronbach's alpha test confirms that the group's Cronbach's alpha has improved – though marginally – from 0.99 to 0.993.

**Table 13:** Reliability Statistics (internal consistency) for Principal Component 1 - Process

Reliability Statistics: Process			
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items		N of Items
0.99	0.993		31

**Table 14:** SPSS Item Statistics (Cronbach's alpha test of internal consistency - Principal Component 1 (Process))

Item	Cronbach's Alpha if Item Deleted	Decision
Insufficient monitoring process for road failure detection	0.993	Delete item
Lack of good leadership/ management capability	0.992	Delete item
Inadequate empowerment (training and resourcing)	0.99	Delete item
Workforce absenteeism	0.99	Delete item
Relation between rehabilitation scale and plant utilization	0.99	Delete item
Frequency of design changes/ change orders/late changes	0.99	Delete item
Lack of effective communication/ clarifications of expectations among key stakeholders	0.99	Delete item
Client's overt influence on the project process	0.99	Delete item
Supplier related issues (delays, inferior goods)	0.99	Delete item
Poor project management and risk management processes	0.99	Delete item
Ineffective approach to road maintenance	0.99	Delete item

Inadequate road failure detection system	0.99	Delete item
Inadequate IT infrastructure and application in road maintenance industry	0.99	Delete item
Low level of skill and experience	0.99	Delete item
Low level of motivation/commitment	0.988	Retain item
Low level of skill and experience	0.988	Retain item
Poor monitoring or appraisal of	0.988	Retain item
Overly long working hours	0.988	Retain item
Poor resource levelling	0.988	Retain item
Lack of experience of current job and operational condition	0.988	Retain item
Workforce health issues	0.988	Retain item
Planning & logistic issues impacting on continuous workflow (e.g. non-closure period)	0.988	Retain item
Un-conducive time frames within which most road works must be carried out	0.988	Retain item
Lack of sufficient planning from the outset	0.988	Retain item
Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council	0.988	Retain item
Lack of organizational learning: (applying lessons learnt from previous projects to solving challenges in current project)	0.988	Retain item
Lack of proper and regular coordination; supervision; performance monitoring and control	0.988	Retain item
Lack of project organisational culture that supports high productivity and performance	0.988	Retain item
Poor collaboration and supply chain management, especially as it relates to "just-in-time" supply principles	0.988	Retain item
Resistance to accept new technologies in road maintenance projects (include new Methods & Materials)	0.988	Retain item
Lack of adequate training on new processes and technologies	0.987	Retain item

### ***Internal consistency test for Principal Component 2 (Output)***

For Principal Component 2 (named ‘Output’), Tables 16 and 17 present the reliability and Item Total Statistics output tables of the SPSS Cronbach’s alpha test, respectively. Table 16 shows that the initial Cronbach’s alpha value for the items that comprise this principal component is 0.995. As provided in Table 16, this value shows excellent internal consistency among the five items that make up this principal component. Again, since the aim is to trim the items to the smallest possible size, the SPSS Item Total Statistics output in Table 17 was checked to see if any of the five items

should be removed from the list. The table shows that all the items should be retained since removing anyone could undermine the initial internal consistency of the group.

**Table 15:** Reliability Statistics (internal consistency) for Principal Component 2 – Output

<b>Reliability Statistics</b>		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.995	.995	5

**Table 16:** SPSS Item Statistics (Cronbach's alpha test of internal consistency - Principal Component 2 (Output))

	Cronbach's Alpha if Item Deleted	
Durability	0.991	Retain item
In Use Condition	0.992	Retain item
Post completion	0.992	Retain item
User/Client Value perception	0.992	Retain item
Post-Construction	0.9929	Retain item

***Internal consistency test for principal component 3 (input)***

For the Input principal component, Tables 18 and 19 provide the reliability and Item Total Statistics output tables of the SPSS Cronbach’s alpha test, respectively. Table 18 shows that the initial Cronbach’s alpha value for the item group is 0.988. As provided in Table 18, this value shows excellent internal consistency among the 12 items that make up this group. To trim the items to the smallest possible size, the SPSS Item Total Statistics output in Table 19 was checked to see if any of the six items should be removed from the list. The table shows that only one of the items out of 12 should be removed to improve the internal consistency of the group from 0.988 to 0.990.

**Table 17:** Reliability Statistics (internal consistency) for Principal Component 3 – Input

<b>Reliability Statistics</b>		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.988	0.989	6

**Table 18:** SPSS Item Statistics (Cronbach's alpha test of internal consistency - Principal Component 3 - Input)

	Cronbach's Alpha if Item Deleted	Decision
Dispute and Legislation Costs	0.984	Retain item
Lender High Interest rate	0.989	Delete item
Financial Capacity	0.984	Retain item
Project Complex	0.984	Retain item
Experience & Competencies	0.984	Retain item
Type of Procurement	0.985	Retain item
Inaccurate Est	0.985	Retain item
Lack of Collaboration	0.985	Retain item
Inadequate Supply	0.985	Retain item
Con-Phase Defect	0.985	Retain item
Under Value W	0.985	Retain item
Late Payments	0.983	Retain item

***Internal consistency test for principal component 4 (operating environment)***

Tables 20 and 21 present the reliability and Item Total Statistics output tables for this component. Table 20 shows that the initial Cronbach’s alpha value for the items is 0.99. This shows excellent internal consistency among the 20 items that make up this principal component. To trim the items further, the SPSS Item Total Statistics output in Table 21 was checked to see if any of the items should be removed from the list. The table shows that only one of the items should be deleted to marginally improve the internal consistency of the group from 0.996 to 0.9963.

**Table 19:** Reliability Statistics (internal consistency) for Principal Component 3 – Input

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.995	.9963	6

**Table 20:** SPSS Item Statistics (Cronbach's alpha test of internal consistency - Principal Component 4 – Operating Environment)

	Cronbach's Alpha if Item Deleted	Decision
Employment Relations Act	0.995	Retain item
Market conditions and level of competitions in the industry for jobs	0.997	Delete item
Inflation / fluctuations in material prices	0.995	Retain item

Frequent changes in government policies/ legislations impacting on	0.995	Retain item
On-site accidents/ Acts of God	0.995	Retain item
Unforeseeable ground conditions necessitating revisions	0.995	Retain item
Fair Trading Act	0.995	Retain item
Interest rate/cost of capital	0.995	Retain item
Energy crises/rising costs	0.995	Retain item
Natural disasters	0.995	Retain item
Inclement weather	0.995	Retain item
Resource Management Act	0.995	Retain item
Fluctuations in exchange rate	0.995	Retain item
Health & Safety in Employment Act	0.995	Retain item
Overly long working hours	0.995	Retain item
Construction Contracts Act	0.995	Retain item
Low level of motivation/commitment	0.995	Retain item
Type of Procurement	0.995	Retain item
Nature and significance of road in the Road Hierarchy	0.995	Retain item
Poor resource levelling	0.995	Retain item

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## **CHAPTER 5: RESEARCH MODEL DEVELOPMENT AND VALIDATION**

### **5.1 The Input-Process-Environment-Output (IPEO) Model of Constraint Factors Discussions**

#### **5.1.1 Naming of the principal components**

Results of the SPSS-based exploratory factor analysis showed that four principal components were extracted from the initial 68 constraints identified during the survey. The principal components were named based on the characteristics of the underlying subcomponents or items from which they were extracted. Blunch (2012) advised that the name for a particular principal component should be a phrase or word that captures succinctly the characteristics of the underlying items or “the message they are passing across” (p. 15).

In diminishing order of influence, the four principal components are named as follows:

1) Process, 2) Operating environment, 3) Input and 4) Output constraint groups.

The most influential constraints in the four groups are 1- Insufficient monitoring process for road failure detection, 2- Site Location, 3- Dispute and legislation costs, and 4- Durability of the project outcome.

#### **5.1.2 Principal component 1: Process constraint group**

The importance attached to process constraint factors derives mainly from the inclusion of the ‘process of project implementations’, which involves many different key components. For recognising the productivity constraints in this field, and as described by TransitNZ (2004), the level of risk of each constraint needs to be identified to be able to minimise the effect of the constraints; this will consequently improve the project performance phase, which has been defined as the process in this study. The risk levels presented by the process constraint factors group to the road pavement maintenance and rehabilitation contractors (RPMRCs) are mainly based on project finance, unforeseen event statutory compliances, workforce, and, most importantly, project

management. Because the operation process was recognised as the main constraint group, which covers many sub-constraints, and as the NZTA suggests, prioritisation was required to be able to tackle the existing risks by developing options and systems for addressing and mitigating productivity constraints and risks (Tonkin+Taylor, 2020).

### **5.1.3 Principal component 2: Operating environment constraint group**

The operating environment described by TransitNZ (2004) comprises the implementation subcomponents in contrast to the operating environment subcomponent of the research model. It is evident that a multi-party working environment such as road maintenance projects will create its own constraints and complications and limits achieving high performance and productive environment (Lau & Kong, 2006), therefore to apply the theory of constraints to create a step by a step road map to help decision-making process when facing constraints which exist in such environment, categorising operating environment constraints into one group and prioritising them, will increase the chance of tackling them efficiently and successfully.

The main focus of this group is on the dynamics of the operating environment, which the design, construction, and facility operating conditions seek to address through the specifications of the as-built quality standards and customer/ user priority needs in the performance-based contract.

### **5.1.4 Principal component 3: Input constraint group**

The NZTA has explained project input as a group of factors that have a considerable impact on all phases of a project and particularly on the level of project productivity from the very early stages of a project until project completion. The importance of an input constraints group is that once these constraints are managed in the early stages of a project, it can positively affect constraints that may happen in the next stages of the project.

Table 12 presents all productivity constraints factors, which have been grouped under project input. These factors are as important as other factors because they easily help decision-makers correct and enhance the project outcome at very early stages of a project; these factors directly impact other component groups from the early stages of a project until its final stages.

### **5.1.5 Principal component 4: Output constraint group**

The importance attached to output constraint factors derives largely from the inclusion of ‘customer (or user) levels of service’ as one of two key components of service levels from which performance is expected in a performance-based contract. The National Asset Management Steering Group (NAMSG, 2006) distinguished between ‘customer’ and ‘technical’ levels of service. ‘Customer levels of service’ relate to how the customer evaluates the quality of the service provided by the infrastructure asset in regards to customer priority needs. The evaluation is based on how the customers or users experience the service in a way that they can understand. On the other hand, ‘technical levels of service’ are based on the specifications and assumptions that underpin the asset's design and construction, as envisaged by the asset engineer. Technical levels of service are part of the quality assurance plan that guides the service provider in translating the asset engineer’s design into a physical asset. The NAMSG (2006) has recommended that technical levels of service should help day-to-day guide work on the assets and form the basis of contract specifications with suppliers.

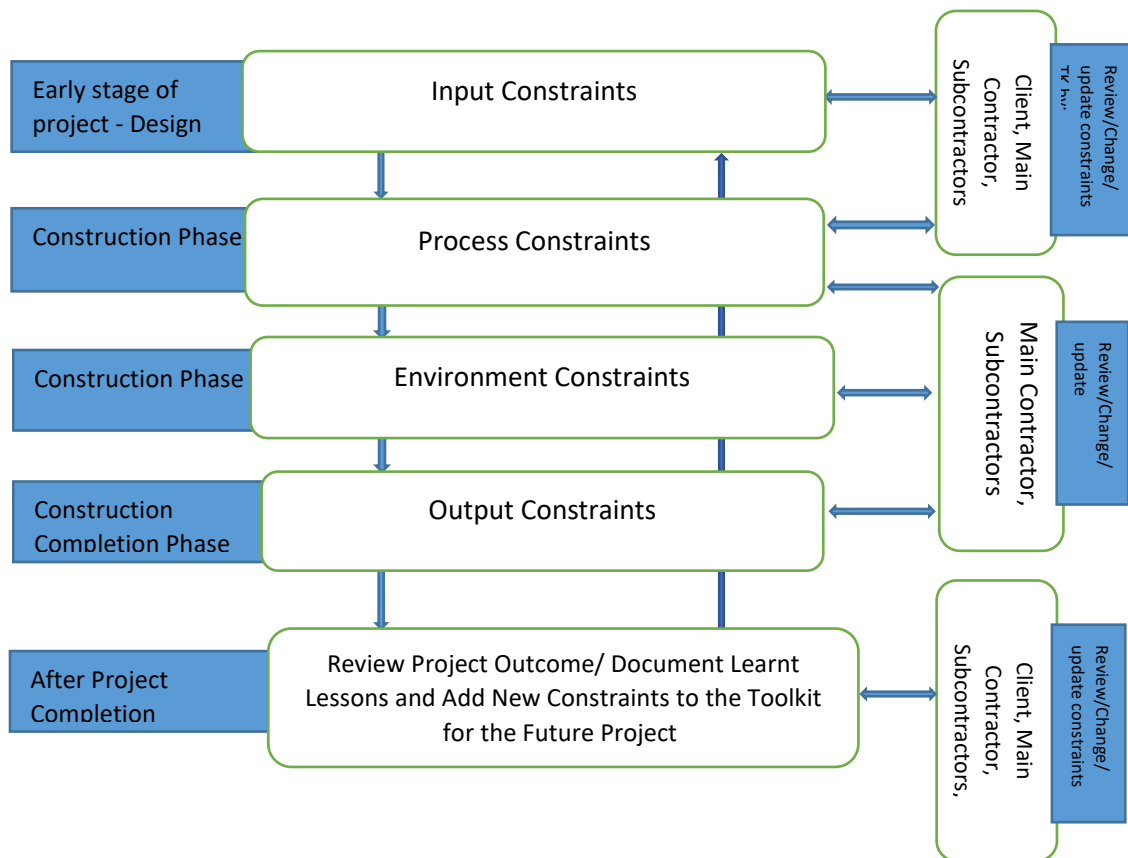
The risk levels presented by the output constraint factor group to the RPMRCs are often based on the uncertainties surrounding the exact definition of customer service levels. Because customers or users of the road network are undefined, the NZTA, as the principal, anticipates the priority user needs and specifies key characteristics of customer levels of service for which the service provider must demonstrate performance in the performance-based contract. The specified customer levels of service are a guide rather than accurate performance metrics. Because it is expected that an experienced and diligent RPMRC should reasonably understand and work towards achieving the user satisfaction criteria (AuditNZ, 2010); NZTA, 2006), the contractual clause in this respect transfers the overall risk of performance of the defined user satisfaction levels to the RPMRCs. An RPMRC is at risk of poor performance if there is a sole focus on the specified attributes that should translate to expected customer levels of service and if these specifications are at variance with what the majority of the road network users actually expect of the road network, which has been completed to the specified criteria, and the outcome of their post-completion experience. AuditNZ (2010) hinted that the level of user satisfaction of road condition and performance is usually known as part of the outcome of routine road roughness and condition rating surveys, adding that

“condition assessment, performance assessment, and the resulting remaining useful life of the asset provide a basis for the asset maintenance and renewal decisions” (p. 56).

## 5.2 The model

The results of this study have provided a guide to RPMR contractors on typical constraints they could encounter in their routine road pavement maintenance and rehabilitation operation. The study has also provided some measures for addressing the constraints with a view to improving the contractors’ productivity and performance. Figure 18 provides a high-level model of the constraints.

To operationalize the model into a practical toolkit for use by the contractors, the conceptual framework in Figure 18 guided the development of a constraint register spreadsheet for this purpose.



**Figure 19:** The Input-Process-Environment-Output (IPEO) model of the productivity constraints in the road pavement maintenance and rehabilitation projects

Please note that section 4.8 describes what analysis method has been used to prioritise the constraints under eight main categories to possible minimum number 4 main categories based on effectiveness and importance of the main constraints rated by participants.

### **5.3 Further discussions on the model & Developed Toolkit**

As discussed in the introduction chapter, around 3 billion dollars (NZTA, 2019) is spent on maintaining a roading network in New Zealand every year. Therefore, even a tiny percentage of productivity improvement is expected to positively impact New Zealand's economy and NZ's taxpayers. Therefore, this research is designed based on the expectation that productivity can be improved in four main parameters: project costs, project quality & durability, project completion time frame, and environmental effects. As explained in the continue, the Input-Process-Environment-Output (IPEO) model focuses on improving the parameters mentioned above by identifying main constraints during each stage of a road maintenance project and helping to mitigate or manage them.

The four components structure of the Input-Process-Environment-Output (IPEO) model formulated for the key factors constraining contractors' productivity and performance in the road pavement maintenance and rehabilitation projects are somewhat consistent with the four-component model of road asset management used by TransitNZ (2000) and also consistent with the recent national resilience programme business case provided by Tonkin+Taylor (2020) for New Zealand Transport Agency. The key differences are mainly in terms of differing objectives and sub-component contents. Transit New Zealand's focus is on the underpinning variables for the road asset management process. In contrast, the IPEO model identified in this study focused on road productivity constraints faced by contractors in the road pavement maintenance and rehabilitation process. Furthermore, Transit NZ's model comprises the implementation of subcomponents compared to the research model's operating environment subcomponent. However, both subcomponents focus on the dynamics of the operating environment. The design, construction, and facility operating conditions seek to address the specifications of the as-built quality standards and customer/ user priority needs in the performance-based contract.

However, the IPEO constraint model contrasts with the accountability or role-player perspective of the sources of productivity constraints faced by RPMRCs. For instance, TransitNZ (2000) identified three sets of parties involved in the managing and maintaining of the road assets: the client, consultants, and contractors. Productivity constraints are mainly a result of the actions or inaction of these three parties. In its Asset Management Manual No. SM020, TransitNZ (2000) listed the typical role of the client, which could be potential sources of constraints: influence of the policies and procedures for road asset management and the way the client manages funding issues; implements network-level pavement management strategies; and exercises its regulatory control on the role of the contractors and consultants.

On the other hand, the actions or inaction of the network management consultants could pose productivity constraints to the RPMRCs through the way they communicate and implement their forward work programme and maintenance intervention strategies; check and approve work programme and claims; observe and/or audit field operations and achievements; collect, maintain, and interpret conditions data; and administer and supervise contracts. Contractors themselves could be responsible for some of the constraints they encounter through the way they prioritise the programme works to reflect the requirements of the forward work programme and maintenance intervention strategies advised by the consultants, execute the works, submit claims for payment, and the quality of their work, especially about the satisfaction of defect liability requirements.

Judging which approach is superior to the other is a matter of individual preference and the targeted goals. Overall, the IPEO model established in this study better reflects a productive system's key attributes and the categorisation of the associated constraints. In this context, the IPEO model is more beneficial. However, the accountability/ role-player perspective is more applicable at the systems level when the focus is on apportioning poor performance risks on the parties based on their actions or inactions, which is outside this study's scope.

In addition to setting up an appropriate toolkit that can be used according to the IPEO model, a spreadsheet has been developed using this research finding. The developed spreadsheet includes all four groups of Input Constraints, Process Constraints, Operation Environment Constraints and Output Constraints with their relative level of impact on productivity improvement. This toolkit can be used during each stage of road maintenance and rehabilitation projects, from initial stages such as design through final stages called OUTPUT based on the IPEO model.

The developed spreadsheet has been attached to Appendix D.

#### 5.4 Preliminary validation of the model

Validation of the suggested toolkit is the final step in this research. Six subject matter experts were contacted to provide their feedback on the designed toolkit to provide reliable validation. This has helped to validate and extend the knowledge of the research.

The validation procedure was to contact Subject Matter Experts (SMEs) via email and provide enough information about the research background, research finding and purpose of the toolkit with a copy of the toolkit, and then request them to provide their feedback via an online open-end questionnaire. It must be mentioned that email contact was made due to Covid-19 restrictions; otherwise, one-to-one sessions were initially planned. In the following section, the result of the valuation has been explained and summarised.

#### 5.5 Demographic Data of the Participants

The table below has been provided to provide an overview of participants’ backgrounds. The participants have worked in the construction and roading industry in New Zealand and overseas for 18 years on average, in many different positions, from site engineer to project manager, project director and general manager of their company. Therefore, it can be concluded from the participants' backgrounds that all participants were highly experienced and qualified to provide accurate, reliable evaluation feedback.

**Table 21-** Demographic information of the SMEs

<b>Demographic Information</b>	<b>SME 1</b>	<b>SME 2</b>	<b>SME 3</b>	<b>SME 4</b>	<b>SME 5</b>	<b>SME 6</b>
Education background	Bachelor of Civil Engineering	Bachelor of Civil Engineering	Bachelor of Construction Management	PhD in Construction Management	Bachelor of Quantity Surveying	Bachelor of Construction Management

Year of experience in the construction & roading industry	16	21	15	18	19	17
Years at a senior manager level	7	10	9	8	10	7

**5.6 The Scope of Evaluation Questionnaire**

The following notes explain key questions asked of participants to evaluate the proposed toolkit and objectives of the survey design. These questions were designed based on the initial feedback received from participants during the phone conversation and some of the previous feedbacks received during the primary survey stage.

There were four main key targeted objectives when the evaluation survey was designed:

- 1- To evaluate the structure of the designed toolkit
- 2- To evaluate if there are any barriers to the adoption of the toolkit
- 3- To ensure the initial content of the toolkit is comprehensive enough
- 4- To understand any risks of using the toolkit and receive feedback around the areas that need further development.

The following sections give a detailed description of the above four objectives and evaluation survey.

**5.6.1 Objective 1- Question 1 and Received Feedbacks:**

The first objective was evaluating the toolkit's clarity, structure, and practicality; therefore, the first open-end question was: Is the structure of the toolkit clear to you?

As presented in Table 23, five of the six participants have rated this question with a definite “Yes!” One of the five participants responded to this question with “Probably yes”.

Also, one SME has commented that using the IPEO model is better than using the standard typical linear risks/constraints register used in the industry. Another SME stated that it is easier to follow

the IPEO model during the day-to-day operation of a project because it allows users to focus on certain risks at each phase of the project. More importantly, it allows them to leverage their limited resources into the key constraints/ risks at each project phase, rather than struggling to find priority risks/ constraints during each phase.

Also, one of the SME commented that having a more detailed explanation about constraints and more detailed constraints will improve the toolkit's quality.

### **5.6.2 Objective 2- Question 2 and Received Feedbacks:**

The second objective was to evaluate if there is any barrier to adopting the toolkit; therefore, the question was: Do you foresee any barriers to adopting the toolkit?

The aim was to find out the possibility of difficulties if they decide to use the toolkit. The open-end question also helped record if they have any ideas about tackling the possible barriers.

As presented in Table 23, the result shows that two respondents have chosen “Extremely unlikely” to see any barriers. One person has chosen “Somewhat likely”, and one person “Neither likely nor unlikely”; however, one person has chosen “Extremely likely” to have some barrier when using the toolkit.

Two of the SMEs commented that there might be some resistance from those who are using the typical industry method of the Risks & Constraints assessment.

### **5.6.3 Objective 3- Questions 3 to 6 and Received Feedbacks:**

The third objective was to make sure about the toolkit's content for each phase of the toolkit, namely Input, Process, Operational Environment, and Outcome (IPEO) phases. This could help us determine if any missed productivity barrier could be added to the toolkit.

The received responses showed that most of the participants believe most of the constraints have not been covered and suggest that it would be better to use a detailed list of constraints to cover existing constraints. Detailed responses regarding Questions 3 to 6 are presented in Table 23.

### 5.6.4 Objective 4- Question 7 & Additional Comments and Received Feedbacks:

Finally, the last objective was to understand if there are any risks to using the toolkit. Therefore, participants were asked if they foresee any risks from using the toolkit?

As shown in Table 23, one of the participants stated that the only risk would be the lack of some productivity risks or constraints because the proposed toolkit mainly covers broad items and not project-specific constraints/risks. However, the majority of the respondents do not foresee any risk by using the toolkit. However, similar to the first SME, they suggest that the toolkit needs to be used more often for many projects until each IPEO phase's constraints register can be developed further and cover as many as possible risks/constraints that may happen during the day-to-day operation of different projects. They believe this is the only way to develop the toolkit further and make the best use of the proposed toolkit based on the IPEO model.

**Table 22: Evaluation Survey Results**

Q1- Clarity - Answers	Count No	%	Q2- Barrier to Adoption- Answers	Count No	%
Definitely Yes	6	100.00%	Extremely Likely	1	16.67%
Probably Yes	0	0.00%	Somewhat Likely	1	16.67%
Might or Might Not	0	0.00%	Neither Likely nor Unlikely	1	16.67%
Probably Not	0	0.00%	Somewhat Unlikely	0	0.00%
Definitely Not	0	0.00%	Extremely Unlikely	3	50.00%
Q3- Input Phase Barrier Coverage- Answers	Count No	%	Q4- Process Phase Barrier Coverage- Answers	Count No	%
Definitely yes	1	16.67%	Definitely yes	2	33.33%
Probably yes	1	16.67%	Probably yes	1	16.67%
Might or might not	1	16.67%	Might or might not	0	0.00%
Probably not	2	33.33%	Probably not	3	50.00%
Definitely not	1	16.67%	Definitely not	0	0.00%
Q5- Operational EP Barriers Coverage- Answers	Count No	%	Q6- output EP Barriers Coverage- Answers	Count No	%
Definitely yes	1	16.67%	Definitely yes	0	0.00%
Probably yes	2	33.33%	Probably yes	3	50.00%
Might or might not	0	0.00%	Might or might not	1	16.67%
Probably not	3	50.00%	Probably not	2	33.33%
Definitely not	0	0.00%	Definitely not	0	0.00%
Q7- Risks of Unsing Toolkit - Answers	Count No	%			
Definitely yes	0	0.00%			
Probably yes	0	0.00%			
Might or might not	2	33.33%			
Probably not	3	50.00%			
Definitely not	1	16.67%			

### **5.6.5 Further Recommendations:**

The evaluation survey ended by asking participants to provide their general comments or recommendations. Most recommended developing the toolkit further; however, one of the participants recommended that the results of the toolkit should be reviewed once at the beginning and a second time after implementation of the recommendations in the participating organisations. There also needs to be a deadline set for the observation period - perhaps one or two fiscal years - to see if the impact of the implementation of the recommendations is tangible at the end of the observation period.

### **5.6.6 Conclusion on Received Feedbacks:**

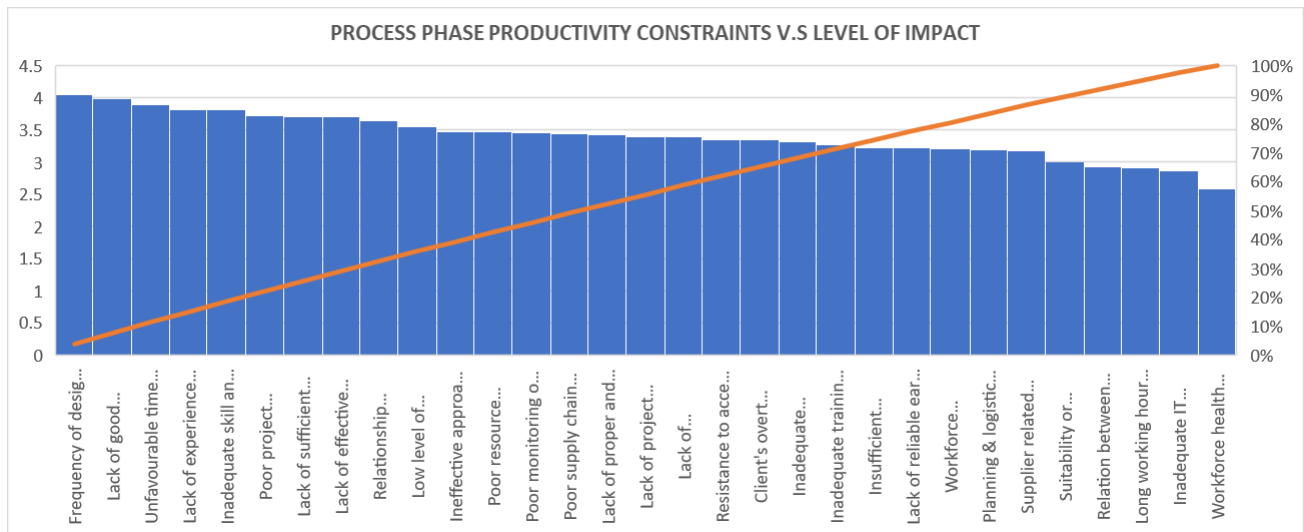
Feedback from six experienced individuals who participated in the validation interview showed that the Input-Process-Environment-Output (IPEO) constraints model is a better reflection of the challenges they face during day-to-day operation than the typical industry Risks & Constraints assessment methods, especially if it is used more often for many projects and updated based on lessons learned from different projects. First, the industry stakeholders prefer succinctness and are more eager to adopt the 'leaner' 4-component model than the regular standard models. Secondly, industry stakeholders thought of the IPEO model as being more practical and easy to follow. All six participants confirmed that the model presents new and more enriching perspectives into how contractors could leverage their limited resources to address key constraints. Also, two participants mentioned that the toolkit would be a valuable tool if used in many projects, so more constraints can be added to it based on the lessons learned from each project. This will help them capture all the possible risks and constraints, which will help guarantee future projects' success and increase future projects' productivity.

Furthermore, one of the participants showed interest in using the developed toolkit as part of their project process from the early stages of tendering to operations. The developed toolkit will reduce the risks of facing unknown constraints during each project stage. Appendix G shows the letter of their acceptance of using the developed toolkit.

The developed toolkit which is presented in Appendix D includes all four of the IPEO Model group: Input Constraints, Process Constraints, Operation Environment Constraints, and Output Constraints with their relative level of impact on productivity improvement. This toolkit can be

used during each stage of road maintenance and rehabilitation projects, from initial stages such as the design stage called INPUT through final stages called OUTPUT based on the IPEO model.

Also, the design toolkit includes a chart that shows the level of correlation between productivity constraint and their level of impact on productivity (Productivity line) for each phase. An example has been provided below.



**Figure 20:** Process phase productivity constraints vs Level of impact

The fully developed toolkit can be seen in the attached Appendix D.

## CHAPTER 6: CONCLUSIONS

### 6.1 Overview

This chapter concludes the key findings of this research by presenting findings in regards to the research objectives and roading industry practices. The key findings mainly contribute to the overall knowledge about improving productivity and performance strategies. Findings helped to develop recommendations that will benefit roading contractors, especially in the field of road pavement and maintenance contractors. Also, it is beneficial for government organisations such as New Zealand Road Transport Agency and other regulators. This chapter also recommended further areas for investigation. Moreover, there are highlighted limitations regarding the ability to meet a

full number of required sampling frame participants. Also, part of the key findings which were published as a Journal Article, has been attached to the end of this Chapter, and it also will be sent to the participants who requested receiving a copy of the findings of this research.

## **6.2 Key findings**

The main objectives of this study were to investigate the constraints RPMR contractors face in New Zealand (NZ) and prioritise them, then find the best strategies and mitigation measures for improvement. Final findings of the main survey from medium- to large-sized roading contractors in NZ showed four principal items extracted from the initial 68 identified constraints. In diminishing order of influence, these are as follows: Process, Operating Environment, Input, and Output constraint groups. The most influential constraints in the four groups which are explained in Table 5 are Inadequate Supply, the high cost or required resources, funding, labor, materials & machinery, Frequency of design changes, inclement weather, and post-construction defective or non-compliant work.

The findings advanced existing knowledge by revealing critical factors constraining the productivity and performance of New Zealand road maintenance and rehabilitation projects, as well as associated improvement measures.

In addition, research findings contributed to choosing the Input-Process-Environment-Output IPEO model for managing contractors' constraints during a roading project.

## **6.3 Finding in regards to research objectives**

To be able to address the research aim, which was increasing productivity within roading projects, this research mainly focused on three objectives:

- 1- Identifying and prioritising road maintenance projects productivity constraints which are hindering project productivity rate during the lifetime of a road maintenance project based on their level of impact during each phase of a road maintenance project,

- 2- Explore the measures for mitigating the identified constraints with a focus on improving efficiency and productivity in the road maintenance and rehabilitation project delivery process,
- 3- To establish/develop a model that suits the related industry and then provide a toolkit for managing existing constraints, for guiding stakeholders' productivity improvement in the road maintenance projects process; this enables contractors to improve their productivity rate during a project's lifetime by adopting the proposed model and developed toolkit. In the sections below, key findings of this research will be discussed in relation to each objective.

#### **6.4 Findings in regards to the first objective: Identify and prioritise constraints**

The first objective of this study was to identify and prioritise the factors that constrain contractors' productivity performance in road maintenance and rehabilitation projects in New Zealand.

68 constraints were found through in-depth literature review and interview-based survey from medium- to large-sized roading contractors in New Zealand, as has been explained in detail in Chapter 4, then prioritised via the main survey based on their level of impact on productivity in road maintenance projects. All identified factors were then categorised into eight main categories: project finance, workforce, new technologies/ processes, project management/ project team characteristics, project characteristics, statutory regulatory compliance, unforeseen circumstances, other external factors. The most influential category among all eight categories was workforce which received the highest rating, followed by project management/ project team characteristics, unforeseen circumstances, project characteristics, project finance, technology/process, statutory/regulatory compliance, and other external factors (economic, political, industry, etc.). The relative level of impact of the broad categories of constraint factors on contractors' productivity has been explained in greater detail in Table 6 Section 4.6.2 of Chapter 4.

The main survey feedback also presented the most influential individual constraints among each category as listed in Table 23 below:

**Table 23:** Two main factors within each broad category

<b>Broad constraint category</b>	<b>Sub-constraints</b>
Workforce	1) Lack of good leadership/management capability 2) Inadequate skill and experience with current project type
Project management/ Project team characteristics	1) Frequency of design changes/change orders/late changes 2) Poor project management and risk management processes
Unforeseen circumstances	1) Inclement weather 2) Unforeseeable ground conditions forcing design revisions
Project characteristics	1) Unfavourable time frames within which most road works must be carried out; 2) Sites location and environmental constraints (e.g. traffic volume, climate, subsoil and topography);
Project Finance Issues	1) Inadequate supply or high cost of required resources: funding, labour, materials & machinery 2) Lack of collaboration between consultant & contractor;
Technology/ Process	1) Ineffective approach to road maintenance 2) Resistance to accept new technologies and methods for road maintenance & rehabilitation projects
Statutory/ Regulatory compliance	1) Health & Safety in Employment Act 2) Resource Management Act
Other/ external factors	1) Market conditions and level of competition in the industry for jobs 2) Post-construction defective or non-compliant work

In addition to the above finding and after an in-depth analysis of the survey results, all identified constraints have been re-categorised into four main categories which are called the four main components. These four main components were then used to develop a model called IPEO, which is discussed in the following sections.

## **6.5 Findings in relation to second objective: Explore productivity constraints mitigation measures**

The second objective of this study was to explore the measures for mitigating the identified constraints with focus on improving the efficiency and productivity in the road maintenance and rehabilitation project delivery process.

Nineteen mitigation measures were identified during the research. They are listed below based on their level of impact on addressing productivity constraints. Full details can be seen in Table 7 with all related levels of importance. The improvement measures are:

1-Early contractor involvement, 2- Communication, 3- Planning, 4- Supervision, 5- Skilled workforce, 6- Teamwork/ collaboration, 7- Staff training, 8- Project review & experiential learning, 9- Scheduling, 10- Worker empowerment through engagement, 11- Technical & management competencies of decision-makers, 12- Innovation & win-win outcomes, 13- Staff motivation, 14- Outcome- rather than process-focused, 15- Procurement & contract strategies, 16- Funding/ resourcing, 17- Information technologies, 18- More competitive market structure, 19- Over-regulation.

As presented in Figure 16, all 19 mitigation measures and their level of impact were clustered under five broad categories - technology/ process, human resources management, leadership/ project management, contract, and financial management, and external measures - to present a better overview. As shown in Table 7 in Chapter 4, three mitigation measures were rated as the most influential measures out of the 19: early contractor involvement with a value of 4.25, communication with a rating of 4.06, and planning with a rating of 4.04. Also, 12 other measures were rated with high impact, two with moderate and one with low impact on improving productivity. Furthermore, participants offered suggestions on corrective mitigation measures, which were highly related to the problems that they encountered and solutions they came up with during the project implementation phase. The corrective measures which were suggested by participants and applied to the problems encountered are highlighted under the key clusters as follows:

### D) Technology/ process:

- Adopt the new available technologies.

- Existing equipment becoming obsolete or inadequate for new standards: Acquire or hire new equipment.
- Equipment breakdown: Hire equipment from a new supplier.

E) Human resources management:

- Make the road maintenance industry an attractive place to work. Losing skilled staff at crucial project stages, e.g., through sickness or secondment: Hire new staff.
- Teams need to share a motivation to achieve. It is hard to work towards a common goal where there are competing drivers.
- Good communications between the design team, management, and field staff with reasonable and realistic expectations of goals and achievements.

F) Project management

- More accurate design work and investigation prior to construction. The number one issue on-site crew continues to encounter is inaccurate plans resulting from a failure in attention to detail, inaccurate investigations or inaccurate survey in the design phase, which put design management among one of the high priority preventive mitigation measures.
- An agile approach to programming means there is little certainty for contract teams about workload. This means it is difficult to commit resources and even harder to engage subbies to programs that are subject to change. This supply chain issue prevents flow and prevents a team from gaining any momentum in continuous improvement.

More detailed findings related to the second objective have been discussed in Section 4.7 of Chapter 4.

## **6.6 Findings in relation to the third objective: Establish/ Develop a model and a toolkit**

The third objective of the study was to establish/ develop a conceptual model of the identified constraints and mitigation measures as a toolkit for guiding stakeholders' productivity improvement during a road maintenance project. Therefore, the research outcomes from the first

and second objectives were used to establish/ develop the model and, consequently, the toolkit which is explained in detail in Chapter 5.

### **6.6.1 The IPEO Model**

To be able to develop a model, the first step was to focus on the smallest number of key constraint factors that have the most significant impact on productivity and performance of road maintenance contractors' productivity as by having the smaller group of factors which are prioritised, and subcontractors are able to focus on key constraints and use the key mitigation measure to improve their productivity rates; therefore SPSS-based exploratory factor analysis was used to identify/extract the priority constraints and reduce the number of constraint categories to a few priority ones. After analysing the principal components extracted from the initial constraint factors, based on Eigenvalue greater than 0.99, four principal components were extracted, and among four principal components, the first factor contained 79.2% of the variances in all constraint factor and the rest of the principal components, in diminishing order only contained 10.8%, 2.7%, and 2.1% of the total variances.

As mentioned in the previous chapters 4 & 5, and as it is advised by Blunch (2012), the name for a particular principal component should be a phrase or word that captures succinctly the characteristics of the underlying items or "the message they are passing across" (p. 15), therefore in diminishing order of principal components impact and influence, the four principal components names as 1- Process, 2- Operating Environment, 3- Input, and 4- Output constraint group which is called IPEO model and used to formulate the model and subsequently the model used for developing a toolkit which is called IPEO productivity toolkit.

### **6.6.2 The IPEO Productivity toolkit**

The results of this study have provided a guide to Road Pavement Maintenance & Rehabilitation (RPMR) contractors on typical constraints they could encounter in their routine road pavement maintenance and rehabilitation operation. To develop a practical toolkit and to provide some measures for addressing the constraints with a view to improving the contractors' productivity and performance and operationalise the developed model, a spreadsheet was developed by considering all the findings that all road maintenance contractors can use in all stages of a road maintenance

project in order to identify and mitigate the involved constraints that contractors may face during project implementations. The developed toolkit contains all constraints but is categorised into four Principal Components using the data analysis method of Principal Component Analysis, leading to choosing the IPEO (Input, Process, Environment, & Outcome model) model.

which is described in chapters 4 & 5 in detail,

The figure below provides a high-level concept of the IPEO model in the road maintenance and rehabilitation industry to help manage productivity constraints during each project phase.

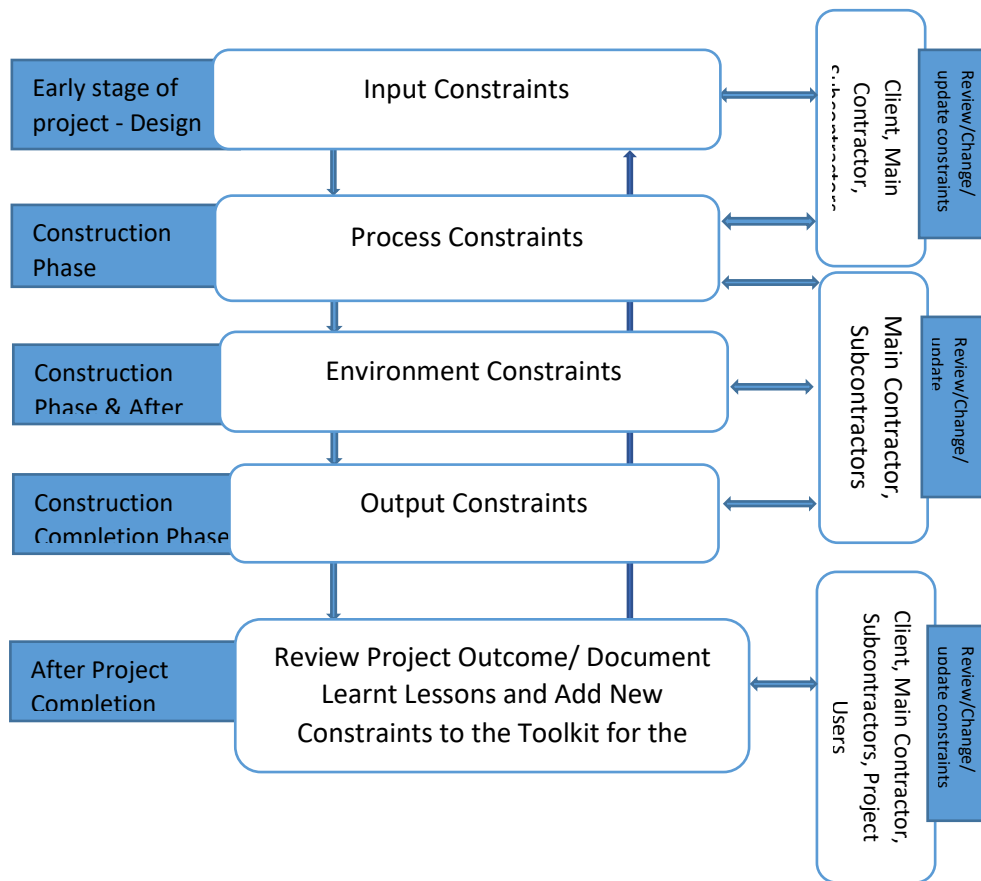


Figure 21: The high-level concept of IPEO (Input, Process, Environment, & Outcome model) in the road maintenance and rehabilitation industry

Overall, the IPEO (Input, Process, Environment, & Outcome model) model established in this study gives a better reflection of the critical attributes of a productive system and the categorisation of the associated constraints. In this context, the IPEO model is more practical; however, the accountability/ role-player perspective is more applicable at the systems level when

the focus is on apportioning risks of poor performance of the parties based on their actions or inactions.

In addition to setting up an appropriate toolkit that can be used according to the IPEO model, a spreadsheet has been developed using the research findings. The developed spreadsheet includes all four main groups of Input Constraints, Process Constraints, Operation Environment Constraints, and Output Constraints with their relative level of impact on productivity improvement. This toolkit can be used during each road maintenance and rehabilitation project stage, from initial stages such as design, which can be called the INPUT phase, through final stages called the OUTPUT phase, based on the IPEO model.

Moreover, the developed toolkit presents mitigation measures associated with each constraint, allowing contractors to quickly identify the mitigating measures and manage the potential constraints appropriately. It also gives the ability to the contractors to develop the toolkit further, once they continue using it on more projects as they can record any upcoming productivity risk or constraints; therefore, this enables Toolkit to be developed and updated based on the lesson learned Appendix D presents a full copy of the developed toolkit.

The conceptual framework in figure 20 guided the development of the productivity constraints register toolkit to operationalise the model into a practical toolkit that the contractors can use. The developed toolkit also can be used as a tool to record & categorise all the constraints that may be identified during different phases of a project. At the moment, the toolkit only shows higher-level constraints. However, it can be extended to a very detailed level if used regularly by all involved parties within the time of a project. It can also be modified for similar construction projects, such as industrial and commercial concrete flooring/ pavement projects.

Furthermore, it is suggested to develop this toolkit to more detailed productivity risks/ constraints, sub-categorised under each one of the identified risks before the start of each phase of the project to identify, manage or mitigate productivity constraints early as possible. Knowing the risks, possible constraints, and their level of impact on the final productivity of a project as early as possible will give the advantage to the project managers and directors to plan for dealing with identified risk/constraint as early as possible before the negative impact of a constraint on project productivity and outcome appears.

The below figures shows the toolkit based on each stage of the IPEO model.



ITEM	PROCESS PHASE PRODUCTIVITY CONSTRAINTS	LEVEL OF IMPACT RATING
1	Frequency of design changes/ changes orders/ late changes	4.05
2	Lack of good leadership/ management capability	3.99
3	Unfavourable time frames withing which most road works must be carried out	3.89
4	Lack of experience of current job & operational condition	3.82
5	Inadequate skill and experience with current project type	3.82
6	Poor project management & risk management processes	3.72
7	Lack of sufficient planning from outset	3.71
8	Lack of effective communication/ clarifications of expectations among key stakeholders	3.71
9	Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council	3.65
10	Low level of motivation/ commitment	3.55
11	Ineffective approach to road maintenance	3.48
12	Poor resource management	3.47
13	Poor monitoring or appraisal of performance	3.46
14	Poor supply chain management, especially as it relates to "just-in-time" supply principles	3.44
15	Lack of proper and regular coordination; supervision; performance monitoring and control	3.42
16	Lack of project organisational culture that supports high productivity and performance	3.39
17	Lack of organisational learning: (learning from previous projects)	3.39
18	Resistance to accept new technologies in road maintenance & rehabilitation projects (include new methods and materials)	3.35
19	Client's overt influence on the project process	3.34
20	Inadequate empowerment (training and resourcing) for employees	3.32
21	Inadequate training on new processes & technologies	3.27
22	Insufficient monitoring process for road failure detection	3.23
23	Lack of reliable early road failure detection system	3.23
24	Workforce absenteeism	3.2
25	Planning & logistics issues impacting on continues work flow (e.g. non-closure period)	3.19
26	Supplier related issue (delays, inferior goods)	3.17
27	Suitability or adequacy of the plant & equipment employed	3
28	Relation between rehabilitation or maintenance scale and plant utilisation;	2.92
29	Long working hours with insufficient rest periods, especially during night work	2.91
30	Inadequate IT infrastructure & application in road maintenance industry	2.86
31	Workforce health issues	2.58
<b>Other Risks to be added:</b>		

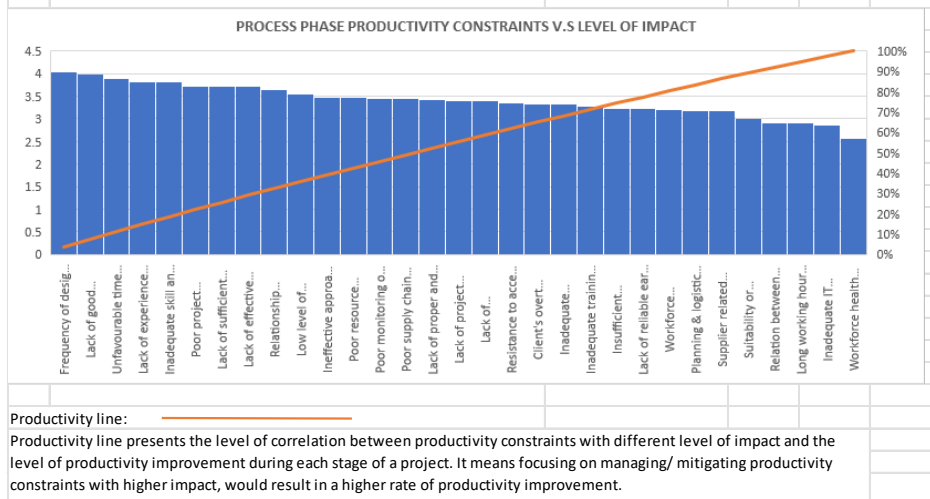


Figure 23: PROCESS Stage

ITEM	OPERATION ENVIRONMENT PRODUCTIVITY CONSTRAINTS	LEVEL OF IMPACT RATING
1	Inclément weather	4.25
2	Unforeseeable ground conditions necessitating revisions	3.97
3	Site location & environmental constraints (e.g. traffic volume, climate, subsoil & topography)	3.89
4	Market conditions & level of competitions in the industry for jobs	3.7
5	Health & Safety in Employment Act	3.53
6	Resource Management Act	3.34
7	Public notification issues (e.g. community and environmentalists' resistance to infrastructure development plans)	3.19
8	Nature & significance of road in the road hierarchy	3.11
9	Statutory Consent Compliance	2.96
10	Inflation/ fluctuations in material prices	2.89
11	Local Authority Bylaws	2.87
12	Construction Contracts Act	2.83
13	Frequent changes in government policies/ legislations impacting on construction	2.68
14	On-site accidents	2.66
15	Employment Relations Act	2.52
16	Fluctuations in exchange rate	2.48
17	Energy crisis/ rising costs	2.45
18	Natural disasters	2.4
19	Interest rate/ cost of capital	2.34
20	Consumer Guarantees Act	2.3
21	Fair Trading Act	2.16
<b>Other Risks to be added:</b>		

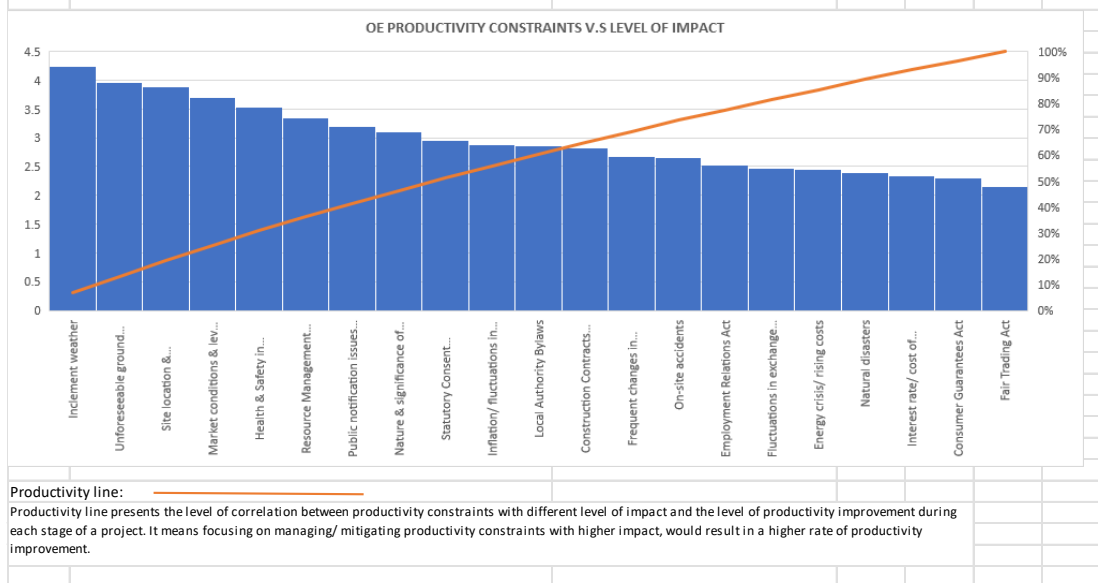


Figure 24: OPERATIONAL ENVIRONMENT Model



model presents new and more enriching perspectives into how contractors could leverage their limited resources to address critical constraints. One of the model validation survey participants showed interest in accepting the IPEO model and the designed toolkit to be used as part of their productivity constraints/risk management process. The toolkit will then be used as part of their process from the early stages until the project completion. Appendix G presents the letter of adopting the developed toolkit received from the contractor.

Also, Appendix H shows the validation survey questions and final results.

## **6.8 Implications of the finding for research and industry practice**

As stated in NZTA National Resilience Programme (Tonkin+Taylor, 2020), the key success in any plan for improving productivity in roading projects is a clear understanding of existing risks and, at the same time, opportunities. Therefore, this research was conducted by aiming to give a clear understanding of existing productivity constraints and related mitigation measures to the roading industry. It also helped in creating a clear pathway for all professionals who are working in the field of road maintenance to have a practical, clear pathway on recognising the existing productivity obstacles in the early stages of a project and to use the provided mitigation measures to manage the obstacle and, lastly, improve their productivity rate. The developed toolkit also helps the industry make informed decisions when thinking about improving the productivity and performance of a roading project. Also, the survey feedback analysis served to provide richer insights into the whole research process and a strategic pathway from designing the research through implementing the plan and analysing the data to interpreting and reporting the results.

## **6.9 Key contribution to knowledge**

The key contribution of this research is to fill the existing knowledge gap both in the road maintenance industry as well as in the literature in regards to New Zealand's roading industry; there is a demand for research in this field - to be able to improve productivity in the field of infrastructure construction (ProductivityCommission, 2020). The findings of this research have contributed to enhancing knowledge about improving productivity and performance in New Zealand road maintenance projects; this research has provided statistical data on many existing

constraints that road maintenance contractors face during a project from early stages until project completion. It also helped identify opportunities for efficiencies in delivering road maintenance projects.

The next important contribution of this research to existing knowledge in New Zealand literature is about enhancing road maintenance contractors' and other parties' knowledge about the importance of productivity risks identification and risk mitigation measures in different phases of a project. The industry might already know this importance. However, there is a shortage in research in this field. The findings of this research will also provide a theoretical tool to choose the best practical method for managing productivity and performance constraints that can improve their productivity rate and project outcomes. Yi and Chan (2014) stated that construction productivity primarily depends on human effort and performance. Therefore, any effort to reduce or mitigate productivity risk and constraints during a construction activity will significantly increase the chances of improving productivity.

This study also benefits consultants who are involved in road maintenance projects, from design, planning stage, and other stages, as they would be able to predict possible constraints that may happen during road maintenance and rehabilitation projects and be prepared and able to plan to tackle them. If the constraint is related to the design stage or design changes are required later during the project, then, obviously, adequate planning at the early stages is essential when risks are well known (Smith et al., 2014).

Moreover, this research finding will assist consultants in finding practical mitigation measures to manage to raise constraints and risks during road maintenance projects based on the priority of the constraints.

Moreover, this study also provided a framework that offers a theoretical and practical method and guidance to researchers to seek new ways to enable roading project contractors to improve their productivity and enhance their project expected outcomes.

#### **6.10 Limitation and recommendation for future studies**

There were a few practical limitations for this research during the data collection stage, such as difficulties accessing more experts in this field as more participants in the research could result in

finding more productivity constraints. The other limitations were discovered during other phases of the research, which are listed below.

This study focused on exploring productivity constraints in road maintenance and rehabilitation. However, there are many other issues that need further investigation to explore other influencing factors on improving productivity in this field.

During this study, it has been found that the lack of investigation on applying new technologies is quite apparent. New Technologies such as new roads failure detection systems can improve productivity by setting up more preventive maintenance in New Zealand. Also, it was found that there is resistance from consultant companies on accepting new technologies such as slipform paving machines which potentially could provide huge budget savings on a big scale paving project. This type of technology has been used in many developed countries for many years and has shown proven benefits. However, it has not been used in New Zealand in large-scale projects.

Furthermore, this study found some problems, such as the lack of a formal measurement regime applying to road maintenance to measure performance and productivity in the road maintenance sector. Derek Gill and James Zuccollo (2012, p. 1) Also found in the same issue: "The first problem is that there is no cycle of performance measurement. Rather, there is an open-loop with limited direct and indirect feedback from the monitoring and measurement subsystem to design programs and policies. This lack of a closed-loop is impeding performance improvements from being identified and implemented. The lack of measurement of the effectiveness of interventions, such as pavement treatments, inhibits learning and the development of asset management expertise". Therefore, this field could be another subject for more investigation. Other areas recommended for further investigations include:

1. Quantitative analysis of the extent to which productivity could be improved by applying the recommendations made in this study. This is required to inform investment decisions in road pavement maintenance and rehabilitation operations.
2. This research focused on productivity issues in the roads of significance (i.e., road classification). Research should be extended to other road classes for a more holistic understanding of productivity issues in the whole sector.

3. Also, the study focused on the North Shore area of Auckland. Research should be extended to other parts of New Zealand.

4. The methodology developed could be applied to studying productivity issues in roading sectors of other economies.

No negative feedback was received during the questionnaire survey; however, only a couple of critical feedbacks which have been addressed in the conclusion chapter.

### **6.10.1 Generalisation**

This study aims to generalise this research study for Australia and New Zealand; however, it can also be generalised to other countries with similarities in their environment, population, and policies. Also, the aim is that the developed toolkit can be used as a base tool by contractors in different countries with similar situations for improving their productivity and performance and final project outcome. The tool developed in this study can be used in countries with similar conditions to track their productivity obstacles, categorise them into smaller groups, prepare a plan to tackle them, and at the end, remeasure the productivity outcome, and repeat this strategy & procedure of using the toolkit for every single project until their productivity improve significantly.

## **CHAPTER 7: PUBLICATIONS**

### **7.1 Publication**

Appendix F presents the article which is published by the Journal of Engineering, Architecture, and Construction Management.

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## APPENDICES

## Appendix A: Low Risk Notification

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### Human Ethics Notification - 4000016433

1 message

humanethics@massey.ac.nz <humanethics@massey.ac.nz>

Mon, Jul 18, 2016 at 5:34  
PM

To: A.Lindsay@massey.ac.nz, Saeed.Haji.Karimian.1@uni.massey.ac.nz, J.I.Mbachu@massey.ac.nz,  
N.A.Tassell-Matamua@massey.ac.nz  
Cc: M.E.Thomas@massey.ac.nz

HoU Review Group

Ethics Notification Number: 4000016433

Title: PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE & REHABILITATION PROJECTS:  
PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS & CONSULTANTS ON THE  
CONSTRAINTS AND IMPROVEMENT MEASURES

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

If situations subsequently occur which cause you to reconsider your ethical analysis, please log on to <http://rims.massey.ac.nz> and register the changes in order that they be assessed as safe to proceed.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director (Research Ethics), email [humanethics@massey.ac.nz](mailto:humanethics@massey.ac.nz)."

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter, please login to the RIMS system, and under the Reporting section, View Reports you will find a link to run the LR Report.

Yours sincerely

Dr Brian Finch  
Chair, Human Ethics Chairs' Committee and

## Appendix B: Survey Package

### Appendix B1- Recommendation Letter



School of Engineering and Advanced Technology  
College of Sciences  
Private Bag 102904  
North Shore, Auckland 0745  
New Zealand  
T 64 9 414 800 x 43577  
F 64 9 4439774  
E-mail: [J.Mbachu@massey.ac.nz](mailto:J.Mbachu@massey.ac.nz)

26 March 2015

TO WHOM IT MAY CONCERN

Dear Sir/ Madam

Re: Saeed HAJI KARIMIAN [REDACTED]

The above named student is enrolled in the PhD Construction programme in our School of Engineering & Advanced Technology, Massey University, Albany. His research is at the fieldwork stage, which involves empirical data gathering by interviews, record search and surveys.

We understand that the empirical data he will be seeking from industry practitioners may be classified. In line with the Massey University Research Ethics, the feedback or records he requires for his study will be used solely for his academic research and will be treated in strict confidence. Also while compiling his final report, any revealing details about any project, client or provider of the empirical data will be deleted. We'll therefore appreciate it if you could assist him with the research data he requires. Your assistance will contribute to advancing built environment research in New Zealand and to providing cutting edge knowledge that will underpin innovative and best practice standards in the industry. He will also provide summary of the research findings to you.

Should you require further information about the student or his intended research, please do not hesitate to contact me.

Yours truly

A handwritten signature in black ink, appearing to read "Jasper Mbachu".

Jasper Mbachu, PhD

---

Dr Jasper Mbachu PhD MCIQB AMACPM MNZIOB MNZIQS  
Senior Lecturer and Coordinator, Construction Programmes



**MASSEY UNIVERSITY**  
**TE KUNENGA KI PŪREHUROA**  
**UNIVERSITY OF NEW ZEALAND**

**PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES**

**1. RESEARCH SURVEY: INTRODUCTION**

The aim of this research is to improve productivity in road pavement rehabilitation and maintenance in New Zealand. This is a research project in the School of Engineering and Advanced Technology, Massey University, Auckland, New Zealand. The study aims to establish the key constraints on productivity and performance within the New Zealand road maintenance industry. The expected outcomes of this research will include:

- 1) Identified key constraints on productivity in the New Zealand road maintenance sector , including their relative levels of impact and frequencies of occurrence.
- 2) A map of the risk levels of the identified constraints on the Influence – Frequency Matrix.
- 3) Innovative ways of improving productivity that resonate well with the New Zealand roading sector.

Your participation in the survey would be very much appreciated as your responses and inputs will provide the data for the study. On average, completing the questionnaire may take 5 to 10 minutes of your time. By participating, you will be contributing to the advancement of research and knowledge in this field.

Should you have any questions about this study, please do not hesitate to contact either of the research team members below.

Saeed Karimian: saeedhajikarimian@gmail.com

Dr Jasper Mbachu: j.i.mbachu@massey.ac.nz

Thank you very much in advance.

Saeed Karimian

**PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES**

**2. INTERNAL CONSTRAINTS**

The following broad categories of internal factors have been identified as the key constraints to the achievement of productivity. Under each category, sources of the constraints are listed. Using the 5-point rating scale provided, please could you rate the level of impact of each constraint source based on your experience? It will be appreciated if you could add further constraints in the text boxes provided, which have not been included in the list.

**1. Project Finance**

	Very low	Low	Moderate	High	Very High	No Idea
1. Inaccurate estimate (Client, consultant and contractors);	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Lack of collaboration between consultant & contractor;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Inadequate supply or high cost of required resources: funding, labour, materials & machinery;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Construction-phase defective or non-compliant work;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Under-valued work;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Late payments;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Dispute and litigation costs;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Lenders' high interest charges;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Financial capacity for the scale and complexity of work involved;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other sources of cash flow problems? Please specify:

## 2. Workforce

	Very Low	Low	Moderate	High	Very High	No Idea
1. Lack of good leadership/ management capability;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Low level of motivation/commitment;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Inadequate skill and experience with current project type;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Poor monitoring or appraisal of performance;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Long working hours with insufficient rest periods, especially during night work;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Inadequate empowerment (training and resourcing) for employees;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Poor resource management;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Unfamiliarity with current project type and project environment;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Workforce health issues;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. Workforce absenteeism;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other workforce constraints? Please specify:

## 3. Technology/ Process

	Very Low	Low	Moderate	High	Very High	No Idea
1. Suitability or adequacy of the plant & equipment employed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Ineffective approach to road maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Inadequate training on new processes and technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Resistance to accept new technologies and methods for road maintenance & rehabilitation projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Inadequate IT infrastructure and application in road maintenance industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Lack of reliable early road failure detection system	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Insufficient monitoring process for road failure detection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other technology/ process constraints? Please specify:

#### 4. Project Characteristics

	Very Low	Low	Moderate	High	Very High	No Idea
1. Planning & logistic issues impacting on continuous work flow (e.g non-closure period);	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Unfavourable time frames within which most road works must be carried out;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Sites location and environmental constraints (e.g. traffic volume, climate, subsoil and topography);	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Public notification issues (e.g. community and environmentalists' resistance to infrastructure development plans);	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Nature and significance of road in the road hierarchy;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Project complexity: scale, design;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Type of procurement adopted;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Relation between rehabilitation or maintenance scale and plant utilisation;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other project characteristic constraints? Please specify:

#### 5. Project Management/ Project Team Characteristics

	Very Low	Low	Moderate	High	Very High	No Idea
1. Lack of sufficient planning from the outset	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Poor project management and risk management processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Lack of effective communication/ clarification of expectations among key stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Lack of proper and regular coordination; supervision; performance monitoring and control	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Lack of project organisational culture that supports high productivity and performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Experience and competencies of the project team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Frequency of design changes/ change orders/late changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Client's overt influence on the project process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. Poor supply chain management, especially as it relates to "just-in-time" supply principles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. Lack of organisational learning: (learning from previous projects)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. Supplier related issues (delay, inferior goods)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other project management constraints? Please specify:

## PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES

### 3. EXTERNAL PRODUCTIVITY CONSTRAINTS

The following broad categories of external constraints have been identified as the key restraints to the achievement of productivity. Under each category, sources of the constraints are listed. Using the 5-point rating scales as before, please could you rate the level of impact of each constraint source based on your experience? It will be appreciated if you could add other constraints which have not been included in the list.

#### 1. Statutory Compliance

	Very Low	Low	Moderate	High	Very High	No idea
1. Health & Safety at Work Act	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Resource Management Act	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Local Authority Bylaws	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Construction Contracts Act	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Employment Relations Act	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Consumer Guarantees Act	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Fair Trading Act	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Statutory Consent Compliance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other legislations or compliance issues? Please specify:

#### 2. Unforeseen Circumstances

	Very Low	Low	Moderate	High	Very High	No Idea
1. Inclement weather	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Unforeseeable ground conditions that necessitating design revisions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. On-site accidents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Natural disasters/ Acts of God	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other unforeseen events issues? Please specify:

**3. Other External Factors**

	Very Low	Low	Moderate	High	Very High	No Idea
1. Inflation / fluctuations in material prices;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Fluctuations in exchange rate;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Energy crises/rising costs;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Interest rate/cost of capital;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Market conditions and level of competitions in the industry for jobs;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Frequent changes in government policies/ legislations impacting on construction;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Post-construction defective or non-compliant work;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. User/Client value perceptions;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Durability of completed work within the defects liability period or warranty/guarantee;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. Post completion deterioration rate relating to rough use;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. In-use conditions being at variance with prior production assumption;	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other constraints from miscellaneous sources? Please specify:

**PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES**

**4. BROAD CATEGORIES OF INTERNAL AND EXTERNAL CONSTRAINTS**

For the broad categories of internal and external constraints mentioned previously, how would you rate their relative levels of impact on the achievement of productivity? Five-point rating scales have been provided as before.

**1. BROAD CATEGORIES OF INTERNAL AND EXTERNAL CONSTRAINTS - RATING OF LEVELS OF IMPACT OF PRODUCTIVITY CONSTRAINTS:**

	Very Low	Low	Moderate	High	Very High
1. Project finance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Workforce	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Technology/process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Project characteristics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Project management/ project team characteristics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Statutory/ regulatory compliance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Unforeseen circumstances	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Other external factors (economic, political, industry, etc)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

## PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES

### 5. PREVENTIVE MITIGATION MEASURES

To address the most important preventive mitigation measures with a view to improve productivity and performance, how would you rate the effectiveness of the following measures for mitigating constraints to productivity in road pavement maintenance & rehabilitation projects?

Five-point rating scales have been provided as before.

#### 1. PREVENTIVE MITIGATION MEASURES

Very Low      Low      Moderate      High      Very High

Teamwork/ collaboration through coordination: Use good coordination skills to foster collaboration and teamwork among key stakeholders;

Communication: Ensure effective communication network to permit adequate information flow for clarity and prompt decision-making;

Staff training: Provide adequate training to update and broaden staff skills on current best practices and trends;

Outcome- rather than process-focused: Focus on outcomes rather than process to avoid the current practice of missing the goal and 'covering of tracks just in case things might go wrong'

Encouraging more competitive market structure;

Funding/ resourcing: Provide adequate funding and cash flow to ensure good progress and quality of work;

Early contractor involvement: Encourage early contractor involvement in the design and planning phase in order to ensure buildability and minimisation of costly and time-consuming variation and rework associated;

Information technology (IT): Integrate information and communication technology (ICT) in the work processes to improve efficiencies, productivity and performance;

Staff motivation: Provide adequate incentives to motivate staff for peak performance;

Technical and management competencies of decision-makers;

Procurement and contract strategies: Adopt more collaborative procurement and contract strategies that focus on life cycle value and win-win outcomes for all stakeholders;

Scheduling: Schedule operations to smoothen peaks and troughs in resource demand in line with resource ceilings/ capacity;

Worker empowerment through engagement: Involve all those that will implement the project in the planning and decision-making process so everyone knows the goals and expectations and can take ownership and commit to achieving expected outcome;

Planning: Ensuring proper upfront planning to establish the benchmarks for downstream performance reviews and progress update;

Minimise regulatory and statutory controls that inhibit innovation, efficiencies and productivity;

Project review and experiential learning: Ensure continuous improvement by debriefing on completed sections or for the whole projects and documenting valuable lessons for the future;

Innovation and win-win outcomes: Minimise red-tape and bureaucracy to speed up decision-making processes;

Innovation and win-win outcomes: Minimise red-tape and bureaucracy to speed up decision-making processes;

Skilled workforce: Employ only qualified and experienced workers to minimise poor quality of workmanship and accidents on sites;

Supervision: Ensure proper supervision of the workforce to minimise idle time and poor productivity;

What is your piece of advice to further improve productivity?

**PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES**

**6. ADVICE/ GENERAL COMMENTS**

**1. If there is one piece of advice you can give to improve productivity in the New Zealand road maintenance industry, what would that be? (You are welcome to supply more than one piece of advice, if you choose to!):**

**PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES**

**7. DEMOGRAPHIC BACKGROUND**

The following information is for statistical analysis purposes.

**1. Kindly indicate only one of the following as your most frequent role as a member of the project team:**

- Consultant       Client/ owner       Contractor       Subcontractor

Other (please specify)

**2. Kindly indicate how long you have been working in the industry in the above capacity?**

- >25 years       20 - 25 yrs       15-19 yrs       10 - 14 yrs       5 - 9 yrs  
 < 5 yrs

**3. Which one of the following best describes your job position?**

- Director / Executive  
Director/  
Associate Director       General Manager       Project Manager       Contract Manager       Project Engineer
- Site Engineer       Design Engineer       Team Leader/  
Supervisor       General foreman /  
sectional head

Other (please specify)

## Appendix B4- Request for Research Finding

### 4. APPRECIATION:

Thank you for your time and valuable feedback. If you have any comments in relation to the contents or any aspect of this questionnaire, or if you have any further advice that may improve the outcome of this project, it will be appreciated if you could contact the researcher [+64 27 541 9815](tel:+64275419815) (cell); Email: [saeedhajikarimian@gmail.com](mailto:saeedhajikarimian@gmail.com). Otherwise, please state your overall comments below, if any:

5. Should you wish to receive a summary of the key findings of this survey, please provide your email address below:

## PRODUCTIVITY IN ROAD PAVEMENT MAINTENANCE AND REHABILITATION PROJECTS: PERSPECTIVES OF NEW ZEALAND ROADING CONTRACTORS ON THE CONSTRAINTS AND IMPROVEMENT MEASURES

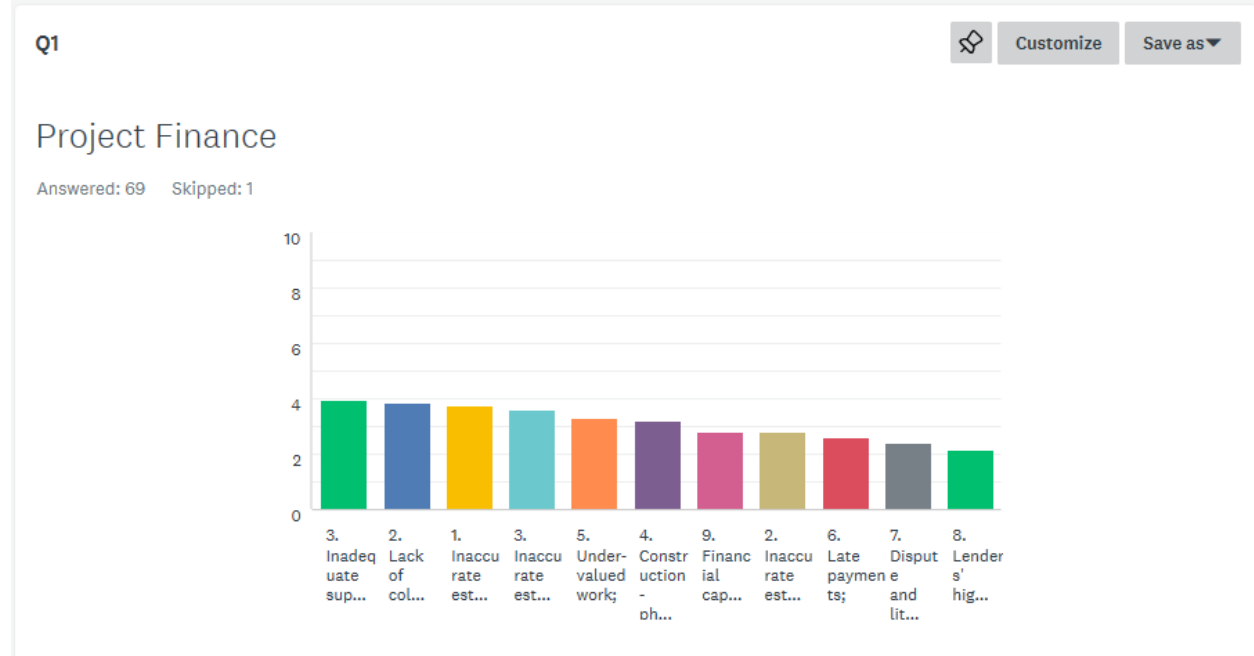
### 8. DISCLAIMER

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the Massey University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone [06 350 5249](tel:063505249), email: [humanethics@massey.ac.nz](mailto:humanethics@massey.ac.nz).

# Appendix C: Survey Analysis

Page 2: INTERNAL CONSTRAINTS

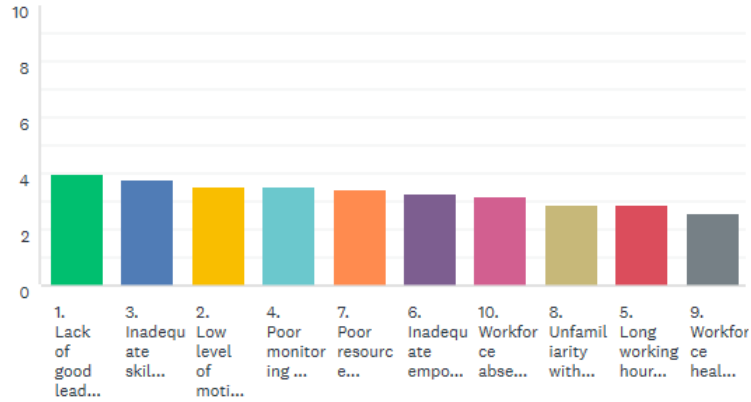


	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	NO IDEA	TOTAL	WEIGHTED AVERAGE
3. Inadequate supply or high cost of required resources: funding, labour, materials & machinery;	0.00% 0	5.80% 4	26.09% 18	31.88% 22	34.78% 24	1.45% 1	69	3.97
2. Lack of collaboration between consultant & contractor;	1.47% 1	5.88% 4	27.94% 19	32.35% 22	29.41% 20	2.94% 2	68	3.85
1. Inaccurate estimate (Client, consultant and contractors);	1.45% 1	8.70% 6	26.09% 18	34.78% 24	23.19% 16	5.80% 4	69	3.74
3. Inaccurate estimate (Contractors);	0.00% 0	20.00% 1	20.00% 1	40.00% 2	20.00% 1	0.00% 0	5	3.60

▼ 5. Under-valued work;	4.48% 3	16.42% 11	32.84% 22	34.33% 23	8.96% 6	2.99% 2	67	3.28
▼ 4. Construction-phase defective or non-compliant work;	2.90% 2	18.84% 13	42.03% 29	23.19% 16	10.14% 7	2.90% 2	69	3.19
▼ 9. Financial capacity for the scale and complexity of work involved;	14.93% 10	19.40% 13	29.85% 20	20.90% 14	5.97% 4	8.96% 6	67	2.82
▼ 2. Inaccurate estimate (Consultant);	0.00% 0	40.00% 2	40.00% 2	20.00% 1	0.00% 0	0.00% 0	5	2.80
▼ 6. Late payments;	16.18% 11	32.35% 22	26.47% 18	13.24% 9	5.88% 4	5.88% 4	68	2.58
▼ 7. Dispute and litigation costs;	26.09% 18	31.88% 22	14.49% 10	10.14% 7	8.70% 6	8.70% 6	69	2.38
▼ 8. Lenders' high interest charges;	20.29% 14	37.68% 26	17.39% 12	5.80% 4	1.45% 1	17.39% 12	69	2.16

# Workforce

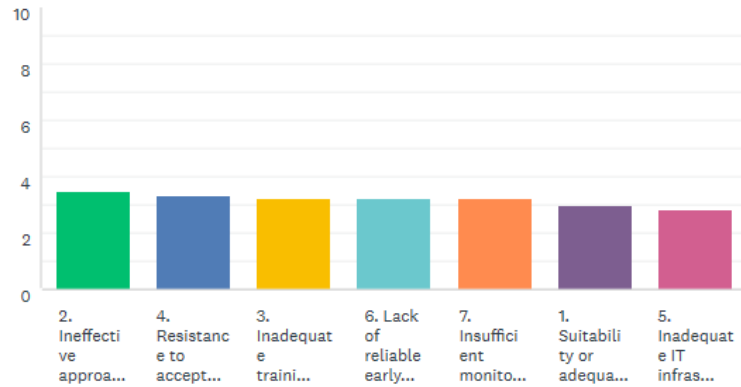
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	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	NO IDEA	TOTAL	WEIGHTED AVERAGE
1. Lack of good leadership/ management capability;	2.94% 2	7.35% 5	14.71% 10	38.24% 26	36.76% 25	0.00% 0	68	3.99
3. Inadequate skill and experience with current project type;	1.47% 1	7.35% 5	29.41% 20	29.41% 20	30.88% 21	1.47% 1	68	3.82
2. Low level of motivation/commitment;	7.35% 5	8.82% 6	25.00% 17	35.29% 24	20.59% 14	2.94% 2	68	3.55
4. Poor monitoring or appraisal of performance;	4.41% 3	8.82% 6	32.35% 22	33.82% 23	17.65% 12	2.94% 2	68	3.53
7. Poor resource management;	2.94% 2	20.59% 14	22.06% 15	36.76% 25	17.65% 12	0.00% 0	68	3.46
6. Inadequate empowerment (training and resourcing) for employees;	1.47% 1	22.06% 15	30.88% 21	33.82% 23	11.76% 8	0.00% 0	68	3.32
10. Workforce absenteeism;	5.88% 4	23.53% 16	27.94% 19	22.06% 15	16.18% 11	4.41% 3	68	3.20
8. Unfamiliarity with current project type and project environment;	8.82% 6	25.00% 17	32.35% 22	25.00% 17	4.41% 3	4.41% 3	68	2.91
5. Long working hours with insufficient rest periods, especially during night work;	10.45% 7	23.88% 16	35.82% 24	20.90% 14	7.46% 5	1.49% 1	67	2.91
9. Workforce health issues;	11.76% 8	38.24% 26	27.94% 19	13.24% 9	4.41% 3	4.41% 3	68	2.58

# Technology/ Process

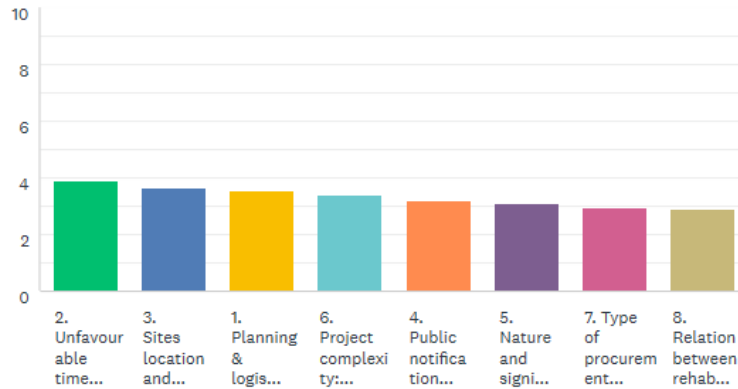
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	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	NO IDEA	TOTAL	WEIGHTED AVERAGE
2. Ineffective approach to road maintenance	2.94% 2	16.18% 11	27.94% 19	26.47% 18	20.59% 14	5.88% 4	68	3.48
4. Resistance to accept new technologies and methods for road maintenance & rehabilitation projects	2.94% 2	26.47% 18	22.06% 15	22.06% 15	22.06% 15	4.41% 3	68	3.35
3. Inadequate training on new processes and technologies	1.47% 1	20.59% 14	35.29% 24	29.41% 20	10.29% 7	2.94% 2	68	3.27
6. Lack of reliable early road failure detection system	4.48% 3	19.40% 13	26.87% 18	34.33% 23	7.46% 5	7.46% 5	67	3.23
7. Insufficient monitoring process for road failure detection	5.97% 4	17.91% 12	26.87% 18	32.84% 22	8.96% 6	7.46% 5	67	3.23
1. Suitability or adequacy of the plant & equipment employed	4.41% 3	25.00% 17	38.24% 26	27.94% 19	2.94% 2	1.47% 1	68	3.00
5. Inadequate IT infrastructure and application in road maintenance industry	5.88% 4	26.47% 18	42.65% 29	16.18% 11	4.41% 3	4.41% 3	68	2.86

## Project Characteristics

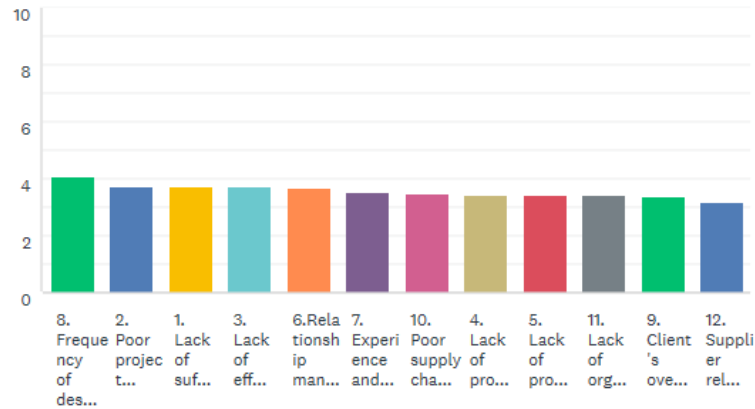
Answered: 68 Skipped: 2



	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	NO IDEA	TOTAL	WEIGHTED AVERAGE
2. Unfavourable time frames within which most road works must be carried out;	4.41% 3	2.94% 2	23.53% 16	32.35% 22	32.35% 22	4.41% 3	68	3.89
3. Sites location and environmental constraints (e.g. traffic volume, climate, subsoil and topography);	4.41% 3	7.35% 5	25.00% 17	36.76% 25	19.12% 13	7.35% 5	68	3.63
1. Planning & logistic issues impacting on continuous work flow (e.g non-closure period);	1.47% 1	10.29% 7	36.76% 25	22.06% 15	22.06% 15	7.35% 5	68	3.57
6. Project complexity: scale, design;	2.94% 2	11.76% 8	33.82% 23	38.24% 26	8.82% 6	4.41% 3	68	3.40
4. Public notification issues (e.g. community and environmentalists' resistance to infrastructure development plans);	4.41% 3	20.59% 14	32.35% 22	26.47% 18	10.29% 7	5.88% 4	68	3.19
5. Nature and significance of road in the road hierarchy;	4.48% 3	16.42% 11	40.30% 27	26.87% 18	4.48% 3	7.46% 5	67	3.11
7. Type of procurement adopted;	8.82% 6	19.12% 13	35.29% 24	19.12% 13	7.35% 5	10.29% 7	68	2.97
8. Relation between rehabilitation or maintenance scale and plant utilisation;	5.88% 4	23.53% 16	38.24% 26	19.12% 13	4.41% 3	8.82% 6	68	2.92

## Project Management/ Project Team Characteristics


Answered: 69 Skipped: 1



	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	NO IDEA	TOTAL	WEIGHTED AVERAGE
8. Frequency of design changes/ change orders/late changes	2.94% 2	1.47% 1	20.59% 14	35.29% 24	36.76% 25	2.94% 2	68	4.05
2. Poor project management and risk management processes	1.47% 1	14.71% 10	19.12% 13	38.24% 26	25.00% 17	1.47% 1	68	3.72
1. Lack of sufficient planning from the outset	1.45% 1	13.04% 9	27.54% 19	27.54% 19	28.99% 20	1.45% 1	69	3.71
3. Lack of effective communication/ clarification of expectations among key stakeholders	1.49% 1	10.45% 7	26.87% 18	34.33% 23	23.88% 16	2.99% 2	67	3.71
6. Relationship management/ degree of harmony, trust and cooperation between contractor, consultant and council	2.99% 2	5.97% 4	37.31% 25	26.87% 18	23.88% 16	2.99% 2	67	3.65
7. Experience and competencies of the project team	2.94% 2	13.24% 9	33.82% 23	27.94% 19	19.12% 13	2.94% 2	68	3.48
10. Poor supply chain management, especially as it relates to "just-in-time" supply principles	1.47% 1	17.65% 12	27.94% 19	27.94% 19	16.18% 11	8.82% 6	68	3.44

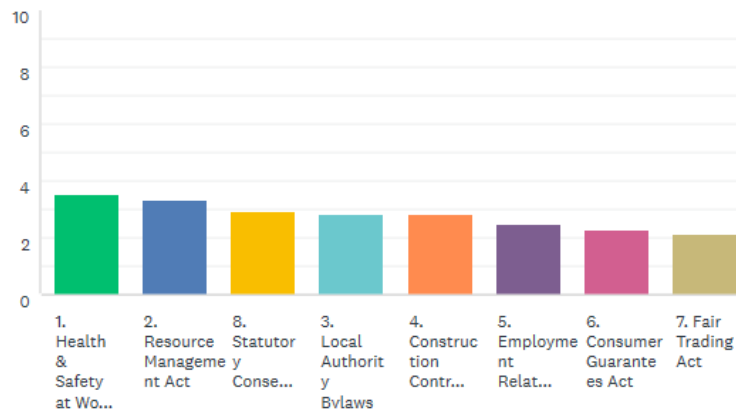
▼ 4. Lack of proper and regular coordination; supervision; performance monitoring and control	4.41% 3	10.29% 7	35.29% 24	32.35% 22	13.24% 9	4.41% 3	68	3.42
▼ 5. Lack of project organisational culture that supports high productivity and performance	4.41% 3	16.18% 11	27.94% 19	33.82% 23	14.71% 10	2.94% 2	68	3.39
▼ 11. Lack of organisational learning: (learning from previous projects)	5.88% 4	11.76% 8	29.41% 20	38.24% 26	11.76% 8	2.94% 2	68	3.39
▼ 9. Client's overt influence on the project process	4.48% 3	14.93% 10	32.84% 22	32.84% 22	11.94% 8	2.99% 2	67	3.34
▼ 12. Supplier related issues (delay, inferior goods)	5.88% 4	17.65% 12	36.76% 25	27.94% 19	8.82% 6	2.94% 2	68	3.17

Q6

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## Statutory Compliance



Answered: 66 Skipped: 4



▼	VERY LOW ▼	LOW ▼	MODERATE ▼	HIGH ▼	VERY HIGH ▼	NO IDEA ▼	TOTAL ▼	WEIGHTED AVERAGE ▼
▼ 1. Health & Safety at Work Act	3.03% 2	12.12% 8	28.79% 19	36.36% 24	16.67% 11	3.03% 2	66	3.53
▼ 2. Resource Management Act	3.03% 2	15.15% 10	36.36% 24	22.73% 15	15.15% 10	7.58% 5	66	3.34
▼ 8. Statutory Consent Compliance	11.67% 7	23.33% 14	23.33% 14	20.00% 12	11.67% 7	10.00% 6	60	2.96
▼ 3. Local Authority Bylaws	7.69% 5	27.69% 18	35.38% 23	15.38% 10	7.69% 5	6.15% 4	65	2.87

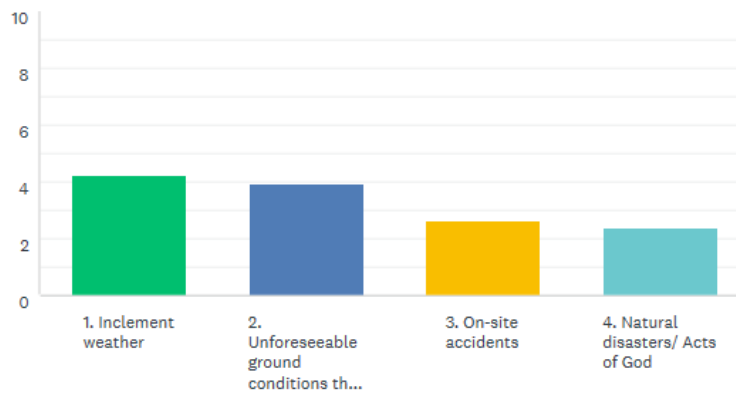
▼ 4. Construction Contracts Act	7.58% 5	30.30% 20	36.36% 24	13.64% 9	7.58% 5	4.55% 3	66	2.83
▼ 5. Employment Relations Act	9.09% 6	37.88% 25	36.36% 24	6.06% 4	3.03% 2	7.58% 5	66	2.52
▼ 6. Consumer Guarantees Act	18.18% 12	39.39% 26	24.24% 16	6.06% 4	3.03% 2	9.09% 6	66	2.30
▼ 7. Fair Trading Act	18.18% 12	45.45% 30	24.24% 16	4.55% 3	0.00% 0	7.58% 5	66	2.16

Q7

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## Unforeseen Circumstances

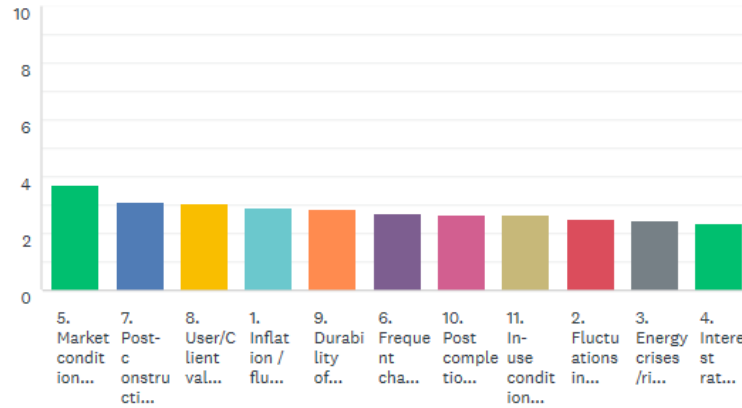
Answered: 65 Skipped: 5



▼	VERY LOW ▼	LOW ▼	MODERATE ▼	HIGH ▼	VERY HIGH ▼	NO IDEA ▼	TOTAL ▼	WEIGHTED AVERAGE ▼
▼ 1. Inclement weather	0.00% 0	0.00% 0	21.54% 14	32.31% 21	46.15% 30	0.00% 0	65	4.25
▼ 2. Unforeseeable ground conditions that necessitating design revisions	0.00% 0	1.54% 1	23.08% 15	52.31% 34	23.08% 15	0.00% 0	65	3.97
▼ 3. On-site accidents	10.77% 7	36.92% 24	29.23% 19	21.54% 14	1.54% 1	0.00% 0	65	2.66
▼ 4. Natural disasters/ Acts of God	32.31% 21	29.23% 19	15.38% 10	12.31% 8	10.77% 7	0.00% 0	65	2.40

## Other External Factors

Answered: 66 Skipped: 4

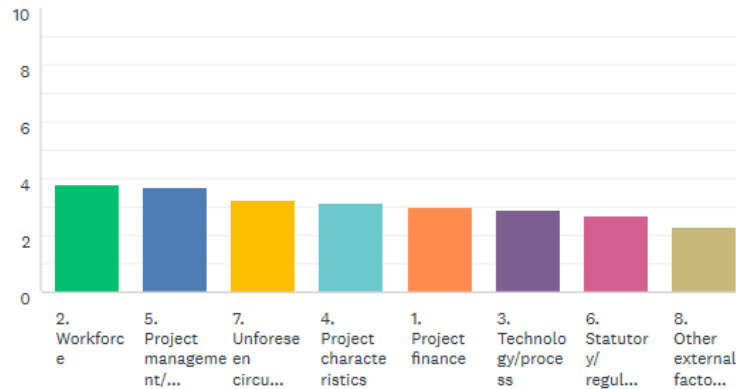


	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	NO IDEA	TOTAL	WEIGHTED AVERAGE
5. Market conditions and level of competitions in the industry for jobs;	4.55% 3	3.03% 2	31.82% 21	33.33% 22	22.73% 15	4.55% 3	66	3.70
7. Post-construction defective or non-compliant work;	3.03% 2	28.79% 19	33.33% 22	24.24% 16	9.09% 6	1.52% 1	66	3.08
8. User/Client value perceptions;	6.06% 4	16.67% 11	40.91% 27	31.82% 21	1.52% 1	3.03% 2	66	3.06
1. Inflation / fluctuations in material prices;	7.58% 5	22.73% 15	45.45% 30	12.12% 8	7.58% 5	4.55% 3	66	2.89
6. Frequent changes in government policies/legislations impacting on construction;	9.09% 6	37.88% 25	25.76% 17	16.67% 11	4.55% 3	6.06% 4	66	2.68
10. Post completion deterioration rate relating to rough use;	10.61% 7	28.79% 19	37.88% 25	16.67% 11	0.00% 0	6.06% 4	66	2.65
11. In-use conditions being at variance with prior production assumption;	12.12% 8	25.76% 17	36.36% 24	15.15% 10	1.52% 1	9.09% 6	66	2.65
2. Fluctuations in exchange rate;	12.12% 8	42.42% 28	27.27% 18	6.06% 4	6.06% 4	6.06% 4	66	2.48
3. Energy crises/rising costs;	15.15% 10	36.36% 24	30.30% 20	9.09% 6	3.03% 2	6.06% 4	66	2.45
4. Interest rate/cost of capital;	16.67% 11	36.36% 24	31.82% 21	6.06% 4	1.52% 1	7.58% 5	66	2.34



## BROAD CATEGORIES OF INTERNAL AND EXTERNAL CONSTRAINTS - RATING OF LEVELS OF IMPACT OF PRODUCTIVITY CONSTRAINTS:

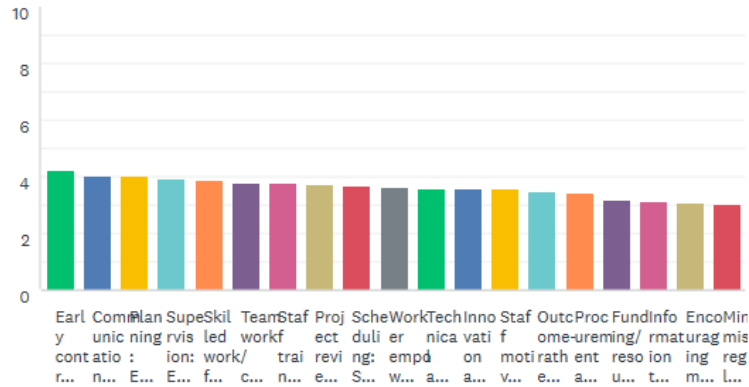
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	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	TOTAL	WEIGHTED AVERAGE
2. Workforce	1.59% 1	3.17% 2	33.33% 21	38.10% 24	23.81% 15	63	3.79
5. Project management/ project team characteristics	1.61% 1	14.52% 9	25.81% 16	29.03% 18	29.03% 18	62	3.69
7. Unforeseen circumstances	4.76% 3	19.05% 12	36.51% 23	26.98% 17	12.70% 8	63	3.24
4. Project characteristics	1.59% 1	19.05% 12	46.03% 29	26.98% 17	6.35% 4	63	3.17
1. Project finance	4.92% 3	31.15% 19	31.15% 19	26.23% 16	6.56% 4	61	2.98
3. Technology/process	1.59% 1	30.16% 19	46.03% 29	19.05% 12	3.17% 2	63	2.92
6. Statutory/regulatory compliance	7.94% 5	38.10% 24	38.10% 24	9.52% 6	6.35% 4	63	2.68
8. Other external factors (economic, political, industry, etc)	17.74% 11	45.16% 28	27.42% 17	8.06% 5	1.61% 1	62	2.31

## PREVENTIVE MITIGATION MEASURES

Answered: 62 Skipped: 8



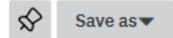
	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	TOTAL	WEIGHTED AVERAGE
Early contractor involvement: Encourage early contractor involvement in the design and planning phase in order to ensure buildability and minimisation of costly and time-consuming variation and rework associated;	0.00% 0	6.56% 4	8.20% 5	39.34% 24	45.90% 28	61	4.25
Communication: Ensure effective communication network to permit adequate information flow for clarity and prompt decision-making;	1.61% 1	3.23% 2	16.13% 10	45.16% 28	33.87% 21	62	4.06
Planning: Ensuring proper upfront planning to establish the benchmarks for downstream performance reviews and progress update;	1.61% 1	4.84% 3	16.13% 10	41.94% 26	35.48% 22	62	4.05
Supervision: Ensure proper supervision of the workforce to minimise idle time and poor productivity;	1.64% 1	4.92% 3	16.39% 10	52.46% 32	24.59% 15	61	3.93

<p>▼ Skilled workforce: Employ only qualified and experienced workers to minimise poor quality of workmanship and accidents on sites;</p>	4.84% 3	6.45% 4	9.68% 6	51.61% 32	27.42% 17	62	3.90
<p>▼ Teamwork/ collaboration through coordination: Use good coordination skills to foster collaboration and teamwork among key stakeholders;</p>	1.67% 1	10.00% 6	13.33% 8	55.00% 33	20.00% 12	60	3.82
<p>▼ Staff training: Provide adequate training to update and broaden staff skills on current best practices and trends;</p>	0.00% 0	3.23% 2	32.26% 20	43.55% 27	20.97% 13	62	3.82
<p>▼ Project review and experiential learning: Ensure continuous improvement by debriefing on completed sections or for the whole projects and documenting valuable lessons for the future;</p>	0.00% 0	4.84% 3	32.26% 20	45.16% 28	17.74% 11	62	3.76
<p>▼ Scheduling: Schedule operations to smoothen peaks and troughs in resource demand in line with resource ceilings/ capacity;</p>	0.00% 0	11.29% 7	24.19% 15	48.39% 30	16.13% 10	62	3.69

<p>▼ Worker empowerment through engagement: Involve all those that will implement the project in the planning and decision-making process so everyone knows the goals and expectations and can take ownership and commit to achieving expected outcome;</p>	1.61% 1	11.29% 7	24.19% 15	45.16% 28	17.74% 11	62	3.66
<p>▼ Technical and management competencies of decision-makers;</p>	1.61% 1	12.90% 8	22.58% 14	48.39% 30	14.52% 9	62	3.61
<p>▼ Innovation and win-win outcomes: Minimise red-tape and bureaucracy to speed up decision-making processes;</p>	3.33% 2	8.33% 5	30.00% 18	41.67% 25	16.67% 10	60	3.60
<p>▼ Staff motivation: Provide adequate incentives to motivate staff for peak performance;</p>	4.84% 3	4.84% 3	30.65% 19	46.77% 29	12.90% 8	62	3.58
<p>▼ Outcome-rather than process-focused: Focus on outcomes rather than process to avoid the current practice of missing the goal and 'covering of tracks just in case things might go wrong'</p>	1.64% 1	9.84% 6	39.34% 24	36.07% 22	13.11% 8	61	3.49
<p>▼ Procurement and contract strategies: Adopt more collaborative procurement and contract strategies that focus on life cycle value and win-win outcomes for all stakeholders;</p>	1.64% 1	13.11% 8	34.43% 21	40.98% 25	9.84% 6	61	3.44

▼ Funding/ resourcing: Provide adequate funding and cash flow to ensure good progress and quality of work;	4.84% 3	24.19% 15	29.03% 18	29.03% 18	12.90% 8	62	3.21
▼ Information technology (IT): Integrate information and communication technology (ICT) in the work processes to improve efficiencies, productivity and performance;	0.00% 0	22.95% 14	45.90% 28	26.23% 16	4.92% 3	61	3.13
▼ Encouraging more competitive market structure;	3.23% 2	27.42% 17	38.71% 24	19.35% 12	11.29% 7	62	3.08
▼ Minimise regulatory and statutory controls that inhibit innovation, efficiencies and productivity;	9.68% 6	12.90% 8	45.16% 28	25.81% 16	6.45% 4	62	3.06

Q11



If there is one piece of advice you can give to improve productivity in the New Zealand road maintenance industry, what would that be? (You are welcome to supply more than one piece of advice, if you choose to!):

Answered: 31 Skipped: 39

[RESPONSES \(31\)](#)

[WORD CLOUD](#)

[TAGS \(0\)](#)

Sentiments: OFF

## Appendix D: Risk & Constraint Identification Toolkit

Dear (participants Name),

You are receiving this invitation as you have participated in a research survey in 2017-2018 on improving productivity in road maintenance and rehabilitation projects in New Zealand.

We have been able to complete the research and successfully publish the findings because you contributed your time to provide your valuable opinion, therefore, to appreciate your help in this research, the published article has been attached to this email.

Besides, based on the research findings, we have been able to design a risk/constraint assessment Toolkit to introduce to the roading and pavement maintenance industry. The designed Toolkit is developed, based on the feedback of highly experienced experts in road maintenance and construction industry. It provides a framework for the industry expert, for the future projects to categorise, prioritise & mitigate productivity constraints that they may face during each phase of a road pavement maintenance or rehabilitation project.

The developed Toolkit is also following the Input, Process, Environment, & Operation (IPEO) model, the model which is chosen by experts during the research phase. The attached Toolkit includes all four main groups of Input Constraints, Process Constraints, Operation Environment Constraints and Output Constraints with their relative level of impact on productivity improvement. This Toolkit can be used during each stage of road maintenance and rehabilitation projects, from initial stages such as design which can be called INPUT phase, through final stages which are called OUTPUT phase, based on IPEO model.

To operationalise the model into a practical toolkit that can be used by the contractors, the conceptual framework in below figure guided the development of productivity constraints register toolkit for this purpose. This spreadsheet also can be used as a Toolkit to record & categorise constraints that will be identified during a project. At the moment, the Toolkit only shows higher-level constraints; however, it still can be extended to a very detailed level if it is used regularly by all involved parties within the lifetime of a project. It also can be modified to be used for a similar type of construction projects such as industrial and commercial concrete flooring/ pavement projects.

Also, it suggested developing this Toolkit to more detailed productivity risks/ constraints, sub categorised under each one of the identified broad risks before the start of each project phase, to be able to manage or mitigate productivity constraints as early as possible. It is obvious that knowing the risks & possible constraints and their level of impact on the final productivity of the project as early as possible, will give confidence to the project managers and directors to plan to deal with each constraint, as early as possible, before a productivity constraint makes a negative impact on the productivity.

Therefore, we would highly appreciate if you could please provide your feedback on the attached Toolkit as well, by using the below link:

We again thank you for devoting your 2 minutes for participating in this short survey and for your contribution to the construction industry.

**The IPEO Model:**

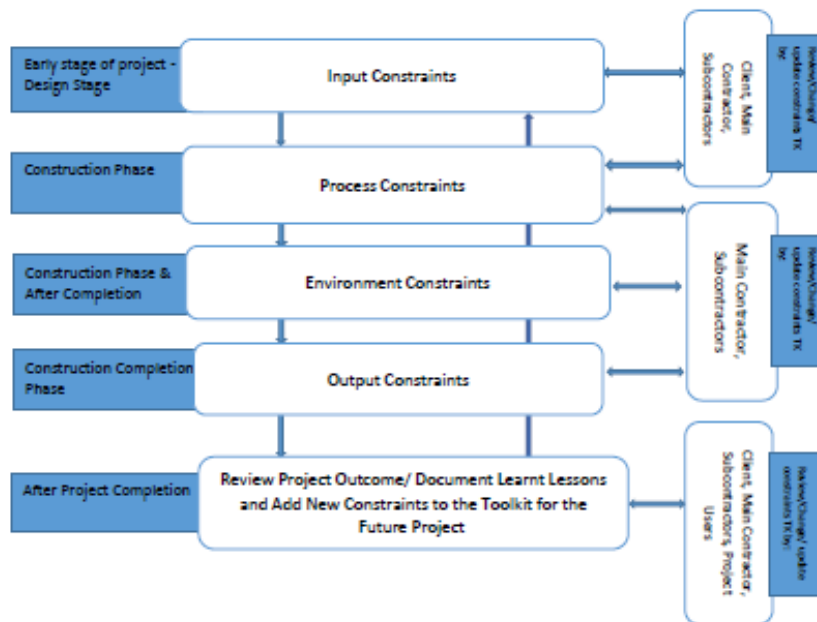
The results of the research study: *Improving efficiency in roading projects: a New Zealand study* (Karimian, et, all. 2019) have provided a guide to Road Pavement Maintenance & Rehabilitation (RPMR) contractors on typical constraints they could encounter in their routine road pavement maintenance and rehabilitation operation. The study has also provided some measures for addressing the constraints with a view to improving the contractors' productivity and performance. The below figure provides a high-level concept of IPEO (Input, Process, Environment, & Outcome model) in the road maintenance and rehabilitation industry to help manage productivity constraints during each phase of a project.

Overall, the IPEO model established in the above mentioned study, gives a better reflection of the key attributes of a productive system and so the categorisation of the associated constraints. In this context, the IPEO model is more useful, however, the accountability/ role-player perspective is more applicable at the systems level, when the focus is on apportioning risks of poor performance on the parties based on their actions or inactions.

In addition to setting up an appropriate toolkit which can be used in accordance with the IPEO model, this spreadsheet has been developed by using the research findings. The developed spreadsheet includes all four main groups of Input Constraints, Process Constraints, Operation Environment Constraints and Output Constraints with their relative level of impact on productivity improvement. This toolkit can be used during each stage of road maintenance and rehabilitation projects, from initial stages such as design which can be called INPUT phase, through final stages which is called OUTPUT phase, based on IPEO model.

To operationalize the model into a practical toolkit that can be used by the contractors, the conceptual framework in below figure guided the development of productivity constraints register toolkit for this purpose. This spreadsheet also can be used as a toolkit to record & categorise all the constraints that may be identified during a project. At the moment the toolkit only shows higher level constraints but it has the ability to be extended to a very detailed level, if it is being used regularly by all involved parties within the time of a project. It also can be modified to be used for similar types of construction projects such as industrial and commercial concrete flooring/ pavement projects.

Furthermore, it is suggested to develop this toolkit to more detailed productivity risks/ constraints, sub categorised under each one of the identified risks before the start of each phase of project to be able to identify, manage or mitigate productivity constraints as early as possible. Knowing the risks & possible constraints and their level of impact on the final productivity of the project as early as possible, will give the advantage to the project managers and directors to plan for dealing with each risk/constraint as early as possible before negative impact of a constraint on project productivity and outcome appears.



**References:**

Karimian, S. H., Mbachui, J., Egbelakin, T., & Shahzad, W. (2019). *Improving efficiency in roading projects: a New Zealand study*. Engineering, Construction and Architectural Management.









ITEM	Improvement Measures	Weighted Average	
1	Early contractor involvement: Encourage early contractor involvement in the design and planning phase to ensure buildability and more innovation that can reduce costly and time-consuming variation and rework associated with design solutions not aligning with practical site conditions.	Very High	4.25
2	Communication: Ensure effective communication network to permit adequate information flow for clarity and prompt decision-making and to minimise duplication of efforts due to communication gap to the 'frontline' people.	Very High	4.06
3	Planning: Proper planning should be done upfront to establish the benchmarks for downstream performance reviews and progress update; also provide plans for other challenges such as risks for statutory compliance (health and safety, environmental impact, traffic management, etc.)	Very High	4.04
4	Supervision: Ensure proper supervision of the workforce to minimise idle time and poor productivity;	High	3.93
5	Skilled workforce: Ensuring only qualified and experienced workers are employed to mitigate poor quality of workmanship and accidents on sites;	High	3.9
6	Teamwork/ collaboration through coordination: Use good coordination skills to foster collaboration among key stakeholders - client, contractor, consultants, suppliers, etc. - to work collaboratively and ensure maximum value delivery from design through production and construction to operation and maintenance.	High	3.82
7	Staff training: Provide adequate training programme to update and broaden staff skills on current best practices and trends, e.g. new occupational health and safety requirements on site. Up-skill the people making the decisions – i.e. engineers, clients and contractors.	High	3.82
8	Project review and experiential learning: Ensure continuous improvement by debriefing on completed sections or for the whole projects and documenting valuable lessons for the future;	High	3.76
9	Scheduling: Proper scheduling of operations to smoothen peaks and troughs in resource demand in line with resource ceilings/ capacity. Schedule work to minimise impact of weather; e.g. weather affected works should not be planned in winter.	High	3.69
10	Worker empowerment through engagement: Involve all those that will implement the project in the planning and decision-making process, so everyone knows the goals and expectations and can take ownership and commit to overall outcome achievement and, as well, are updated on changes.	High	3.66
11	Technical and management competencies of decision-makers: Improve technical/practical knowledge and management capability of road authority engineers & consultants to align their decisions to practical realities and in line with contractors' innovative processes for optimum productivity and outcomes.	High	3.61
12	Innovation and win-win outcomes: Minimise red tape and bureaucracy in decision-making processes; encourage innovation and share equally any associated rewards for cost and time savings among contributors.	High	3.6
13	Staff motivation: Provide adequate incentives to motivate staff for peak performance;	High	3.58
14	Outcome - rather than process-focused: Focus on outcomes rather than processes to avoid the current practice of missing the goal and 'covering of tracks just in case things might go wrong'	High	3.49
15	Procurement and contract strategies: Clients should rethink preference for lowest price conforming tenders and traditional system approaches to more collaborative procurement and contract strategies that focus on life cycle value and win-win outcomes for all stakeholders.	High	3.44
16	Funding/ resourcing: Provide adequate funding and cash flow to ensure good progress and quality of work; ensure adequate level of resources to suit work demands and optimise efficiency and utilisation (i.e. not too much or too little plant and people resource)	Mod	3.21
17	Information technology (IT): Integration of IT in the work processes to improve efficiencies, productivity and performance, using minimal resource inputs.	Mod	3.13
18	More competitive market structure: Resolve oligopoly to improve efficiencies through fostering competition and innovation. Encourage smaller work packages to enable small to medium competitors to compete for jobs rather than having gigantic projects that only the few big companies have capacity to compete for, which excludes the majority of the SMEs	Mod	3.08
19	Over-regulation: Minimise regulatory and statutory controls that inhibit innovation and creativity towards efficiencies and productivity. The regulators should be in partnership with the service providers, get on-board and work as teams, guiding each other along the way rather than waiting for mistakes and passing on blame.	Low	3.06

## Appendix E: List of Pre-qualified Contractors



Prequalified Contractors as of 31 January 2016					
No	Registered Name of Company	Prequalification Work Category and Classification Level			
		Routine & Minor Works	Surfacing	Bridge Construction	Construction
1	Armitage Group Ltd	1A			
2	Ashburton Contracting Ltd	1B	2C		4B
3	Askew Contracting Ltd	1C			4C
4	Base Civil Ltd				4C
5	B.Bullock (2009) Ltd				4B
6	BIG Contracting Ltd				4A
7	Blakely Construction Ltd	1A		3C	4A
8	Brian Perry Civil			3A	4A
9	Brierty Ltd	1A			4A
10	Broadspectrum (formerly known as Transfield)	1A	2A		4A
11	Calcon Ltd	1B		3D	4B
12	Cambridge Construction Co. Ltd				4A
13	Carran Scott Contracting Ltd	1D			4C
14	Ching Contracting	1D			4D
15	City Care	1A	2B	3D	4A
16	Civil Construction Limited	1B			4B
17	Civil Construction Services Co Ltd	1B			4B
18	Coastline Roadmarkers	1C			
19	Collis Murdoch Earthmoving Ltd				4A
20	Combined Road & Traffic Services	1C			
21	Concrete Structures (NZ) Ltd			3A	4C
22	Conspec Construction Ltd	1B		3B	4B
23	Construction Techniques Ltd			3C	4D
24	Crafar Crouch Construction Ltd				4C
25	Delta Utility Services Ltd	1A	2C	3D	4A
26	Dempsey & Wood Civil Contractors Ltd			3A	4A
27	Dews Construction Ltd	1C	2C	3C	4C
28	Directionz Limited	1C			
29	Dominion Constructors Ltd			3A	4A
30	Donaldson Civil Limited	1C			4C
31	Dormer Construction Ltd	1C			4C
32	Downer	1A	2A	3A	4A
33	Electrix Ltd	1A			
34	ElectroNet Services	1D			
35	Ferrovial Agroman NZ Ltd	1A	2A	3A	4A
36	Fibretek Ltd	1B		3B	
37	The Fletcher Construction Company Ltd, Engineering Division			3A	4A
38	Freyssinet NZ Ltd			3C	
39	Fulton Hogan Ltd	1A	2A	3A	4A
40	Geotech Ltd				4A
41	Geovert Ltd			3C	4B
42	G.H.K Piling 2000 Ltd			3D	4D
43	Gibbons Contractors Ltd			3D	4D
44	Gideon Contractors Ltd				4A
45	Goodman Contractors Limited				4A
46	G.T. Liddell Contracting Ltd	1D		3D	4D
47	Graffiti Doctor NZ Ltd	1D			
48	Hawkins Construction Limited	1A		3A	4A
49	HEB Construction Ltd	1A	2A	3A	4A
50	Higgins Contractors Ltd	1A	2A	3A	4A
51	Hiway Stabilizers	1A			4A
52	Hopper Construction Ltd				4A

Prequalified Contractors as of 31 January 2016					
No	Registered Name of Company	Prequalification Work Category and Classification Level			
		Routine & Minor Works	Surfacing	Bridge Construction	Construction
53	HTS Group Ltd	1C			
54	Hunter Civil Ltd			3B	
55	I D Loader Ltd	1D			4B
56	Ice Construction	1C		3C	4C
57	Inframax Construction Ltd	1A	2C		4A
58	Infratel Networks Ltd			3C	
59	The Isaac Construction Co Ltd	1A	2A	3A	4A
60	J & J Walters Ltd		2A		
61	J Swap Contractors Ltd	1A			4A
62	John Fillmore Contracting Ltd				4A
63	Johnstone & Masters Ltd		2C		
64	Juno Civil Ltd			3A	4A
65	KB Contracting & Quarries Ltd	1B			4B
66	Kidson Construction Ltd			3B	
67	Leighton Contractors	1A	2A	3A	4A
68	MainPower New Zealand Limited	1D			
69	March Construction Ltd				4C
70	Maxbuild Ltd			3D	
71	MBD Contracting	1B			4B
72	McConnell Dowell Constructors Ltd	1A		3A	4A
73	McDonough Contracting Ltd	1D		3D	
74	McNatty Construction	1B		3C	4B
75	Mike Edridge Contracting Ltd	1D		3D	4D
76	Nelmac Ltd	1D			
77	Northland Transport Ltd	1C			4C
78	Obrasoon Huarte Lain Pty Ltd			3A	4A
79	Opie Contractors Ltd				4C
80	Opus International Consultants Ltd	1A			
81	Orsbom Roadmarking Ltd	1C			
82	Paul Smith Earthmoving 2002 Ltd	1C		3C	4C
83	Quality Roading & Services (Wairoa) Ltd	1B		3C	4B
84	Reefton Crane Hire Ltd			3C	
85	Riverside Construction Ltd	1B		3B	4B
86	Roadmarkers NZ Ltd	1C			
87	Rooney Earthmoving Ltd	1A			4A
88	Ross Reid Contractors Ltd			3A	4A
89	Russell Roads Ltd	1A	2B		4B
90	Schick Construction and Cartage Ltd	1A			4A
91	Services South East NZ Ltd	1A	2A	3D	4B
92	Siconferguson Ltd	1B		3B	4B
93	Simcox Construction Ltd				4D
94	Southroads Ltd	1A	2C	3C	4A
95	Speirs Contracting Ltd	1D			
96	Spray Marks Roadmarking Ltd	1B			
97	Steve Bowling Contracting Ltd	1D		3D	4D
98	Strada Corporation Ltd	1A	2C		4A
99	Stringfellow Contracts Ltd	1A			4A
100	Stuart Tarbotton Contractors Ltd	1D			4D
101	Taranaki Civil Construction	1C		3C	4B
102	Tasman Civil Limited				4C
103	Taylor's Contracting Co Ltd	1A			4A
104	TC Nicholls Ltd		2C		4C
105	Tebo Services Limited	1D	2D		

Prequalified Contractors as of 31 January 2016					
No	Registered Name of Company	Prequalification Work Category and Classification Level			
		Routine & Minor Works	Surfacing	Bridge Construction	Construction
106	The Roding Company Ltd	1C			4B
107	Total Bridge Services			3A	
108	Traffic Systems Ltd	1B	2D		4B
109	Transpacific Industrial Solutions	1D		3D	
110	Troy Wheeler Contracting Ltd	1C		3C	4C
111	Truline Civil Ltd	1B		3B	4B
112	Tyco Traffic and Transportation	1C			
113	United Civil Construction Ltd	1A			4A
114	Visionstream Pty Limited	1A			
115	Waiotahi Contractors	1A			4A
116	Westroads Ltd	1B			4B
117	Wharehine Construction Group	1A			4A
118	Wilson Contractors (2003) Ltd	1C			4C
119	Whitaker Civil Engineering Ltd	1C		3A	4A
120	Whitestone Contracting Limited	1A	2A	3A	4A

For enquiries please contact: [prequalification@nzta.govt.nz](mailto:prequalification@nzta.govt.nz)

## Appendix F: Publication



### Engineering, Construction and Architectural Management

Improving efficiency in roading projects: a New Zealand study

Saeed Haji Karimian, Jasper Mbachu, Temitope Egbelakin, Wajiha Shahzad,

#### Article information:

To cite this document:

Saeed Haji Karimian, Jasper Mbachu, Temitope Egbelakin, Wajiha Shahzad, (2019) "Improving efficiency in roading projects: a New Zealand study", Engineering, Construction and Architectural Management, <https://doi.org/10.1108/ECAM-02-2018-0060>

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## Appendix G: Letter of Toolkit Acceptance by Industry



21 Heritage way, Otara, Auckland  
Tel: 09 279 4121  
Fax: 09 250 4129

23 May 2021

To whom it may concern,

This letter confirms that Conslab Limited would like to investigate using the productivity improvement toolkit, which is the research outcome of one of Massey University's PhD students on productivity improvement in pavement projects. We hope using the toolkit can help us improve our project productivity and performance, especially during the risk assessment stage. We also hope that by using the toolkit, we will be able to document the existing risks and productivity constraints during the project life cycle to improve our future projects productivity outcomes.

If there is any further information you require, do not hesitate to get in touch.

Yours faithfully,  
Technical & Compliance Team  
Conslab Limited.

## Appendix H: Validation Survey & Results



### Industry evaluation survey on findings of the research:

Productivity in road pavement maintenance & rehabilitation projects: perspectives of New Zealand roading contractors on the constraints & improvement measures.

This short survey has been designed to evaluate the research findings by receiving feedback from experienced professionals who are working in the roading & pavement industry in New Zealand.

Based on the research findings, a model has been developed, which has categorised project productivity constraints & risks into broad categories of Input, Process, Environment, & Outcome (IPEO). This model can help all parties who are involved in a road pavement maintenance project to predict, assess, & mitigate the risks and productivity constraints during each stage of a project and improve project productivity outcome.

The published research finding article which is published by the journal of Engineering, Construction and Architectural Management, has been attached to the survey invitation email, as well as the developed Toolkit.

Therefore, based on the supplied information, please answer the following questions and comments in the comment box below each question if there is any further comment.

Thank you for participating in this short survey & providing valuable feedback on the research findings. The published research finding article which is published by the journal of Engineering, Construction and Architectural Management, has been attached to the survey invitation email, as well as the developed Toolkit.

Therefore, based on the supplied information, please answer the following questions and comments in the comment box below each question if there is any further comment.

Thank you for participating in this short survey & providing valuable feedback on the research findings.

1. Is the structure of the toolkit clear to you?

- Definitely yes
  - Probably yes
  - Might or might not
  - Probably not
  - Definitely not
- 

Do you have any comments on improving the structure of toolkit?

---

2. Do you foresee any barriers to the adoption of toolkit?

- Extremely likely
  - Somewhat likely
  - Neither likely nor unlikely
  - Somewhat unlikely
  - Extremely unlikely
- 

Mention the barriers to the adoption of toolkit

3. Do you think that all the “input phase productivity” barriers are covered in the toolkit.

- Definitely yes
  - Probably yes
  - Might or might not
  - Probably not
  - Definitely not
- 

Do you have any “input phase productivity” barriers to add/remove

---

4. Do you think that all the “process phase productivity” barriers are covered in the toolkit.

- Definitely yes
  - Probably yes
  - Might or might not
  - Probably not
  - Definitely not
- 

Do you have any “process phase productivity” barriers to add/remove.

5. Do you think that all the “operational environment productivity” barriers are covered in the toolkit.

- Definitely yes
  - Probably yes
  - Might or might not
  - Probably not
  - Definitely not
- 

Do you have any “operational phase productivity” barriers to add/remove.

---

6. Do you think that all the “output environment productivity” barriers are covered in the toolkit.

- Definitely yes
  - Probably yes
  - Might or might not
  - Probably not
  - Definitely not
- 

Do you have any “output phase productivity” barriers to add/remove.

7. Do you foresee any risk of using the toolkit?

- Definitely yes
  - Probably yes
  - Might or might not
  - Probably not
  - Definitely not
- 

What are those risks (if any)

---

It will be most appreciated, if you could provide any general comments that could assist this research

Responseid	DistributionChannel	Q1	Q2	Q3	Q4
Response ID	Distribution Channel	1. Is the structure of the toolkit clear to you?	Do you have any comments on improving the structure of toolkit?	2. Do you foresee any barriers to the adoption of toolkit?	Mention the barriers to the adoption of toolkit
R_bQOWYIzURhnFaF	anonymous	Definitely yes	More detailed list of constraints would be very helpful	Neither likely nor unlikely	
R_3CSYIXWfBbDxOhY	anonymous	Definitely yes Definitely yes		Somewhat likely Extremely unlikely	
R_2aqxFReqTs75DV7	anonymous	Definitely yes	I think using IPEO model seems much easier than common risk assessment practice in the industry as its easier to follow and it is phasing the project to 4 main phase.	Extremely unlikely	There might be some resistance from those who get use to common methods
R_1H7WVVViQyOSLACS	anonymous	Definitely yes	It is better than using the common risk and constrains register as it is easy to follow and let the project people focus on certain barriers rather than common model. Helps utilising the resources as well	Extremely likely	Any new method or tools will face resistance at first
R_2rMwTe2AGl8F08i	anonymous				
Q5	Q6	Q7	Q8	Q9	Q10
3. Do you think that all the "input phase productivity" barriers are covered in the toolkit.	Do you have any "input phase productivity" barriers to add/remove	4. Do you think that all the "process phase productivity" barriers are covered in the toolkit.	Do you have any "process phase productivity" barriers to add/remove.	5. Do you think that all the "operational environment productivity" barriers are covered in the toolkit.	Do you have any "operational phase productivity" barriers to add/remove.
Might or might not Probably not	More detailed barrier can be added	Definitely yes Probably not		Probably yes Probably not	
Definitely yes Definitely not Probably not		Definitely yes Probably not Probably not		Definitely yes Probably not Probably not	
Q11	Q12	Q13	Q14	Q15	
6. Do you think that all the "output environment productivity" barriers are covered in the toolkit.	Do you have any "output phase productivity" barriers to add/remove.	7. Do you foresee any risk of using the toolkit?	What are those risks (if any)	It will be most appreciated, if you could provide any general comments that could assist this research	
Probably yes Might or might not Probably yes		Probably not Might or might not Definitely not		I believe this tool could be further developed when used practically. This will allow details of the items to be further investigated during the different phases of the project.  Best of luck.	
Probably not	Better to using it for many project and add more detail barriers or risks to it. The proposed barriers are mainly broad items.	Probably not	The risk may be using the toolkit which I think is not covering every possible risk. Again need to be developed further. It can easily develop when using the toolkit for a few projects	It is useful toolkit but further development is suggested	
Probably not		Might or might not	The only risk might be lack of covering all the risk. This toolkit need to be used for some project and developed more based on risks associated with each project. Then will be really useful.		

## Appendix I: A Few Samples of Explanatory Interviews



School of Engineering & Advanced Technology  
Private Bag 120 904, North Shore City 0745  
Auckland, New Zealand  
Tel: +64 9 414 0800 extn 41544 Fax: +64 9 443 9774

Dear Sir/Madam

**Survey Topic: Productivity in Road Pavement Maintenance & Rehabilitation Projects: Perspectives of New Zealand Roading Contractors on the Constraints and Improvement Measures**

My name is Saeed Karimian, a PhD research student of the School of Engineering and Advanced Technology, Massey University, New Zealand. My research is entitled, "Productivity in Road Pavement Maintenance & Rehabilitation Projects: Perspectives of New Zealand Roading Contractors on the Constraints and Improvement Measures".

The aim of this study is to investigate the level of impact and frequencies of occurrence of the key productivity constraints as well as establishing innovative ways of improving productivity in the road maintenance industry. The outcomes of the study are expected to guide efficiency planning, monitoring and performance, to improve productivity in the New Zealand future road projects.

The questions below will be asked to industry operatives who are involved in road pavement rehabilitation and maintenance projects. You have been selected to participate in the research survey based on your related experience in the field of road maintenance.

Participation in this research is voluntary and you are under no obligation to accept this invitation. However, feedback from representatives of reputable organizations or experts, such as you, will help to achieve the objectives of the study. I would therefore be grateful if you could grant me your time for this purpose. I assure you that your responses will be treated with strictest confidentiality and will be used solely for the purpose of this research.

I will highly appreciate your time and help for making this research a success. If you have any queries or want to have access to a summary of the project findings when it is concluded, please contact me through my contact details:

Saeed Haji Karimian  
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Private Bag 102 904, North Shore City 0745  
Auckland, New Zealand  
Cell: +64 27 541 9815  
Fax: +64 9 443 9774  
Email: saeedhajikarimian@gmail.com

You may wish to contact my supervisors:

Dr. Jasper Mbachu

Senior Lecturer and coordinator, Construction Programs

School of Engineering & Advanced Technology

Private Bag 102 904, North Shore City 0745

Auckland, New Zealand

Tell: +64 9 414 0800 extn 41543

Fax: +64 9 4439774

Email: [J.I.Mbachu@massey.ac.nz](mailto:J.I.Mbachu@massey.ac.nz)

Kacha Vuletich

Resurfacing Manager at Fulton Hogan

Waitakere City Council Road Maintenance Contract

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PO Box 305, Silverdale, 0944, New Zealand

Phone +64 9 427 0447 Ext 9327

[kacha.vuletich@fultonhogan.com](mailto:kacha.vuletich@fultonhogan.com)

Saeed Haji Karimian (Researcher)

Yours faithfully