Rework Management in Construction Contracts:

An assessment of NZS3910:2013 provisions

A thesis submitted in partial fulfilment of

the requirements for the degree of

Doctor of Philosophy in Engineering

Construction Project Management

Massey University

Auckland, New Zealand

Ramin Asadi

December 2021

Copyright

Abstract

Contracts play a significant role in achieving project goals in the construction industry. To enhance a project's performance by implementing a professional contract, construction practitioners must understand how contraction issues are addressed in the contract conditions. Although various contributing factors that affect construction contracts have been investigated and several methodologies have been proposed, the contract provisions that contribute to rework in construction projects have not been assessed adequately. Rework is of interest in the construction industry as it occurs throughout the project life cycle and affects its performance. The lack of understanding of construction practitioners under rework events may lead to cost overruns and delay in projects, resulting in contractual claims and disputes. Therefore, this research aims to investigate the contract clauses to improve the conditions that affect the project's performance by addressing rework.

On the other hand, the contract is an essential means of controlling and managing interactions between parties under various situations. The assessment of contract provision in addressing contractual issues has been practiced effectively over the years to overcome conflicts between contract parties. Thus, the selected concept is helpful for improving the contract conditions under different circumstances. This study attempts to address issues related to rework in construction projects, which significantly improves the contract conditions. Initially, through conducting a comprehensive literature review, the root causes of rework are identified and then using a systematic literature review approach, the identified causes are classified with liable contract parties. The classified rework causes then are investigated in New Zealand construction projects using a questionnaire survey to find the relevant common causes of rework in contracts. The relationship between rework causes and contract clauses is then established through common sources of rework and contractual claims. For this purpose, the case of NZS3910 is selected as the most commonly used standard form of contract in New Zealand to assess the contract provisions under rework events. The initial findings show that the current condition of the contract does not address rework adequately. After investigating the relational aspect of rework in the construction contract, a series of professional interviews are conducted to explore the strengths and weaknesses of the contract conditions related to rework in construction projects. Then, the best practice to address rework is followed up.

Furthermore, the current provisions stipulated in NZS3910 are evaluated as a documentary review to collect evidence for validation of interview results. It is observed that, while rework has not been defined in the contract, some of the contract clauses can be referenced for addressing rework. It is also confirmed that more clarification in the contract provision is required during contract preparation to avoid contractual claims originating from rework. Thus, the study develops a list of recommendations for improving the contract conditions that address rework issues. The research concludes by providing guidelines for addressing rework in contract provisions of NZS3910 and some general recommendations for improving the contract conditions. This research adds to the body of knowledge by improving the contract practices for rework management and achieving higher project performance with fewer contractual claims and disputes. Finally, and based on the study's findings, a framework that shows the flow of information for addressing rework is presented and recommended for further investigation in future research.

Acknowledgements

I would like to express my gratitude to my Supervisor, Professor Suzanne Wilkinson, for her continued support during this journey. It has been an absolute honor for me to learn from her. Her kind recommendations and valuable guidance have enlightened me to build my academic knowledge and enabled me to complete this thesis step by step. I would like to extend my appreciation and gratitude to my co-supervisor, Associate Professor James Rotimi, for his constructive comments and remarkable advice, which empowered me to write several publications within my Ph.D. journey. Highly insights and timely communication from my supervisors always encouraged me to step ahead, resulting in this achievement. Thanks for all your support.

In addition, I would like to thank Dr. Mostafa Babaeian Jelodar for his friendly comments, motivations, and academic advice. His excellent knowledge and experiences have always been highly encouraging, and I appreciate his mentorship approach. My respect is also extended to those who participated in the various stages of this research, specifically construction professionals who attended the research interviews and questionnaire surveys.

I am grateful to my family and parents for letting me follow my dreams. I am incredibly fortunate to have such a family who supported me with their unconditional love to come to my wishes true. I am grateful for having a very kind and lovely boy, my son, my hope, my best friend, my everything, Peyman, who has always offered me kindness, respect, and joy. Above all, my most profound appreciation to my wife, Parang Salimi, who supported our lives with unlimited love, stood beside me in all steps, and always motivated me to be strong. Thank you for your love, respect, and patient; however, no words can ever thank you enough; I am proud of myself for having you and Peyman in my life. I also appreciate the love and support from my sisters, in-laws' families, and friends. God bless all of you.

List of peer-reviewed Publications

Journal Articles - (Published)

1) Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2021). Towards contracting strategy usage in construction projects: A comprehensive review. *Journal of Construction Management and Economics,* https://doi.org/10.1080/01446193.2021.2004609.
2) Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (2022). Investigating the relationship between reworks and contractual claims: The salience of contract conditions. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*. 14(1), 04521046, DOI: 10.1061/(ASCE)LA.1943-4170.0000519 (ASCE).
3) Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2021). The common causes of rework in construction contracts: A diagnostic approach. *Journal of Engineering, Design and Technology,* 1726-0531, DOI 10.1108/JEDT-04-2021-0215.

Journal Articles – (Submitted, Under review)

4) Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Rework classification model in the project life cycle with liable parties of the contract. *Journal of Construction Management and Economics.* ID: 214526387.
5) Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Analyzing underlying factors of contractual claims raised from rework in construction contracts. *Journal of Construction Engineering and Management (*ASCE). ID: COENG-12141.
6) Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (n.d.). Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction.* ID: S-22-00087.

7) Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*. ID: LADR-873.

Conference Papers - (Published)

8) Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2020). Rework management in life cycle of project; an outline for construction contracts. *Proceedings*, *6th New Zealand Built Environment Research Symposium (NZBERS 2020),* ISSN 2463-4905.
9) Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2019). Contract document appraisal and rework root causes classification in tendering stage of project. *Proceedings, 43rd Australian Universities Building Education Association Conference (AUBEA 2019),* ISBN: 978-1-921047-51-0.
10) Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2020). Contracts evaluation through classified rework root causes in the construction stage of projects. *Proceedings of International Structural Engineering and Construction,* 7(2), Emerging Technologies and Sustainability Principles, ISSN: 2644-108X.

Conference Papers – (Accepted to be published)

11) Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Classification of rework root causes in the design stage of projects for contract assessment. *CIB World Building Congress (2022).* ID: 9.

Table of Content

Copyright ii

Abstract iii

Acknowledgements v

List of peer-reviewed Publications vi

List of Tables xxii

List of Figures xxvv

List of Abbreviations xxvii

Part one – Introduction, Problem and Definitions

Chapter 1. Introduction and Research Methodology 3

1.1 Introduction 3

1.2 Background of the study 5

1.3 Problem statement 7

1.4 Research gap 9

1.5 Research aim and objectives 12

1.6 Research questions 14

1.7 Research methodology 15

1.7.1 Overview 15

1.7.2 Adopted method for the research 19

1.7.2.1 Step 1: literature review 19

1.7.2.2 Step 2: Design a questionnaire, pilot study and questionnaire survey 20

1.7.2.3 Step 3: Semi structured interviews with professionals 23

1.7.2.4 Step 4: Document review and findings validation 25

1.8 Data collection 26

1.9 Research flowchart 28

1.10 Significance of the study 29

1.11 Structure of the thesis 31

Chapter 2. Towards contracting strategy usage for rework in construction projects: A comprehensive review 36

2.1 Prologue 36

2.2 Abstract 37

2.3 Introduction 37

2.4 Overview of rework in construction 40

2.5 Methodology 41

2.5.1 Searching strategy 44

2.5.2 Document refinement 44

2.5.3 Visual examination 45

2.5.4 Study selection and data extraction 46

2.6 Results of the content analysis 47

2.6.1 Sources of rework 49

2.6.2 Factors affecting rework ... 51

2.6.3 Rework impacts ... 52

2.6.4 Theories and techniques ... 57

2.6.5 Models and solutions ... 57

2.6.6 Management and strategies ... 60

2.7 Discussion and research gaps ... 61

2.8 Conclusion ... 68

2.9 Epilogue ... 71

Chapter 3. Rework management in life cycle of project: An outline for construction contracts ... 73

3.1 Prologue ... 73

3.2 Abstract ... 74

3.3 Introduction ... 74

3.4 Literature review ... 76

3.4.1 Section 1: Rework ... 76

3.4.1.1 Classification of rework ... 77

3.4.1.2 Causes of rework ... 78

3.4.1.3 Rework cost impacts history ... 80

3.4.1.4 Rework reduction strategies ... 80

3.4.2 Section 2: Contracts ... 81

3.4.2.1 Trend of changes in using different types of contract ... 81

3.4.2.2 Common contract models in construction 83

3.4.2.3 Standard contracts 85

3.5 Methodology 86

3.5.1 Design a classification model 87

3.5.1.1 Level 1: contract parties 87

3.5.1.2 Level 2: Project Phases 88

3.5.1.3 Level 3: Root causes 88

3.6 Findings 89

3.7 Discussion 89

3.8 Conclusion 90

3.9 Epilogue 92

Part two – Classification of rework in contracts

Chapter 4. Classification of rework root causes in the design stage of projects for contract assessment 95

4.1 Prologue 95

4.2 Abstract 96

4.3 Introduction 97

4.4 Literature Review 98

4.4.1 Design Process 98

4.4.2 Rework in Design Stage of Projects 99

4.4.3 Design changes ... 100

4.4.4 Design errors ... 101

4.4.5 Design and Construction Interface ... 102

4.4.6 Design Management Strategies on Rework ... 103

4.4.7 Collaboration of design and construction ... 104

4.4.8 Overlapping design and construction activities ... 105

4.4.9 Design and Technology ... 107

4.5 Methodology ... 108

4.5.1 Comprehensive Review ... 108

4.5.2 Refinement from literature ... 108

4.5.3 Categorizing of Rework ... 110

4.5.4 Classification of root causes ... 110

4.6 Findings ... 110

4.7 Conclusion ... 111

4.8 Epilogue ... 115

Chapter 5. Contract documents appraisal and rework root causes classification in tendering stage of project ... 118

5.1 Prologue ... 118

5.2 Abstract ... 119

5.3 Introduction ... 119

5.4 Literature Review ... 123

5.4.1 Contract definitions 123

5.4.2 Contracts type 124

5.4.3 Main standard contracts in New Zealand 124

5.4.4 Rework definitions 125

5.4.5 The nature of rework 126

5.4.6 Sources of rework 127

5.4.7 Impacts of rework on project performance 127

5.4.8 Rework classification systems 128

5.4.9 Rework reduction strategies 129

5.5 Research methodology 132

5.5.1 Selection of a model for rework classification 133

5.5.2 Propose a model for evaluation of contract documents 135

5.6 Findings 136

5.7 Discussion 137

5.8 Conclusion 138

5.9 Epilogue 139

Chapter 6. Contracts evaluation through classified rework root causes in the construction stage of projects 142

6.1 Prologue 142

6.2 Abstract 143

6.3 Introduction 144

6.4 Background of the study 145

6.5 Methodology 145

6.6 Findings and discussion 149

6.7 Conclusion 150

6.8 Epilogue 151

Chapter 7. Rework classification model in the project life cycle with liable parties of the contract 154

7.1 Prologue 154

7.2 Abstract 155

7.3 Introduction 155

7.4 Comprehensive list of rework root causes 157

7.5 Methodology 159

7.5.1 Comprehensive literature review 161

7.5.2 Data collection and analysis 162

7.5.3 Classifying the results 163

7.6. Results 164

7.6.1 Rework classification methods in the reviewed papers 164

7.6.2 Classification model 166

7.6.2.1 Level 1: Project Stages 167

7.6.2.2 Level 2: Contract Liable parties 168

7.6.2.3 Level 3: Root causes 168

7.6.3 Rework causes classification and ranking in the project stages 170

7.6.3.1 Design Stage.. 173

7.6.3.2 Procurement Stage.. 175

7.6.3.3 Construction Stage 176

7.7 Discussion.. 179

7.8 Conclusion 185

7.9 Epilogue... 187

Part three – Relational aspects of rework in contracts

Chapter 8. The common causes of rework in construction contracts: A diagnostic approach... 190

8.1 Prologue... 190

8.2 Abstract.. 191

8.3 Introduction 192

8.4 Rework conceptualization 194

8.5 Methodology.. 195

8.5.1 Stage 1: Systematic literature review.. 195

8.5.1.1 Step a: Developing a review protocol, ... 197

8.5.1.2 Step b: Conducting the review 197

8.5.1.3 Step c: Visual examination.. 198

8.5.1.4 Step d: Analysis and categorizations... 199

8.5.2 Stage 2: Questionnaire survey 200

8.6 Results 201

8.6.1 Category 1- Rework papers on biannual bases 201

8.6.2 Category 2- Contributions of countries to rework research 202

8.6.3 Category 3- Employed methodologies 205

8.6.4 Category 4- List of Journals 206

8.6.5 Category 5- Common causes of rework in construction contracts 208

8.6.5.1 Causes related to work process 209

8.6.5.2 Causes related human factors 210

8.6.5.3 Causes related to materials and equipment 211

8.6.5.4 Causes related to technical factors 211

8.6.5.5 Causes related to general/external factors 212

8.6.6 Survey respondent's characteristics 214

8.6.7 Rework causes in construction contracts 215

8.7 Discussion 216

8.8 Implications of the study 222

8.9 Conclusion 223

8.10 Epilogue 225

Chapter 9. Investigating the relationship between reworks and contractual claims: The salience of contract conditions 227

9.1 Prologue 227

9.2 Abstract 228
9.3 Introduction 229
9.4 Need to explore contract conditions in rework circumstances 231
9.5 Common sources of claim and rework in construction projects 232
9.6 Methodology 235
9.6.1 Literature Review and content analysis of the literature 237
9.6.2 Questionnaire design and Pilot study 237
9.6.3 Conducting survey 239
9.6.4 Data analysis and results 241
9.7 Results of the systematic literature review 242
9.8 Analysis and survey result 243
9.8.1 Internal reliability of the questionnaire 244
9.9 Discussion 249
9.9.1 The main source of claim under rework circumstances 249
9.9.2 Contract conditions in a claim incident from rework 251
9.10 Conclusion 254
9.11 Epilogue 259
Chapter 10. Analyzing underlying factors of contractual claims raised from rework in construction contracts 261
10.1 Prologue 261
10.2 Abstract 262

10.3 Introduction 263

10.4 Literature review 265

10.5 Methodology 269

10.6 Analysis and results 270

10.6.1 Exploratory factor analysis 272

10.7 Discussion 276

10.7.1 Human resources factor 276

10.7.2 Material and equipment factor 277

10.7.3 Management and planning factor 278

10.7.4 Process factor 280

10.8 Conclusion 282

10.9 Epilogue 284

Part four – Solutions and Recommendations

Chapter 11. Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach 287

11.1 Prologue 287

11.2 Abstract 288

11.3 Introduction 288

11.4 Goal and Objectives 291

11.5 Background 291

11.6 Causes of rework in construction contracts 294

11.7 NZS3910: 2013 297

11.8 Method 298

11.9 Result and analysis 300

11.9.1 Step 1: Theoretical conceptualization 300

11.9.2 Step 2: Conducting Survey 300

11.9.3 Step 3: Review of the contract NZS3910 provisions 304

11.9.4 Step 4: Professional interviews 309

11.10 Discussion and research implications 314

11.11 Conclusion 316

11.12 Epilogue 317

Chapter 12. Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations 320

12.1 Prologue 320

12.2 Abstract 321

12.3 Introduction 322

12.4 Literature Review 324

12.5 Contract management and the need for studying contract conditions 325

12.6 Conceptual framework 327

12.7 Methodology 329

12.8 Data analysis and results 332

12.8.1 Theme 1 - Addressing rework in the contract clauses 334

12.8.2 Theme 2- Processing rework in the contract clauses 336

12.8.2.1 Rework risk allocation in NZS3910 336

12.8.2.2 Human resources attributes in NZS3910 339

12.8.2.3 Design issues in NZS3910 340

12.8.2.4 The role of Engineer in NZS3910 340

12.8.3 Theme 3- Mapping rework in the contract clauses 342

12.9 Further discussion on NZS3910 344

12.10 Guidelines for processing rework in contract 348

12.11 Implication of the study 350

12.12 Conclusion 353

12.13 Epilogue 354

Chapter 13. Conclusion and research recommendations 356

13.1 Prologue 356

13.2 Research Overview 356

13.3 Research Objectives achievement 360

13.4 Contribution of research 363

13.5 Research limitations and recommendations for future research studies 364

13.5.1 Limitations to the research 364

13.5.2 The chapters limitations 366

13.6 Epilogue 368

References 370

Appendix A: Ethic approval 401

Appendix B: Questionnaire survey 403

Appendix C: Interview questionnaire 407

Appendix D: Statement of contribution to publications 411

List of Tables

Table 1.1: Methods and strategies on rework reduction and prevention 10

Table 1.2: Methodology used in each chapter of the Thesis.. 27

Table 2.1: Summary of papers number reduction process.. 47

Table 2.2: Major area of studies in rework related papers... 49

Table 2.3: Summary of reported rework cost from literature 55

Table 2.4: List of employed techniques in rework management papers between 1990 and 2020 56

Table 2.5: List of rework management models over the period of 1990-2020............................ 58

Table 3.1: An overview of total rework cost from literature 80

Table 3.2: Methods and strategies on rework reduction and mitigation...................................... 82

Table 3.3: Overview of journals and selected papers 86

Table 3.4: Numbers of classified rework root causes in client and contractor side of contract ... 90

Table 3.5: An Overview of distribution of rework root causes in life cycle of project 91

Table 4.1: Classification of rework root causes in design stage of project................................ 113

Table 5.1: Overview of identified rework root causes distributed within the project life cycle. 136

Table 5.2: List of identified rework root causes from the literatures with referencing to relevant esources.. 137

Table 6.1: List of selected articles following the strategy and criteria of methodology section 147

Table 6.2: Classified rework root causes in the construction stage of project............................ 148

Table 7.1: An overview on the classification methods used in the reviewed papers in study.... 172

Table 7.2: Rework causes classification in design stage - liable to the client-side of the contract 173

Table 7.3: Rework causes classification in design stage - liable to the contractor-side of the contract 174

Table 7.4: Rework causes classification in procurement stage - liable to the client-side of the contract 175

Table 7.5: Rework causes classification in procurement stage - liable to the contractor-side of the contract 176

Table 7.6: Rework causes classification in construction stage - liable to the client-side of the contract 177

Table 7.7: Rework causes classification in construction stage - liable to the contractor-side of the contract 178

Table 7.8: Comprehensive list of rework causes in project life cycle with liable contract parties 184

Table 8.1: Definitions of rework identified in the literature 195

Table 8.2: Codebook list for data extraction and descriptive analysis 199

Table 8.3: List of categories for statistical report 200

Table 8.4: Rework related papers published between 1990 and 2021 202

Table 8.5: Multi-authored Papers Matrix for scoring 203

Table 8.6: Research origin of rework related papers published in construction 204

Table 8.7: Overview of research methodologies on data collection 205

Table 8.8: Overview of the journals and the number of published rework related papers 207

Table 8.9: Participants profile 214

Table 8.10: Ranking of rework causes that affect construction contracts 215

Table 8.11: Included studies in the review and identified rework causes under each group of rework 221

Table 9.1: Demographic characteristic of respondents 243
Table 9.2: Result of T-test for the causes of rework 244
Table 9.3: Relative Importance index of rework causes for objectives of the study: NZS3910 246
Table 9.4: Relative Importance index of rework group factors 247
Table 9.5: Ranking criterion for dividing Relative Importance Index into five levels 248
Table 9.6: Priority list of rework causes for further investigation in the general conditions of the contract NZS3910 252
Table 9.7: Root causes of rework identified from the literature 257
Table 10.1: The common causes of rework in construction contracts 268
Table 10.2: Respondents and background information of their organisation/project 271
Table 10.3: Result of Kruskal-Wallis test for the causes of rework 273
Table 10.4: Component labels, factor loadings, criteria and communality in final rotation of EFA 275
Table 11.1: The common causes of rework in construction project 297
Table 11.2: Respondents and background information 302
Table 11.3: Ranking of rework causes addressed in NZS3910: 2013 304
Table 11.4: Interviewees profile 310
Table 11.5: Summary report of interviewees opinions 313
Table 12.1: Background of the participants 333
Table 12.2: Relevant rework provisions in the identified clause of NZS3910:2013 338
Table 12.3: List of recommendations to improve contract conditions by addressing rework 346
Table 12.4: List of general suggestions to improve contract process 347
Table 12.5: The checklist of items to be controlled for addressing rework in NZS3910 350
Table 12. 6: Guideline for mapping rework in relevant contract provisions of NZS3910:2013 352

List of Figures

Figure 1.1: Research conceptual framework.. 17

Figure 1.2: Research flowchart 29

Figure 2.1: Four steps research framework 43

Figure 2.2: Identified gaps and their relations to construction contracts, a diagram for future studies 70

Figure 5.1: Model of applied rework classification 134

Figure 5.2: Flowchart of rework root causes and evaluation of contract documents 135

Figure 7.1: The process of research methodology 162

Figure 7.2: Conceptual structure for rework root causes classification.................................... 164

Figure 7.3: Classification model for rework root causes in life cycle of project with liable parties of the contract 170

Figure 7.4: Distribution of rework factors in three stages of project 181

Figure 8.1: Flowchart of adopted methodology "Research framework", Search date: 27.06.2021 196

Figure 8.2: Number of published papers biannually within the selected period 203

Figure 8.3: Rework causes related to work process.. 209

Figure 8.4: Rework causes related to human factors 210

Figure 8.5: Rework causes related to materials and equipment 211

Figure 8.6: Rework causes related to technical factors 212

Figure 8.7: Rework causes related to general/external factors 213

Figure 8.8: Distribution of five rework groups over time 217

Figure 9.1: The diagram of applied methodology 236

Figure 9.2: Distribution of respondents and organizations 241

Figure 9.3: Matrix of relative importance index of rework causes 248

Figure 10.1: Diagram of the relationships between contractual claims and underlying factors of rework causes 281

Figure 11.1: Research methodology 299

Figure 12.1: Conceptual framework for validation of the study 327

Figure 12.2: Research methodology adopted for this study 331

Figure 12.3: Rework process map in General Contract Conditions NZS3910 349

Figure 13.1: Research objectives, methodologies and outcomes 361

List of Abbreviations

ACENZ: Association of Consulting and Engineering in New Zealand

ADR: Alternative Dispute Resolution

AHP: Analytic Hierarchy Process

AIC: Automation in Construction

AMINZ: Arbitrators and Mediators Institute of New Zealand

APCC: Australian Procurement and Construction Council

AR: Action Research

ASCE: American Society of Civil Engineers

AUBE: Australasian Universities Building Educators Association

BIM: Building Information Modelling

BOOT: Build, Operate, Own and Transfer:

BRI: Building Research & Information

CCNZ: Civil Contractors New Zealand

CBNZ: Certified Builders New Zealand

CE: Cause and Effect

CII: Construction Industry Institute

CJCE: Canadian Journal of Civil and Engineering

CM: Construction Management

CME: Construction Management and Economics

CRLMF: Conceptual Rework Management Learning Framework

DECOREM: Design construction reduction model

DLP: Defect Liability Period

ECAM: Engineering, Construction and Architectural Management

EFA: exploratory factor analysis

EPC: Engineering, Procurement, Construction

FA: Framework Agreement

FIDIC: Fédération Internationale Des Ingénieurs-Conseils

GMP: Guaranteed maximum price

GDP: Gross Domestic Product

IJPM: International Journal of Project Management

JCEM: Journal of Construction Engineering and Management

JCT: Joint Contract Tribunal

JME: Journal of Management in Engineering

KMO: Kaiser-Meyer-Olkin

NCR: Non-Conformance Report

NEC: New Engineering Contract

NZCIC: New Zealand Construction Industry Council

NZIOB: New Zealand Institute of Building

NZD: New Zealand dollar

OECD: Organization for Economic Co-operation and Development

PM: Project Management

PMBOK: Project Management Body of Knowledge

PMI: Project Management Institute

PMJ: Project Management Journal

RA: Regression Analysis

RII: Relative Importance Index

RPB: Relationship-based Procurement

RRP: Rework Reduction Program

RRC: Rework Root Causes

SCL: Society of Construction Law

SDM: System Dynamic Modelling

SEM: Structural equation modelling

TQM: Total Quality Management

NBC-G: National Building Contract, General

NBC-MW: National Building Contract, Minor Work

NZIA: New Zealand Institute of Architects

NZD: New Zealand Dollars

NZIOB: New Zealand Institute of Building

NZIQS: New Zealand Institute of Quantity Surveyors

NZBERS: New Zealand Built Environment Research Symposium

QS: Quantity Surveyor(s)

UK: United Kingdom

USA: United State of America

WoS: Web of Science

Part 1

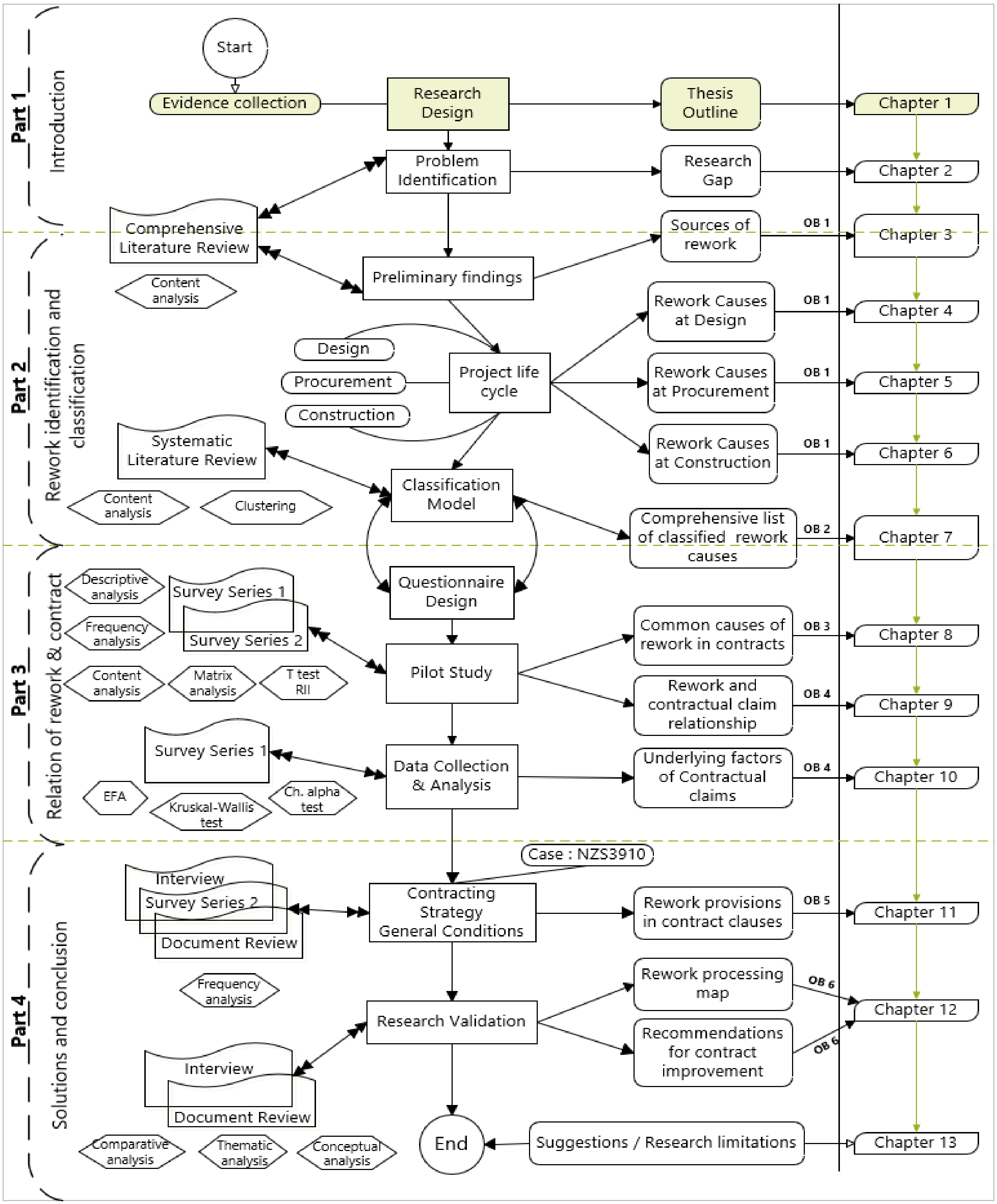
Introduction, Problem and Definitions

Chapter 1. Introduction and Research Methodology

Chapter 2. Towards contracting strategy usage for rework in construction projects: A comprehensive review

Chapter 3. Rework management in life cycle of project: An outline for construction contracts

Thesis-at-a-Glance / Chapter 1



Chapter 1. Introduction and Research Methodology

This chapter introduces the research, provides a background of the study, and outlines the research questions, aims, and objectives. It also explains the adopted research method followed by chapters arrangement in the whole thesis. Then it is followed by a literature review to cover the background, which provides the basis for the next research steps focusing on New Zealand construction contracts

1.1 Introduction

Conventional delivery methods almost lead to disputes and debate in the relationship. Contractor and client relationships need to be coordinated precisely when projects are more complicated to avoid contractual disputes (Pesamaa et al., 2009). Therefore, novel contracting strategies have emerged to solve problems, remove ambiguity, improve collaboration between participants, and define common goals for various contracting parties (Construction Industry Review Committee, 2001). A contractual agreement for construction projects acts as a permit to start the practical work after completing the procurement processes. The contract that is a confirmed document between parties is crucial as it determines the overall construction framework, including responsibilities structure for each party, stakeholder' authorities, covering risks, and any other relevant issues during the construction project execution.

Project performance can be altered with some triggers. Procurement and contracting strategy are key elements that play a vital role in the success of construction projects. The cooperation structure amongst project participants is founded on contract documents as the final output of procurement. Various legal contract frameworks have reported the potential change in contract conditions and the necessity of revising the form of contracts (Chan and Chan, 2017). The contractual relationship development between construction practitioners will result in an acceptable construction performance improvement. Furthermore, the collaboration of construction participants will be improved when ambiguity has been removed in contract conditions.

Time and cost overruns have been experienced in many construction projects where rework is the critical factor most responsible for those problems (Forcada et al., 2017). When time overruns cause delay and cost overruns to change the budget, project performance is experiencing fluctuation. It has been confirmed that rework is a predominant and persistent problem in construction projects. Nonetheless, the construction industry has not been investigated well enough as research results still are inadequate in this area. Since the construction firm's reputation is indirectly affected by the consequences of rework, the industry does not announce rework willingly (Love et al., 2016a). The Institute of Construction Industry has proclaimed that the average rework cost is five percent of the total construction cost. In addition, previous research studies have reported a strong correlation between time and cost overruns and rework. Thus, rework in the construction industry can be considered a practical issue that influences project performance.

The research on construction rework has become a core theme and contributed to the body of knowledge in construction management. Studies conducted in this field have focused mainly on factors affecting rework, causes, and impacts, mitigation models, and rework management following the reduction or prevention strategies. In addition, the slight trend of changes from traditional procurement systems to new contractual models has been considered recently and reflected in academic research and industry practices. As a result, two aspects of the literature review that need to be carried out in this research are reworking as a drawback in processes and construction contracts originating from the procurement stage. The first part will include rework theories, guidelines for reducing its impacts, and a new management method for rework reduction. The second part would consider a general literature review on the condition of contracts, contractual documents, standard contracts, and its contractual models specifically focused on NZS3910, which is used as a standard contract type in New Zealand.

1.2 Background of the study

Rework is identified as a major problem with constant contributions to time and cost overrun, productivity reduction, weak performance, and increasing the likelihood of incidences related to safety issues in construction sites (Love et al., 2016a). Investigated rework causes by other researchers have been mostly considered from two perspectives. Some believe that rework is generally linked with quality issues, and some have focused on rework impacts on project performance, construction practices, and workforce assessment at the activity levels (Zhang et al., 2012). In both categories, the construction industry neglects rework issues as a nonvalue-adding activity that seriously affects project performance (Ahmed and Naik, 2016). The impacts of rework on performance will be managed when the causes of rework are identified and classified at the early stages of projects.

Several rework studies to identify and classify the main root causes of rework have been conducted. Even though rework significantly impacts the project performance, few concrete results have been reported comparatively (Hwang et al., 2009). In other words, little is known about the background and sources of rework, and it has remained an inherent problem (Ahmed and Naik, 2016). Despite the considerable amount of research that has been undertaken to date, there is little evidence can be found of rework reduction in projects (Hwang and Yang, 2014; Kakitahi et al., 2014; Taggart et al., 2014a), and future work is required to determine the underlying factors that contribute to rework. Therefore, there is a critical need for project managers to minimize rework through a model that can effectively address the primary sources of rework (Hwang et al., 2009). The appropriate strategy for reducing rework impacts cannot be effectively implemented with little familiarity with the rework background. Rework can remain a fundamental problem when there is not enough knowledge about the causes of rework (Ahmed and Naik, 2016). Thus, a complete understanding of the contributing factors in rework occurrence will be an essential part of rework management studies to propose an effective reduction strategy (Ye et al., 2015).

However, advanced technologies are the key factors influencing the construction industry; using a wide range of advanced technologies has not adequately improved construction performance. Evidence shows that new technologies improve but cannot effectively reduce the cost of design and construction. Therefore, advanced technology must be employed with a contemporary management concept (Aziz and Hafez, 2013). Contract management is a project concept that plays a significant role in project success. According to Love et al. (2005), a weak reputation in the construction industry lacks communication and coordination among all parties. Creating an adversarial relationship based on the contract is the other main reason for lagging behind the industry. One of the most influencing processes in which the precise roles of each party are defined is through contracts. The construction industry's performance can be improved through several project management approaches. Contract management, as one of those contemporary concepts, can generate the highest value as it covers the project's life cycle. Similarly, the construction industry has claimed the need to improve contract documents that could overcome the increasing rate of claims and disputes. It is believed that contracts directly impact project performance and success.

Rework research has contributed mainly to the body of knowledge by identifying rework causes, measuring rework impacts, and proposing rework reduction models. On the other hand, research on the different types of contracts in recent years has shown a trend toward shifting from traditional procurement systems to contractual models. Industry practices show the same tendency to use a standard type of contract. This thesis mainly focused on identifying root causes at early stages and then the classification of causes as a platform for further investigation of the construction contracts to improve the conditions that address rework causes and prevent rework occurrence and contractual claims simultaneously. Thus, the literature review in this report will be on two aspects of rework and contracts.

1.3 Problem statement

Over the past 40 years, the productivity and performance of the construction industry have been declining worldwide. In most countries, the construction environment is one of the largest industries; however, this sector debatably has the lowest integration among all other major industrial sectors (Isnani et al., 2015). Such disintegration may result from applying the traditional project management approach (Isnaini et al., 2015). Reports from the industry show the scenario for New Zealand is the same as its GPD lags behind the OECD average by around 15 percent (Walkman and Conway, 2017). This needs more consideration as the official statistics show a strong outlook for spending over NZD300 billion on construction projects (Rotimi et al., 2019). Construction project management and technology are the main key factors in construction industry development. Although some new advanced technologies have been applied recently to improve construction projects' performance and productivity, the industry's efficiency remained low (Aziz and Hafez, 2013). In other words, implementing an appropriate new technology is not enough, and it should accompany a contemporary management concept.

On the other side, while it is increasingly argued that the traditional project management approach is no longer effective (Sohi et al., 2016), most current projects use methodologies that underestimate the influence of the dynamic environment. Rework is one of the dynamic factors influencing the construction performance, and since applied new technologies could not practically decrease some of the errors that mainly are the root causes of rework, it is time to apply the new management concept to manage this drawback in construction projects. Contract management as one of the project management concepts can play a vital role in performance improvement, covering the project's life cycle. While the New Zealand industry is committed to performance management, some aspects, such as contracts and markets, are less prominent than others (Halligan, 2019), and it is time to focus on contract parts.

Davies et al., (2009) argue that it is time to shift the existing paradigm from traditional concepts to modern project management when dealing with challenges in future project management and to cover new requirements of modern practice. For this purpose, the construction sector in New Zealand has aimed to elevate the performance rate up to 20 percent (Seadon and Tookey, 2019); however, current progress is showing far behind the target, and most probably, it will be postponed, which means more effort is required. The problem statement is the lake of using new project management concepts in the construction industry to achieve higher project performance. One way to improve this situation can be by using a standard contract document.

Recent industrial reports also show that it is about time to update the standard contract used in New Zealand (O'Brien and Degerholm, 2019). Against this condition, current research is undertaken as both rework, and contract elements can elevate projects' performance. This research combines the literature on construction rework and construction contracts to find relationships in between and propose a practical framework that provides the basis for revising contract documents. Standard New Zealand is recently looking for the industry's opinion on the necessity of revising contract conditions of the most common standard form of contract known as NZS3910

(Standard NZ, 2021). In this order and apart from the in-depth literature review, data from other sources, including industry reports, government documents, industrial surveys, and professional interviews, are used to trustworthy the expected results.

1.4 Research gap

Construction projects involve multiple parties, and rework happens in such a complex environment, where many activities by many parties take place. Previous research results have shown that adopting and implementing best practices such as pre-project planning, project change management, design effectiveness, alignment, and constructability would effectively reduce rework root causes and positively affect project cost and schedule performance. Some actions can be taken to reduce rework, such as change control, value management, use of information technology, design scope freezing, supervisors training, quality control plan, and project inspection (Wasfy, 2010). While to prevent rework, other various approaches are being used, which include visualization, building information modeling (BIM), modularization, lean construction, constructability reviews between design and construction teams, and relationship-based procurement (RBP) (Love et al., 2016a). Although much literature exists concerning rework reduction, there is a need for further analysis, validation, and improvement of rework reduction methods (Zhang et al., 2012). Different methods have been used in rework management, as has been shown in Table 1.1.

Several studies have been performed on rework in the construction industry in which pure construction projects and design processes had been the core of studies. Even though studies of different construction and design processes have successfully contributed to reworking management, they have failed to provide strategic directions on rework management while almost leaving out the stage of procurement, which is a critical stage in the project life cycle. Previous rework studies have focused more on the general issues of rework impacts, reduction models, and allocating resources to solve the problem partially and separately in the design or construction stages. No approach has been proposed within the life cycle of a project to incorporate rework in construction contracts under the context of project management.

Table 1.1: Methods and strategies on rework reduction and prevention

Focus "Supporting Tool"	Reference	Year
The effect of BIM	Hwang et al.,	2019
Rework prediction model using regression	Forcada et al.,	2017
Motivations and leadership	Love et al.,	2016a
Supervision	Shinde and Kulkarni,	2016
Rework probability model	Simpeh et al.,	2015
System dynamics methodology	Li and Taylor,	2014b
Role of supply chain	Taggart et al.,	2014a
Overlapping strategy matrix of design and construction	Hossain and Chua,	2014
The probability of rework occurrence (risk control)	Love and Sing,	2013
Rework reduction program (RRP)	Zhang et al.,	2012
Stepwise multiple regression	Love et al.,	2010b
Rework cycle	Rahmandad and Hu,	2010
Pre-project and quality management plans	Hwang et al.,	2009
Characterizing the sensitivity of downstream construction activities	Blacud et al.,	2009
Using AAN method, artificial neural networks	Palaneeswaran et al.,	2008

In addition, the mainstream research about contracts in construction projects is mainly under the project management context within a regular time set, without considering barriers such as rework. This shows an existing gap in the literature: not enough is known about rework in contractual terms of construction projects. New Zealand construction industry reports verify that most contract disputes arise from a lack of understanding of contract terms, emphasizing the necessity of updating the standard form of contract (Crook et al., 2018). Accordingly, the Society of Construction Law (SCL) in New Zealand has initiated a debate on revising NZS3910 to make it fit for the construction industry (Crook et al., 2019). Furthermore, the empirical research literature can find limited evidence initially focused on the rework causes and its effects in contract documents. It would be considered a research gap, specifically when rework is considered an acceptable or regular feature in construction projects. Similarly, research in New Zealand has not attempted to develop a framework that could assist the construction industry to heave reliable contract conditions under rework events. As such, the thesis intends to understand the rework management process at the contract level.

With this background, it can be mentioned; however, different methods have been used to control rework, yet investigating the contract process and its documents to manage rework have not been fully explored, and this study will open this new angle to providing the initial basis for future studies by following an adopted method. Searching for rework root causes can be used to study the possible ways of interaction between rework and contract in construction projects. Therefore, looking for rework management through contractual terms and conditions is the novelty of this research.

On the other hand, the impact of rework in construction projects resulting in contractual claims has not been investigated in New Zealand. There are currently no studies examining the contract conditions of NZS3910 in New Zealand, even though this standard form is used in most construction projects. Therefore, this thesis focuses on investigating rework causes and improving contract conditions in the construction sector by searching for these broad questions: How can the impacts of rework on generating contractual claims be assessed and managed to reduce consequences such as conflicts and disputes? What are the causes of rework in New Zealand construction contracts, and how could contract conditions be improved in addressing rework to avoid contractual issues?

1.5 Research aim and objectives

This study aims to manage construction projects' rework through appropriate provisions within the contract conditions. The study investigation will focus on developing the required changes and revisions to the contract conditions of the standard form of NZS3910. Addressing rework in the contract clauses reduces the contractual impacts of rework, such as contractual claims and disputes. Reducing contractual claims and disputes consequently improves the performance of construction contracts. As such, revising contract provisions will assist the construction practitioners in having reliable contract conditions to manage construction projects under rework events. Specific objectives of the study are:

1. To identify the direct and indirect sources of construction rework (rework root causes) from a critical literature review and converge all identified causes in one list.
2. To design a model for classification of the identified rework root causes across the project's life cycle achieved from objective one, with respect to the liable parties of the contract.
3. To investigate the common causes of rework in New Zealand construction contracts.
4. To establish the relationship between rework causes and contractual claims. This can be used to develop the underlying causes of rework in generating contractual claims.
5. To find the relationship between rework causes and clauses of the construction contracts; and thereby identify rework provisions used in the contract conditions.
6. To set out a platform consisting of solutions and recommendations on the existing contract documents that would need to be revised for addressing rework.

The preliminary investigations and the comprehensive literature review are utilized to identify rework causes. This approach results in a list of identified rework root causes in the project's life cycle, including design, procurement, and construction stages. The designed classification model is the literature review's primary outcome and is used to prepare the comprehensive list of rework causes. The comprehensive list of rework causes covers three stages of the project with two liable parties of the contract, including the client and contractor. This list is appropriately matching with the research needs. Objectives three to six are conventionally achieved based on the comprehensive list of rework causes. The comprehensive list from objective two is examined in New Zealand construction projects to find the most significant causes of rework that affect contracts. This narrows to identifying rework causes that apply to the New Zealand construction contracts. If the common causes of rework are also identified as the sources of contractual claims, then the relational aspects of rework and contract can be explored. Contractual claims and disputes are generally referenced to the clauses of the contract. The identification of contract clauses addressing rework is facilitated by establishing the relationship between rework and contractual claims. Objective five can be achieved through reviewing the contract clauses that address the common causes of rework and contractual claims. This leads to identifying gaps in rework provisions, and the review results can be used to improve construction contracts. The identified gaps in contract provisions in addressing rework can be filled when contract clauses are revised for this purpose. This improves the contract conditions and can support decisions during contract preparation. The achievement of the last objective validates that the contract conditions need improvement for addressing rework.

Before identifying the root causes of rework affecting the construction contracts in New Zealand, it is essential to have an overview of the experience and knowledge of rework management. This can be achieved through a systematic literature review on rework subjects in construction management. The identified causes of rework are then classified based on the research's concepts, and the results are used for designing a questionnaire. The questionnaire is verified through consulting professionals in academia and industry. The classified causes of rework are then examined in the New Zealand construction projects. This will be achieved by conducting a survey and pilot study asking for the industry's opinion. Once the common causes of rework in New Zealand construction contracts are investigated, the relationship between rework causes and contractual claims will be explored to identify underlying factors of contractual claims raised from rework. The result of this part also will be achieved through conducting a survey. The most significant causes of rework in generating contractual claims are assessed based on the contract conditions of the standard form of contract in New Zealand. A combination of survey and professional interviews is used to support the results of this stage. The relational aspect of rework to the contract clauses will be developed based on the findings of the previous stage. After establishing the links between rework and contract clauses, a platform to improve the conditions of the contract by addressing rework will be proposed as the final solution that contributes to the construction contracts by a series of recommendations that can be implemented for revising the contract terms and conditions.

1.6 Research questions

Research questions are developed to address the research "gap" and further define and resolve the research problem, with careful attention to ensure that they meet the empirical norms and are clear, specific, answerable, and substantially relevant. Based on the above objectives and the research aim, the study was able to answer the following main questions:

1) What are the root causes of rework in the project's life cycle, including design, procurement, and construction stages?
2) How can identified rework root causes be classified for further assessment based on the research needs?

3) What are the connection points between the terms of the contract and classified rework root causes?
4) What possible changes in construction contracts can be suggested to manage rework by addressing the causes of rework that consequently result in the prevention of contractual claims and disputes?

To cover the theory, practice, and analysis of the contractual side of these questions, the case of NZS3910:2013, the most commonly used contract in the New Zealand construction industry, needs to be assessed, seeking any required changes and revisions to improve the contract conditions.

1.7 Research methodology

1.7.1 Overview

This thesis is provided paper-based and has no specific chapter to describe the method used for the research. The objectives of this study have been arranged in a chronological sequence. To achieve each objective, a set of research methods is required to be used. Each chapter of this thesis has a detailed methodology section as part of the article. Hence, discussing the adopted research method to meet the study's objectives is an appropriate way to show how the research aim is achieved through the chronological process. As such, an overview of the research methodology is explained in this section. The selection of an appropriate research method influences the study's success (Yeung et al., 2007). Construction management research generally follows one or a combination of four methodologies: qualitative, quantitative, mixed-method, and review. The research method adopted in this study is outlined as follows. This study consists of four main parts that show an adopted mixed method to achieve research aims and objectives.

The four main parts of the study contribute to the development of thirteen chapters of this thesis. The conceptual framework in Figure 1.1 illustrates the concepts and links that this research needs to investigate. This framework presents an overall view of the research and depicts the achievement of six objectives of the study across four prementioned parts. In addition, the list of chapters for achieving each objective is presented in the research flowchart, as shown in Figure 1.2. The conceptual framework demonstrates a chain of activities required to link the causes of rework and contract clauses. The study's primary objective is to understand rework events in construction projects. Since the study focuses on the rework causes in construction contracts, the relevant concepts around this issue are also explored for relationship consolidation. This research aims to assess the construction contract under rework events to address causes that generate contractual claims. Thus, rework root causes are identified and classified with liable contract parties throughout the project life cycle. The study will then investigate the common causes of rework in construction contracts to link rework and contractual claims. The established link between rework and claims leads to the identification of relevant contract clauses that can be referenced in rework circumstances.

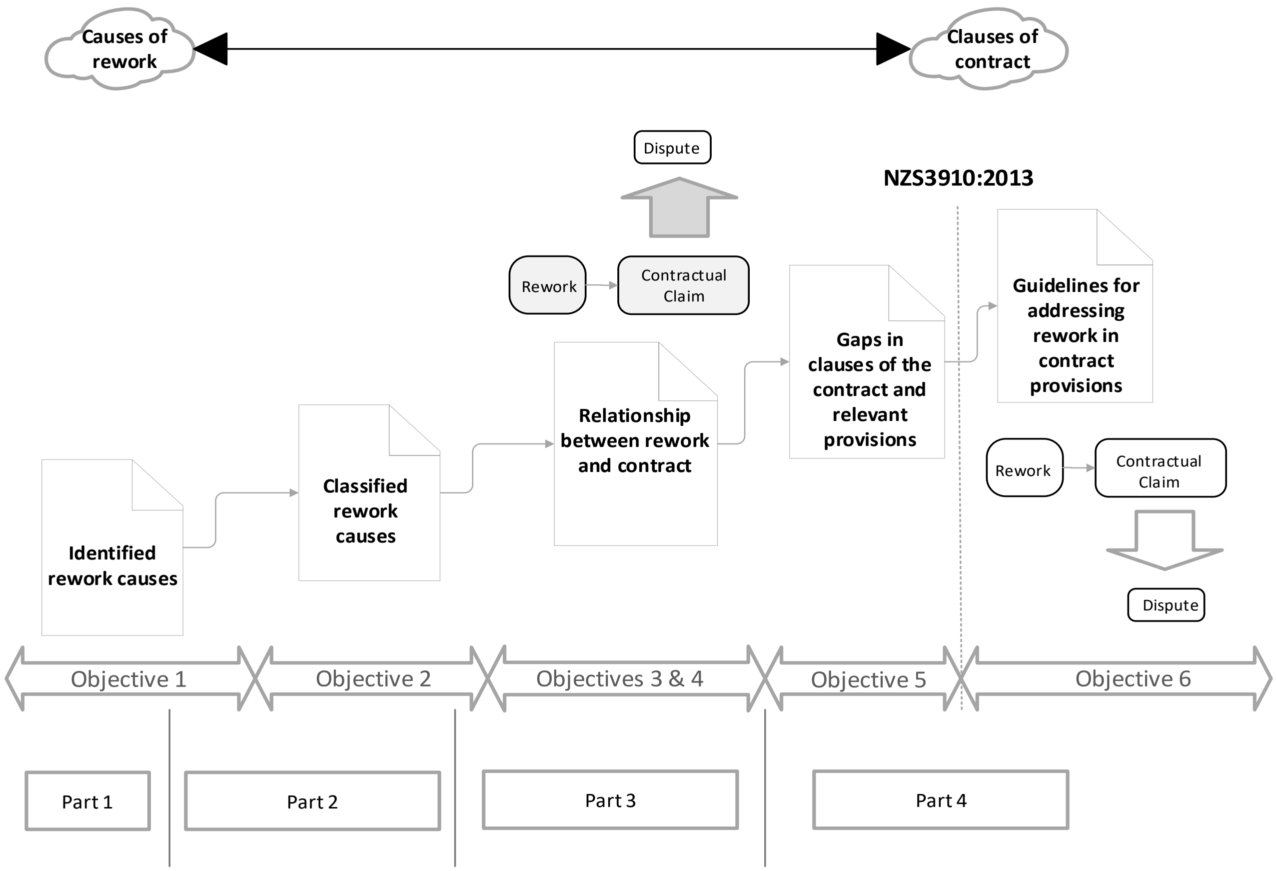


Figure 1.1: *Research conceptual framework*

A research design will be developed based on the research approach. The research approach determines which data collection and analysis techniques are appropriate for a specific study. A mixed quantitative and qualitative approach supported by a research philosophy will be appropriate for achieving objectives 1 to 4 (Fellows and Liu, 2015). Qualitative methods investigate the context or setting of participants based on interviews or observational data where personal values can be brought into the study (Creswell, 2016). The qualitative aspect will cover the overall picture of the subject, which mainly provides support for interpretation. Thus, the qualitative approach follows an interpretative orientation.

In contrast, the quantitative part of the research searches for causal relationships between variables through collecting factual data (Fellows and Liu, 2015). For objectives 5 and 6 triangulation approach is adopted as it involves the document review of a real case. Using triangulation eliminates the weaknesses of qualitative and quantitative approaches individually. Thus, this research benefits from using a quantitative approach to achieve the exploratory objectives and a qualitative approach for the explanatory part of the objectives. As such, mix method allows the researcher to capitalize on the strengths and avoid other weaknesses. According to (Balnaves and Caputi, 2001), the flexibility of mixed-method helps researchers when they want to find out rather than relying on a predetermined position. Research factors will be driven from previous studies as the secondary data and can be modified within the process.

This research follows the systematic method shown in Figure 1.2 to achieve the study objectives. The research framework shows the objectives of the study, chapters of the thesis, research method used, research process and results, and the corresponding parts of the study. However, each paper consists of an independent method to achieve its results. Overall, the method used in this study will consist of four steps (1) literature review, (2) questionnaire design, pilot study and conducting surveys, (3) semi-structured interviews with professionals in the construction contract field in conjunction with (4) the contract document review to find the answers to the research objectives and validate the results. Thus, the research techniques and methods for data collection are based on survey questionnaires, interviews, and document analysis (Johannesson and Perjons, 2014). The findings' analysis will suggest revisions to the contract documents in line with rework management that promotes project performance. The standard contract document of NZS3910 as a commonly used contract document in New Zealand is assessed among all identified rework root causes to find out which items are addressed by the clauses of contract conditions. The study is customized through the following steps for investigating relational aspects of rework in the contract conditions of NZS3910. The following sections briefly discuss the methodology used in the whole thesis.

1.7.2 Adopted method for the research

The objectives of this study are addressed by a mixed method of qualitative and quantitative approach. It also comprises a document analysis by examining NZS3910 that provides validation measures. The adopted method includes four steps: (1) literature review, (2) design questionnaire, pilot study, and questionnaire survey, (3) professional interviews, and (4) document review.

1.7.2.1 Step 1: literature review

The first part of the research aims to identify the causes of rework in various project stages to provide a comprehensive list of rework root causes. This is initially started via a comprehensive literature review. This part of the study allows for identifying research gaps surrounding rework with potential impacts on construction contracts, leading to rework with more focus on rework causes. More detail about this process is presented in chapters 2 and 3. Rework management is complex and dynamic in the design, procurement, and construction stages. Choosing an effective strategy to manage rework will be simplified by a better understanding where the main problems originated. One way to provide a comprehensive list of identified rework root causes is through searching the published articles as the knowledge gaps for further research are identified through literature review (Bao et al., 2018).

The research starts with a comprehensive literature review to understand the key concepts and theories on rework and the best-implemented practices of rework management. The literature review is performed only in construction engineering and management. The literature review shows the knowledge gap and provides the theoretical framework of the research. The initial result of this part is then investigated more by a systematic literature review to prepare a comprehensive list of rework causes. The systematic literature review is implemented as a scientific process to identify, assess, and analyze the published papers within a certain time to investigate new issues for management improvement. Thus, the literature review is then completed by conducting a systematic review on the causes of rework as the research focuses on rework causes.

Employing a precise method of searching through literature provides the summary of validated evidence. The result of a systematic literature review leads to identifying rework causes throughout the project's life cycle and proposing a classification model to classify the identified causes liable to the contract parties. Each project stage's identified rework root causes are classified based on the proposed classification model. The designed model has been adjusted by combining the concepts of previously used classification models in the literature review section and adopted based on current research needs on three levels. The first step of this methodology serves to partially meet objectives 1 and 2 using content analysis and descriptive statistics. The result then develops a conceptual theory based on the identified rework causes in construction projects to understand their relations to the contract sides and project stages. This leads to accomplishing the second objective of this research, and chapters 4 to 7 cover this section of the study.

1.7.2.2 Step 2: Design a questionnaire, pilot study and questionnaire survey

In the second part, a survey questionnaire is designed and developed to identify and rank the most significant causes of rework in contract conditions of NZS3910. The survey aims to collect the industry's comment on the effect of rework on contractual claims and the extent of addressing rework causes in the contract conditions using a questionnaire. The questionnaire is a document that brings a list of questions together based on the conceptual theory of the research and then is distributed to several organizations and individuals to respond. This technique is used for data collection, which the researcher will then analyze and interpret the collected data (Johannesson and Perjons, 2014). This part of the research validates the identified causes of construction rework by utilizing a survey questionnaire. The results and comments collected from the survey are analyzed as the primary data with a deductive approach. Findings are also used to modify the list of causes and finalize the interview questions.

The initial version of the questionnaire is developed based on the comprehensive literature review. The previously identified rework causes from the literature are used in the survey questions. A questionnaire survey is used in this research to extend the exploratory objectives and is distributed using email, while some records also are collected directly by the researcher during the interview step (Saunders et al., 2009). This method allows for an interactive discussion with reliable data in a short time (Fellows and Liu, 2015). The questionnaire is then modified through elite consultation with four experts from academia and industry to ensure the validity and reliability of the designed questions. Ranking of the survey result leads to capturing the most significant and common causes of rework in construction contracts. In doing so, the provided questionnaire is distributed to experts for further discussion in construction contract organizations through a pilot study. The pilot study helps quicker step onto the stage for performing professional interviews. As a result, classified causes of rework are tested in the context of New Zealand contracts leading to the achievement of the third objective of the study. The survey result validates the identified links between the selected contract document "NZS3910" and classified rework root cause for further processing.

A pilot study is appropriate at this stage as it helps to examine the method's practicality to be used for more extensive investigation in the next step. A pilot study improves questions, format, and scales (Creswell, 2016). A pilot study based on the survey's initial results is performed with a smaller group of participants. The survey comprises two series of questions, and the combination of both collected data in the pilot study confirms the relationship between rework and contractual claims with the same sources of rework causes. The first series of questions have been designed to assess the effects of rework causes in the contract. The second series of questions were designed to understand if rework has been addressed adequately in the contract conditions. The collected data from the pilot study are used for initial analysis to identify the most significant causes affecting contracts to generate claims. Further explanations on how common causes of rework in construction contracts are identified will be presented in chapter 8 of the thesis. The collected data is used through series two of the survey questions to identify the relationship between rework and contractual claims. The three clusters of high-ranked rework causes are identified at the end of chapter 9, which affect contractual claims and have not been addressed in the contract conditions NZS3910.

To achieve objective four, the survey continues to collect data to investigate the underlying factors of rework in generating contractual claims. Initially, the effect of causes associated with reworking contractual claims is evaluated. This has been carried out by performing exploratory factor analysis. The result of this evaluation consolidates the relationship between rework and claims. The investigated relationship between rework and contractual claims is further assessed to extract the underlying factors of contractual claims originating from rework. This will be discussed with more detailed information in chapter 9. The result is also used to measure the validity of the achieved results from earlier stages. Thus, the relationship between rework and the claim will be validated. The Relative Importance Index used in this stage enhanced the researchers' insight into the claim factors contributing to the contract. As such, the relevant provisions of the contractual claims can be referenced for rework causes. This reference facilitates the next part of the research for improving relevant contract clauses. Chapter 10 of the thesis presents more details of this process.

Overall, the results of this step meet objectives 3 and 4 by using the Relative Importance Index for ranking common cause, mean factor analysis, matrix analysis, and exploratory factor analysis, which lead to the identification of four underlying factors of contractual claims. A series of statistical techniques are utilized in this research, such as Cronbach's alpha for internal consistency, T-test for measuring consistency and reliability of data among various groups of participants, and Kruskal test to ensure data fits EFA (exploratory factor analysis).

1.7.2.3 Step 3: Semi structured interviews with professionals

An interview is considered a technique for data collection that allows the researcher to observe participants' viewpoints and behavior. The interview can be conducted with structured and semi-structured questions or performed in an unstructured way without the sequence of questions (Fellows and Liu, 2015; Johannesson and Perjons, 2014). Using a semi-structured interview is an appropriate method to meet the research purpose. This approach aims to help researchers understand the problem through purposefully selected participants (Creswell, 2016). Since the method used for this research is qualitative-based, it can be more flexible and responsive to changes. A semi-structured interview provides comments from both sides of the contract to have more resilience on questions. Questions in this step seek to establish a method to change and revise the contract conditions.

After the pilot study and the initial survey data analysis, the professional interview is performed using an adapted face-to-face or online meeting questionnaire. The semi-structured interviews are used for conducting a communication session between the researcher and a person who responds to the questions, and though researcher can control the agenda and observe and record the interviewee's opinion and experience (Johannesson and Perjons, 2014). Since the questionnaire was raised through previous steps, all questions were reliable and answerable. The interview first investigates the nature of rework in the construction industry and how it can be reduced. Then, addressing rework causes in the contract is investigated to explore relevant contract clauses and recommendations to improve the contract conditions. The mainstream of interview questions is to find out which contract clauses require changes to address the causes of rework. Semi-structured interviews are appropriate as they can provide a wide range of descriptive information by allowing the respondent through an open-ended conversation (Patterson and Spreng, 1997). Thus, the findings can be expanded by providing supplementary information at the end of the questionnaire on why rework occurs and how it can be prevented within contracting processes.

The selection of the interviewees is based on their expertise in the field of contracts in the construction industry. All the interviewees are professionals in construction contracts with over an average of 25 years of experience. The number of professional interviews was considered enough due to the data saturation point. The professional interview aims to evaluate contract clauses in addressing rework to collect evidence for validating the results and proposing the best solutions in addressing rework. The result of this step covers objectives 4, 5, and 6, partially using descriptive and thematic analysis. More details of the interview profile and results will be presented in chapters 11 and 12.

Finally, collected data are processed with a qualitative approach to propose a complementary platform to address relevant rework causes. Data analysis can be done by utilizing appropriate software such as Nvivo. Using Nvivo software and program helps sort and search information within the text. It locates all passages in an extensive database by coding data to search for similar ideas differently. Then comparing various codes is facilitated for further analysis. Discussion on predetermined codes in different categories results in the research findings. Finally, results are interpreted to find solutions and propose suggestions and/or recommendations. The outcome of this part of the research could be compared and validated based on the answers from participants. Possible relevant clauses of the contract in New Zealand construction projects are identified, and therefore the previous results of the survey to fulfill objective 4 of the study are validated. The collected data from series 2 of the survey questionnaire in conjunction with professional interviews are then compared with the conditions of the contract. It brings up relevant clauses of the contract that can be referenced as rework provisions. The outcomes of this comparison show whether or not the current conditions of the contract address rework. This allows for examining the relevant contract clauses, leading to objective 5.

1.7.2.4 Step 4: Document review and findings validation

Due to a large number of identified rework root causes from the literature review, this study uses interview and document analysis with the New Zealand construction sector. The contract conditions of NZS3910 are evaluated as part of the document analysis in this research, which provides valid evidence to support other study objectives. Objectives 5 and 6 are concerned with exploring clauses of the contract in NZS3910. Analyzing the conditions of this contract document is an appropriate technique to find the relevant provisions that may link to rework. This document analysis can complete the interview responses, and the literature review findings are then validated (Gibson and Brown, 2009). The concurrent analysis of contract documents and interview responses provide the basis to improve the contract conditions of NZS3910.

The earlier chapters' chronological outcomes are validated by achieving the results of chapter 11. Further analysis of the collected data from the interviews using the thematic technique aligns with the document review on the conditions of NZS3910 and proposes a flowchart to address rework causes across various clauses of the contract. This process also derives certain recommendations for better preparation of contract and administrating it when construction of the project is started.

The flowchart and all recommendations for improving contract conditions of NZS3910 are accordingly reflected in chapter 12. This chapter suggests a systematic approach for reviewing the contract conditions based on the project needs. Using the same method for the other standard contract forms is also advised.

The summary of the adopted methodology in this research based on each chapter to achieve the study's objectives is briefly shown in Table 1.2, including the analytical techniques used. The coherent flow of information between this thesis's chapters is established through each paper's deliverables. The steps of the work are kept in exemplary sequences. The outcome of each chapter feeds into the right after a chapter or the following ones. The coherency of information flow is also presented on each chapter's front page diagrammatically to ease following the flow.

1.8 Data collection

A different set of data for analysis is used in this study, depending on the stages of the research. In the literature review stage, a set of 157 articles, including conference papers and journals, were reviewed, which was then reduced to 35 articles to focus on reworking causes. After identifying and classifying the causes of rework, a pilot study was performed in two steps for initial analysis. Overall, 42 responses were received for analyzing series 1 of the survey; 34 responses for analyzing series 1 and 2 with a repose rate of 26.5%. Finally, a complete survey was conducted in the next research stage with 124 valid responses. For the last research stage, 12 professionals were incorporated to participate in the interview.

Table 1.2: Methodology used in each chapter of the Thesis

Chapter	Title	Aim/ Objective	Analysis/ Method	Deliverables
1	Introduction and research methodology	Justification and definition of the research process	Review and deductive reasoning	Research objectives/conceptual framework/Thesis outline
2	Contracting strategy usage	Understanding the nature of rework	Comprehensive review content analysis	Identify research area of rework/knowledge gaps
3	Rework management in life cycle of project	Outline for construction contracts	literature review clustering rework root causes	An overview of rework causes and sources of rework in three stages of a project
4	Contract assessment in the design stage of projects	Identify rework causes in design stage	literature review	List of 48 causes in design stage
5	Contract appraisal in tendering stage of projects	Identify rework causes in tendering stage	literature review	List of 15 causes in tendering stage
6	Contract evaluation in construction stage	Identify rework causes in construction stage	literature review	List of 47 causes in construction stage
7	Rework classification model in project life cycle with liable contract parties	To classify rework root causes	Systematic literature review content analysis clustering	Comprehensive list of rework root causes including 37 causes throughout project and contract sides
8	Common causes of rework in construction contracts	Investigation of the common causes of rework in New Zealand construction contracts	Pilot study questionnaire survey descriptive analysis frequency analysis	Statistical report of rework research trends/ identify 22 common rework causes in New Zealand contracts
9	Relationship between reworks and contractual claims	Establishment of the relationship between rework causes and contractual claims	Pilot study questionnaire Survey 1 & 2 content analysis t-test / RII matrix analysis	Ranking of rework causes and groups/ priority list for further investigation in the contract conditions
10	Analyzing underlying factors of contractual claims raised from rework in construction contracts	Verification of the relationship between rework causes and contractual claims	Questionnaire Survey Exploratory Factor Analysis Kruskal-Wallis test Cronbach's alpha test	Four underlying factors of rework in generating contractual claims
11	Evaluation of contract conditions in addressing rework causes	Development of the relational aspects of classified rework causes and contract conditions	Questionnaire survey contract document review professional interviews frequency analysis	Rework provisions in the contract to identify relevant clauses of the contract
12	Guidelines for mapping rework in contract conditions of construction projects	Set out a platform consisting of solutions and recommendations for addressing rework and the improvement of contract conditions	Questionnaire survey contract document review professional interviews Thematic analysis	A guideline flowchart, rework processing map and checklist for improving the conditions of contract
13	Conclusion and Recommendations	To conclude and show how objectives achieved	Review and deductive reasoning	Limitations of the research and recommendations for future studies

1.9 Research flowchart

The conceptual framework of research in this thesis is shown in Figure 1.2. The research objectives are achieved step by step of the route map indicated in this flowchart. The research background highlighted the importance of identifying rework in construction contracts. The literature review discusses the factors contributing to the root causes of the rework in three stages: design, procurement, and construction. The classification model is then designed to cover all identified rework causes. These two study steps follow a literature review and cover the first and second objectives of the research, as shown in parts 1 and 2 of the flowchart. Rework impacts on contracts are then investigated by establishing the relationship between rework causes and contractual claims. As such, the common causes of rework in construction contracts are prepared first, and then through the relationship between rework and claim, the underlying factors of contractual claims are extracted to meet objectives 3 and 4 of this research. This can be achieved by conducting a questionnaire survey, as shown in part 3 of the research. The questionnaire survey results assist the development of interview questions for chapters 11 and 12. Performing interviews with contracting professionals validates the research findings (Egbelakin et al., 2015). Thus, rework provisions are evaluated to address rework and develop a framework for improving contract conditions. The last part of the research meets objectives 5 and 6 via professional interviews and documentary analysis. Part 4 of the flowchart shows the last research process, which finally leads to proposing solutions and some recommendations in chapter 12 of the thesis.

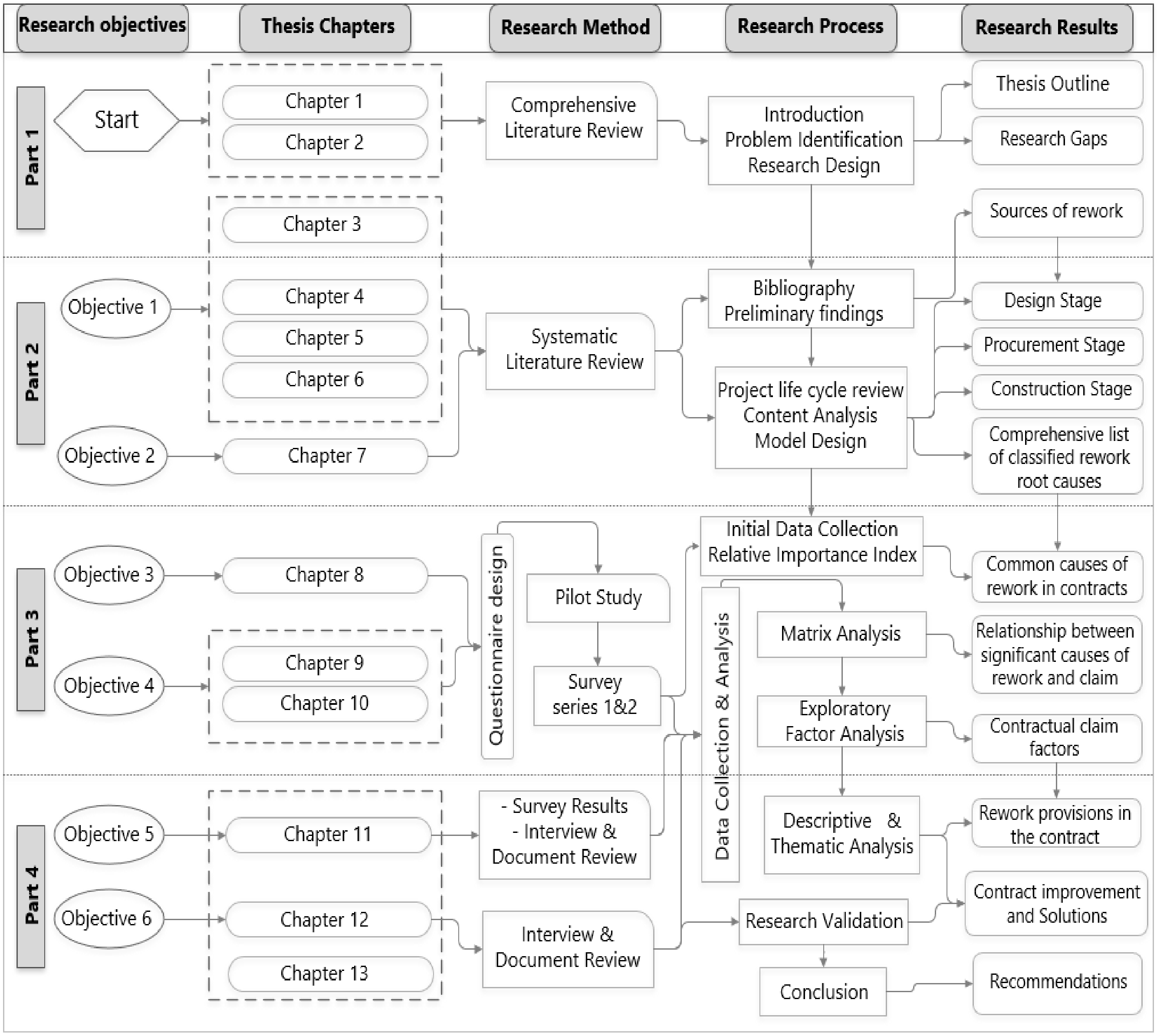


***Figure 1.2**: Research flowchart*

1.10 Significance of the study

The result of this research is expected to bridge the identified gaps in the knowledge between rework and construction contracts. Rework and strategies for reducing rework in projects have received extensive attention in recent years; nonetheless, rework is affecting the construction industry probably because projects are measured out of the project life cycle context (Xue et al., 2010). Life cycle philosophy is critical for construction as all activities in different stages are integrated. Therefore, a systematic literature review is required to improve performance by better understanding the state of rework and its root causes (Boa et al., 2018). This study will provide a platform to give more insights into rework from the project life cycle perspective for further studying the relationship between rework causes and contract clauses.

Recent studies on the performance of the construction projects in New Zealand have highlighted some of the industry's main problems in which factors such as unfair risk allocation, sub-optimal procurement approaches, and low-profit margins can be interlinked with contract documents (Rotimi et al., 2019). The research investigates international and local past experiences on construction rework, possible associated standard contracts for implementation, and relevant regulations and policies. These together will provide a significant contribution to the body of knowledge on construction contracts for rework management and some other practical solutions to use as follows:

The initial outcome of the research would focus on identifying and classifying the main causes of rework and their roots, which are embedded in contract documents. The first part of this study will result in a comprehensive list of the root causes of a rework within the project's life cycle. Classification of rework root causes at this level may allow projects to be managed more efficiently as it will be served as an authentic base for defining a new strategy on rework management is cooperating with the contract. Thus, it can cover the scholar gap in searching for integrated rework solutions that affect both contract sides. In addition, this can be used as a suggestion for the industry's current needs. Standard New Zealand has planned to publish a revised standard contract of NZS3910 in the next few years and is currently looking for suggestions to improve this document (O'Brien and Degerholm, 2019).

Since this study focuses on the dynamic relationship between contract conditions and the causes of rework, the expected outcomes of the research will be an outline of contracting processes that maintain the attitude toward rework management by critical analysis of rework root causes. The likelihood of rework occurrences can be managed more effectively when project participants are able to check the causes of rework at the time of contracting. The classified rework root cause in each stage of the project will provide this opportunity for checking contact documents to ensure that possible impacts of rework are covered thoroughly. Rework management through implementing this mechanism will result in more awareness of contract parties, and higher project performance may achieve when both sides of the contract recognize the benefit of this approach. Evaluation of involved contract clauses and their attachments through a questionnaire based on classified rework root causes can reveal the relational aspect of rework in the contracts. Revising and amending these relational aspects in contract management under this perspective will strengthen the construction project outputs such as performance and productivity. Therefore, the findings of this research contribute to the body of knowledge by providing a framework to improve the conditions of New Zealand's standard form of contract, NZS3910:2013.

1.11 Structure of the thesis

This official document is a doctoral Thesis with publications. It consists of 13 chapters, including an introduction, 11 chapters based on published or under publication research papers, and a conclusion chapter. The central part of the thesis comprising 11 papers, has been developed to cover all the research study objectives. The chapter is arranged chronologically to show the proper flow of information. Chapter 1 addressed the background of the study, knowledge gap, targeted objectives, research methodology, and other required outlines. Chapters 2 and 3 are associated with problem identification and focus on the sources of rework. It collects evidence for contracting strategy usage. Chapters 4 to 6 identified root causes throughout the project's life cycle, and Chapter 7 proposed a classification model to categorize rework causes in a comprehensive list. Chapters 8 and 9 investigated the relationship between rework and contractual claims, and Chapter 10 verified this relation by underlying rework factors in generating contractual claims. Chapters 11 and 12 focused on the rework provisions in the contract conditions and suggested solutions to improve relevant clauses of the contract for addressing rework causes. Chapter 13 proposed further recommendations for future research and better administration of the construction contracts and highlighted the limitation of the study. All the chapters and relevant articles in this thesis are structured as follows:

- **Chapter 1**: Introduction and research methodology
- **Chapter 2:** Towards contracting strategy usage for rework in construction projects: A comprehensive review; deals with understanding of rework in construction projects to identify knowledge gaps that can be filled using contract management.

  Manuscript: Paper number 1 listed in the peer-reviewed publications
- **Chapter 3**: Rework management in life cycle of project; an outline for construction contracts; deals with how rework contributes to construction contracts within project life cycle.

  Manuscript: Paper number 8 listed in the peer-reviewed publications
- **Chapter 4**: Classification of rework root causes in the design stage of projects for contract assessment; deals with the identification of rework root causes at the design stage of the projects.

  Manuscript: Paper number 11 listed in the peer-reviewed publications

- **Chapter 5:** Contract document appraisal and rework root causes classification in tendering stage of project; deals with the identification of rework root causes at the procurement stage of the projects.

  Manuscript: Paper number 9 listed in the peer-reviewed publications

- **Chapter 6:** Contracts evaluation through classified rework root causes in the construction stage of projects; deals with the identification of rework root causes at the construction stage of the projects.

  Manuscript: Paper number 10 listed in the peer-reviewed publications

- **Chapter 7:** Rework classification model in the project life cycle with liable parties of the contract; deals with classifying the identified rework root causes in a model that refers to the liable contract parties.

  Manuscript: Paper number 4 listed in the peer-reviewed publications

- **Chapter 8**: The common causes of rework in construction contracts: A diagnostic approach; deals with the identification of common causes of rework in New Zealand construction contracts.

  Manuscript: Paper number 3 listed in the peer-reviewed publications

- **Chapter 9:** Investigating the relationship between reworks and contractual claims: The salience of contract conditions; deals with the investigation of relationship between rework and contractual claims in the contracts.

  Manuscript: Paper number 2 listed in the peer-reviewed publications

- **Chapter 10**: Analyzing underlying factors of contractual claims raised from rework in construction contracts; deals with the underlying factors of rework in generating contractual claims in construction projects.

  Manuscript: Paper number 5 listed in the peer-reviewed publications

- **Chapter 11**: Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach; deals with rework provision in the contract conditions to address rework causes for preventing contractual claims and future disputes.

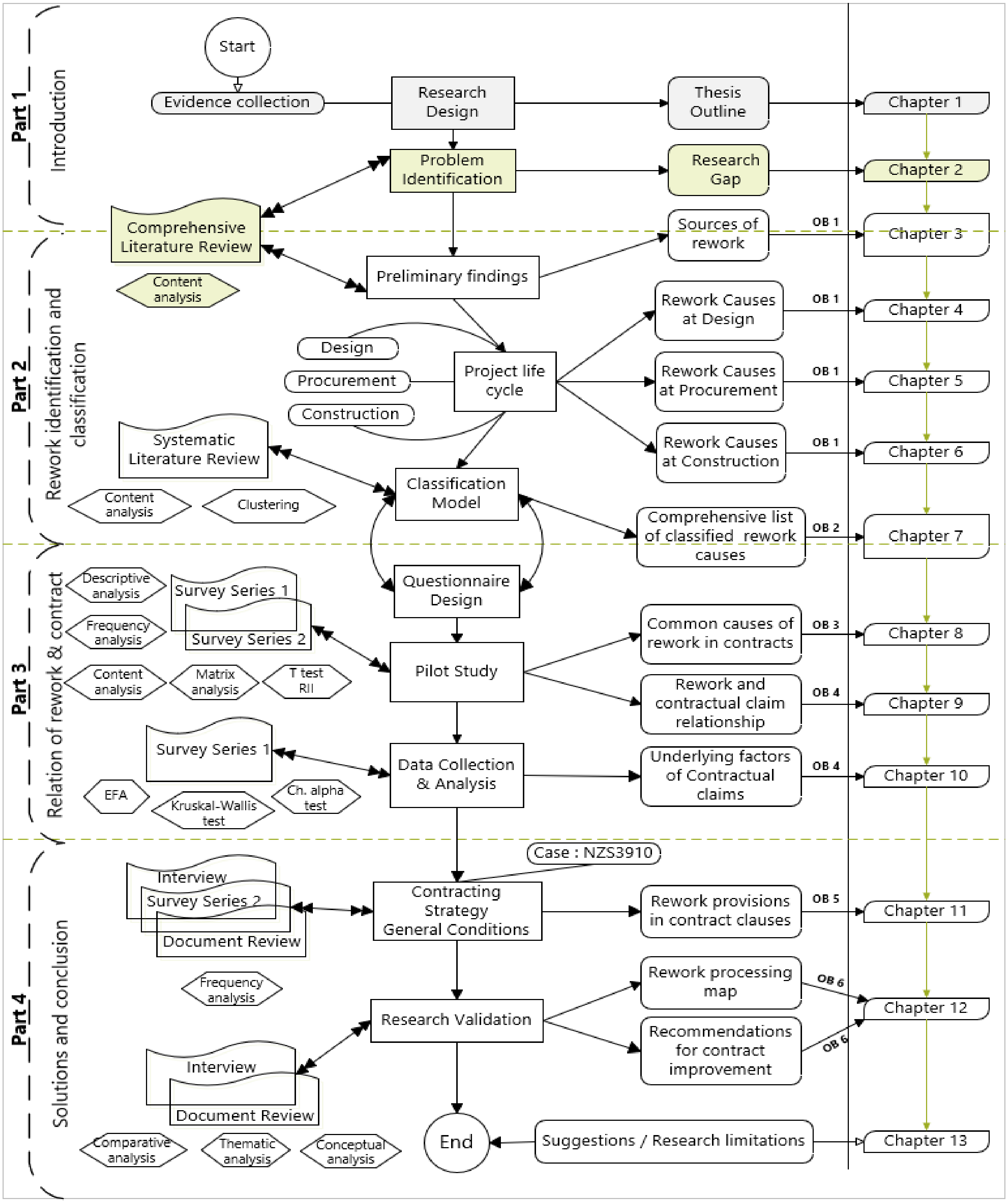
  Manuscript: Paper number 6 listed in the peer-reviewed publications

- **Chapter 12**: Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations; deals with proposing framework to improve the conditions of the contract in addressing rework.

  Manuscript: Paper number 7 listed in the peer-reviewed publications

- **Chapter 13**: Conclusion and research recommendations.

Thesis-at-a-Glance / Chapter 2



Chapter 2. Towards contracting strategy usage for rework in construction projects: A comprehensive review

2.1 Prologue

This chapter disclosures some of the main aspects of rework in construction projects. It provides the scene for further research on rework management through a comprehensive review of relevant background knowledge in construction projects. Various study areas for identifying, measuring, and controlling rework and related methods, models, and strategies used to reduce rework effects are fairly introduced. After identifying the key study areas of rework, it highlights the key elements related to the contract and its process. Rework is then placed in the overall context of the contracting process and defined in the life cycle of construction projects. The chapter identifies some critical knowledge gaps contributing to the construction contracts and discusses how future studies can fill such gaps by focusing on the contract side of the projects. It provides a basis for evaluating rework in the procurement stage of a project and concludes the necessity of contracting strategy usage that can be implemented to improve contract conditions in addressing rework at the early stages of the project.

This chapter is based on the following published Journal paper:

Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2021). Towards contracting strategy usage in construction projects: A comprehensive review. *Journal of Construction Management and Economics*, https://doi.org/10.1080/01446193.2021.2004609.

2.2 Abstract

Rework has been the core of attention for several years in the industry and academia as it affects the performance of projects. However, the trend of rework academic papers indicates an increasing rate in recent years; the overall research lacks a comprehensive review on the implemented theories and proposed models to explore further directions for rework management. Thus, to achieve a better understanding of rework it is necessary to perform an extensive review. This research aims to explore various insights from rework-related articles, to discuss major research areas, and to identify gaps for future studies looking closely at the construction contracts. The selected articles are from three databases: "Scopus, Web of Science, Google Scholar". The findings are categorised in six study areas: sources of rework, models and solutions, management and strategies, theories and techniques, rework impacts, and factors affecting rework. The analysis of the employed techniques across these topics showed that System Dynamic Modelling, Action Research, Analytic Hierarchy Process and Regression have been used more frequently than other methods. The comprehensive review also shed light on the new ways of thinking, analysing, and controlling the impacts of the rework. This paper proposes the assessment of rework causes in the conditions of contract which provides opportunities for improvement of the construction contracts.

2.3 Introduction

Academic published papers concerning rework in construction are critical as rework affects the performance of projects. Performance is one of the topics discussed more than others in construction projects (Yi and Chan, 2014). Different research studies worldwide have confirmed that rework represents a relatively large proportion of cost overruns (Love and Sing, 2013; Simpeh et al., 2015; Eze and Idiake, 2018a). Rework has been considered as the contributing factor to the schedule overrun and delay in projects, low profits, losses in terms of labour productivity, parties' dissatisfaction and the arising contractual claims (Al-janabi et al., 2020). Rework has been at the core of attention both in theory and practice. Thus, various rework reduction and prevention methods with different data analysis methods have emerged over the last few decades. The integration of such diverse literature on rework issues provides a better understanding of the topics and advances more precise research in the future. Achieving in-depth insight into the rework research trends can be accomplished through a comprehensive review of the relevant literature. In alignment with the previously researched reviews (Sommerville, 2007; Love and Smith, 2018), the comprehensive analysis of rework studies that covers the life cycle of construction project identifies the underlying requirements as well as the other possible solutions. The integration of the literature on rework assists construction policymakers to develop more robust methods.

Rework is considered as a none-value adding activity and the control of rework has been regarded as a great concern in the construction process. Failure in dealing with rework in the life cycle of projects leads to the unsuccessful delivery of projects. Therefore, rework management needs to be considered throughout the entire process of construction projects. Within the rework research, various areas have been examined to identify sources of rework, measure the impacts of rework and propose models and solutions for construction projects. For example, Zhang et al. (2018), introduced a conceptual rework management learning framework to identify the significant factors in three case studies in China. Alternately, research conducted by Love et al. (2018a) studied the theory of functional stupidity to better understand the barriers in rework mitigation. Research conducted by Ma et al. (2019c) advised project managers to determine rework in their daily practices by testing a novel method of a critical chain design structure matrix for the purpose of scheduling. Some other studies introduced rework as the result of a lack of knowledge, which is a reality, and it is partly due to a lack of understanding of the project manager or contractor about rework (Love et al., 2019b).

Summarising rework research studies is a necessity to suggest new recommendations. This paper presents an overview of the studies that have critically reviewed the relevant topics around rework in the construction industry, including concepts, causes, impacts, and adopted rework mitigation strategies from 1990 to 2020. The comprehensive review identifies the unexplored research areas and defines the state of the art and trends of rework research studies. The paper results as shown in Table 2.2 revealed that the selected period was an appropriate time span to review rework papers as it includes the majority of rework publications. Furthermore, previous studies have also pointed out that rework problems have been exposed over the last 25 years (Love et al., 2018a), thus the selected period suitably covers the development of rework research in the construction industry.

The essential step of rework management is the identification of rework sources as it assists practitioners to analyse the impacts of rework. The identified rework causes are used for assessment, analysis and for the purpose of proposing models, solutions and adopting strategies. This review reveals new approaches to develop the body of knowledge and helps practitioners improve rework practices in construction projects. The paper intends to contribute to rework management in the construction industry by addressing the study's objectives including (a) addressing the study areas of rework (b) classifying the impacts of rework (c) categorising the implemented theories, proposed models and developed strategies for better understanding and easy referencing, and (d) identifying research gaps and providing suggestions for future research directions.

2.4 Overview of rework in construction

The Construction Industry Development Agency (1995, p 59) described rework as an "activity that involves doing something at least one extra time due to non-conformance to the requirements." Since there was no precise definition for rework in the construction industry before this statement, some other terms can be found in the literature that are similar in wording. Using interchangeable words such as deviation, change, error, omission, defect, failure, damage, repair, non-conformance, and snag, not only have led to a lack of uniformity in the definition of rework, they have also affected the measurement methods, data collection and comprising strategies (Love and Smith 2018). Various definitions can be found in the literature (Robinson et al., 2004; Hwang et al., 2019), but Love and Smith (2018) simplified it as a verb that means to revise or work again. Although different definitions are given for illustrating the concepts of rework in construction projects, a common understanding exists on the key steps of reworking. The process includes identifying the source of rework, analysing the impacts of rework, providing a rectification model, removing the incorrect work, and re-building.

Despite the significant amount of identified rework factors that improve projects' performance, rework remains a real challenge in the construction industry (Love and Smith, 2018; Al-janabi et al., 2020). While the occurrence of rework is related to the nature of the construction industry in splitting the entire work among various parties in the supply chain (Simpeh et al., 2015), the continuity of rework in construction projects may result from the implicit ignorance of rework by practitioners or organisations (Ma et al., 2019a) that is called "uncomfortable knowledge" (Love et al., 2019b). A range of solutions has been placed in two categories of reduction and prevention models to manage rework in construction projects. The former is once rework has occurred whereas the latter involves the process that prohibits rework from taking place. Nonetheless, while various models have been proposed through the years, there is limited research that has been able to identify a comprehensive way in which rework can be entirely controlled (Love et al., 2016b). Without implementing a systematic approach that enables participants to trace rework causes on the overall process, the occurrence of rework cannot be actively reduced or prevented (Palaneeswaran, 2006; Zhang et al., 2018). Thus, it is time to shift the mindset towards critical thinking regarding why rework occurs and how it can be managed systematically even though there is no standard available to describe the characteristics of rework (Love and Smith, 2018). One of the contributions of this study is facilitating the development of new approaches in rework management.

2.5 Methodology

This paper presents a comprehensive review for mapping rework and the development of rework management in construction projects. A literature review is widely used in many research fields to generate and refine research ideas for future studies (Xia et al., 2018; Tezel et al., 2020). The review enables researchers to fit their research project into a broader context through the verified findings (Dixit et al., 2019) and find out more about the research strengths and limitations (Dallasega et al., 2021). The basic steps of such reviews include the following sequences: identification of the needs, developing search criteria, searching databases, selecting the publications and quality assessment, result summarisation and reporting. A four-step methodology to meet the pre-mentioned sequences has been defined and employed in this paper as prescribed in Figure 2.1. The four steps facilitate research content analysis to develop an in-depth knowledge of rework. The four steps include a searching strategy to identify the browsed papers (Dallasega et al., 2021), document refinement to restrain the initial papers (Tezel et al., 2020), visual examination to select the final relevant papers for further processing (Xia et al., 2018), and data extraction and analysis (Schon et al., 2017).

This paper was undertaken based on conducting a comprehensive review and performing content analysis. A comprehensive review of the literature tends to depict the potential future research (Mohandes et al., 2019) which is the aim of this study. In addition, the aim of this study involves categorising the research interest, the method used and the proposed models that can be achieved through content analysis. Content analysis is an inductive method to unfold outlines and organise the extracted data into groups (Ayodele et al., 2020). The search engine of Scopus to recall high-impacted relevant published papers was selected to start the search process. The process was completed by adding two more search engines to ensure identification of all the rework published documents in construction. As an instance, the Scopus engine does not cover some journals such as Project Management Journal (PMJ); furthermore, published papers of Engineering, Construction and Architectural Management (ECAM) before 2003 are not included in the Scopus extent (Hong et al., 2012). Thus, the other two search engines can cover these limitations.

Choosing the right keyword to retrieve the relevant papers is the key part of the search. As discussed earlier in the overview section, searching the other interchangeable words distracts from the result of rework trends in construction projects. Since the paper results are used for the assessment of the contract clauses in addressing rework issues, the keyword “rework” was selected to search the literature. It is difficult to propose a general preventive measurement to control rework as most of the previous studies have used rework along with other interchangeable words (Forcada et al., 2017; Ma et al., 2019a). Love et al. (2004), also claimed that there is a lack of uniformity in the rework data collection due to the various interpretations around rework. The diversity of interpretations due to the interference of the other words has led to a lack of uniformity in the rework data collection (Liu et al., 2020). The degree of ambiguity around rework increases as the other terms have been used interchangeably (Sommerville, 2007). Therefore, to get an accurate and specific result aligned with the research aims the first keyword "rework" was selected. Furthermore, rework is a general word that is used in various industries and to avoid any misleading by irrelevant documents from the other subject areas, the second selected keyword “construction” was used. The search engines then were used to find relevant publications as the following described sequence. The search space included only journals and conference proceedings.

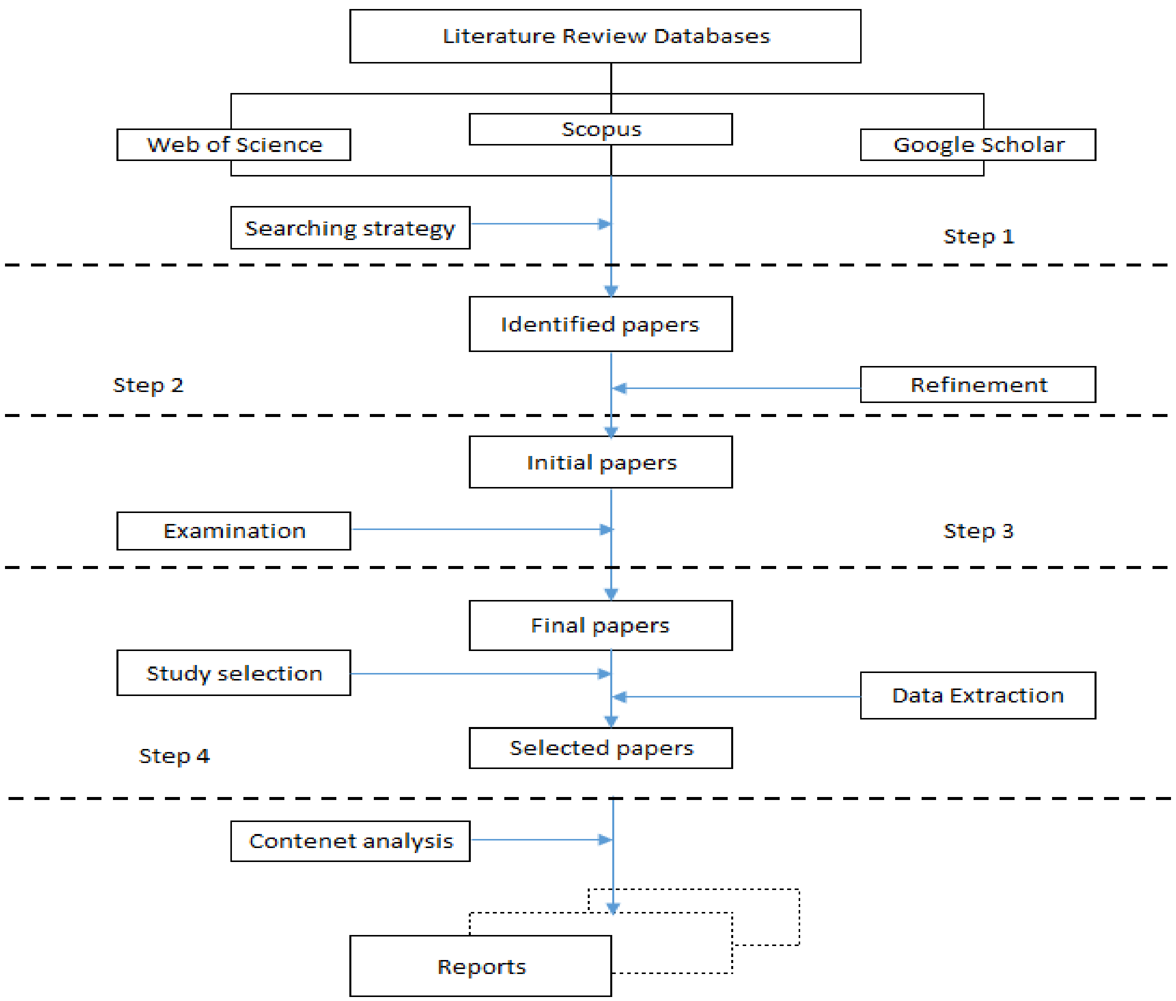


Figure 2.1: *Four steps research framework*

2.5.1 Searching strategy

In step one, the first round of searching publications was launched under the keywords "rework" and "construction" to search the literature published in Scopus. The initial search for the selected period of 1990 to 2020 showed a total of 138 documents. The same process was repeated for the other two selected search engines. The second round of searching of the keywords in WoS revealed 106 documents during the same time period. Then the same scenario was repeated with the Google Scholar search engine. The third round of searching raised 170 documents. The advance search of Google Scholar is limited to two options: searching the keyword anywhere in the article and/or in the title of the article. The central message of the articles is conveyed through the title and this section is more likely exposing the articles' contribution to the theories around the searched topics (Larsen et al., 2019). Therefore, the keywords "rework" and "construction" were searched in the article titles. In summary, a total number of 414 papers were identified and collected by the end of step one.

2.5.2 Document refinement

However, the search was strictly limited to construction projects to exclude any unmatched papers; there were still some unwelcome publications that belong to other science fields. In the second step, more limitations were applied by refining the entire search process to eliminate the proportion of unrelated documents. The Scopus search engine was refined through three categories. The document type was limited only to the peer reviewed articles and conference papers, the publication stage was narrowed only to the final documents, and the language was restricted only to English. The exclusion criteria included no full books, papers where the full text was not available, lessons learned, and recommendations or guidelines. This refinement resulted in 128 documents in the Scopus database. The same refinement was implemented into the Web of Science search engine, and the result showed a total number of 92 papers at the end. The third search engine of Google scholar has no features for refinement except for excluding the citation to eliminate the non-paper rows. Excluding the citation portion of Google Scholar dropped the number of papers down to 109 documents. In total, the refinement process constrained the number of papers to 329 documents as the initial papers for more consideration.

2.5.3 Visual examination

The next step was a visual examination to remove irrelevant and repeated documents with the same titles. Part of the initial identified papers may differ from the research scope; however, they met some of the search keywords' criteria. A more accurate selection of relevant papers will result in a more reliable conclusion, so the papers that did not satisfy the research criteria or those that were found to be totally unrelated to this study's scope must be excluded. The procedure of publications' examination was as follows:

1) All papers' titles were reviewed initially to find out if they were really fitted to the research scope or not. The unfitted papers were removed.
2) The abstract of all remaining documents was scanned and assessed, and the irrelevant papers were deleted to ensure that no more irrelevant papers were available.

After these sequences, the following result was achieved. There were 46 irrelevant papers from Scopus; therefore, this search engine's final papers decreased to 82. This figure for Web of Science and Google Scholar was dropped to 64 and 88 as there were 28 and 21 irrelevant papers, respectively. In total, 234 papers remained as valid documents for further analysis.

2.5.4 Study selection and data extraction

The outputs of the three engines consisted of a total of 234 documents. Due to the high number of recorded studies, the Microsoft Excel program was used to efficiently manage the retrieved information. The Excel file included the following items to take the essential data out of the collected papers and provide required reports. All the collected papers were taken into consideration to carry out the data extraction process:

- Basic information of title, authors, and publication date (for checking the same papers)
- Location: country, university, research centre or affiliations (for reporting the impacts in different regions)
- Aim of the study (for identifying different themes and categorisation)
- The employed method and techniques, contributions, and result (for discussion and identification of further research direction)

Listing all papers in the Excel sheet and sorting them revealed that some papers were the same based on using the three search engines. To make sure that none of the collected documents are duplicated, the Scopus' results were compared to the other two search results in terms of paper title and authors. There were 54 mutual papers found between Scopus and Web of Science. Following that, the cumulative list was compared to the other documents from Google Scholar, and it revealed that there were 40 common papers. In other words, the Web of Science adds only 10 more papers to the retrieved documents from Scopus and Google Scholar added 48 more papers. The limitation of each search engine confirms that relying on only one search engine to analyse the rework contents will not result in a reliable conclusion. Thus, covering the missed papers in the other search engines was necessary, and this study has taken the benefit of this approach. In total, 94 papers were found to be similar in the Excel file and were removed to avoid misleading the analysis. By the end, 140 papers were left as the final selected papers for further processing. Table 2.1 shows an extract from this reduction process in selecting the final papers.

Table 2.1: Summary of papers number reduction process

Search Engine	Step 1	Step 2	Step 3	Common papers in Excel sheet	Final selected papers	Date of Search
Scopus	138	128	82	0	82	14.04.2020
Web of Science	106	92	64	54	10	14.04.2020
Google Scholar	170	109	88	40	48	14.04.2020
Total	**414**	**329**	**234**	**94**	**140**	**-**

2.6 Results of the content analysis

Friedrich et al. (1987), initiated the basis of research on rework topics into two general categories of "developing a systematic technique for counting rework" and "using a method that accounts for the effects of rework to measure the actual status of the project." Thus, the following subcategories had considered summarising the research topics (a) to find out the origins of rework, and (b) to control the effects of the rework. This classification scope was then expanded into a wider area. Zhang et al. (2012), have described these directions and raised the area of rework studies into two clusters of "rework as a quality issue" and "the role of rework on performance." The first group of studies that have considered rework as a quality issue resulted in the emergence of broader research levels to identify the sources of rework through various methods. For example, it was used to treat rework events through the conventional approaches of TQM. The second group of studies attempt to focus on rework impacts on project performance, management practices, and the assessment of factors that affect rework. However, the research interest scope was not limited only to these major directions and later it was expanded.

The comprehensive review revealed that the rework subject in construction papers was repeatedly involved in 1) identifying rework causes (Love and Edwards, 2004b; Oyewobi and Ogunsemi, 2010; Hwang et al., 2014; Forcada et al., 2017); 2) proposing models for reduction or prevention of rework occurrence (Love et al., 2000a; Love et al., 2009a; Simpeh et al., 2015); 3) providing recommendations and tactics for managing rework and strengthening available frameworks to achieve more benefits (Hwang and Yang, 2014; Yap et al., 2017; Love and Curtin, 2019); 4) implementing theories and using methods to facilitate rework identification, classification and mitigation (Robinson et al., 2004; Palaneeswarane et al., 2008; Hossain and Chua, 2014; Ma et al. 2019c); 5) quantifying and measuring the effects of rework on project performance (Josephson et al., 2002; Hwang et al., 2009; Hegazy et al., 2011; Eze et al., 2018b), and 6) evaluating some of the indicators that influence the occurrence of rework (Love et al., 2006; Mills et al., 2010; Oyewobi et al., 2011; Mahamid, 2016b; Hawang et al., 2019).

The paper results clearly show that research interests have continued to develop, and novel ideas have emerged. Some new methods and approaches such as, "functional stupidity theory" and "fuzzy set theory-based" have been introduced (Love et al., 2018a; Hwang et al., 2019) in comparison to the previous qualitative analysis. More focus has also been drawn to the human functions, concepts of learning, and the importance of safety. For instance, the recent studies have recommended the approaches of system thinking and shifting mindset to control rework and errors (Love et al., 2018b; Love et al., 2019a). Therefore, the previously defined categories by Friedrich et al. (1987), and Zhang et al. (2012), must be amended to evaluate the publications between 1990 and 2020. Following the previously introduced research interests and considering the selected publications on rework, six distinct groups of interests are identified as the main rework studies area as shown in Table 2.2.

Table 2.2: Major area of studies in rework related papers

Area of studies	**1998 2000**	**2001 2002**	**2003 2004**	**2005 2006**	**2007 2008**	**2009 2010**	**2011 2012**	**2013 2014**	**2015 2016**	**2017 2018**	**2019 2020**	**Total**
Sources of rework	1		1	1		2	3	3	8	8	6	**33**
Models and solutions	4		3	3	2	2	2	3	3	3	2	**27**
Rework impacts		2		2	1	1	3	5	3	2	3	**22**
Management and strategies	1		1		2	1	1	1	2	8	4	**21**
Theories and techniques		1	1		2		1	6	5	2	3	**21**
Factors affecting rework	2	1	1	1		1	2	1	3	2	2	**16**
Total	**8**	**4**	**7**	**7**	**7**	**7**	**12**	**19**	**24**	**25**	**20**	**140**

Since the research is conducted to compare the results of previous studies, the adopted method for categorising the topic interests will be an appropriate approach (Ke et al., 2009). All selected papers were reviewed in detail to link their study scope with one of the above-classified areas. If a paper covered more than one group, the closer one in terms of theme has been considered. Within the last three decades from1990 to 2020, publications in the construction field perceived an increasing trend in rework research studies. The following sections discuss the main area of studies on rework, existing gaps, and further required research with a project perspective.

2.6.1 Sources of rework

This group of papers has mainly introduced rework sources and identified a cluster of rework causes from different perspectives. The trend of studies on identifying rework causes indicates that this study area has been of interest for several years and remains as an interesting topic in current studies (Love and Li, 2000; Palaneeswaran, 2006; Simpeh et al., 2011; Ye et al., 2015; Safapour et al., 2019; Liu et al., 2020). This group contains the largest number of publications among the reviewed papers that deal with the sources of rework. To identify the cause of rework, the papers that were reviewed have studied various residential buildings, construction, and civil projects. However, the rework can be attributed to an array of complex, interrelated factors (Forcada et al., 2016) in many of the studies; changes, errors, quality deviations, damages, defects, failures, and omissions are referred to as the significant sources of rework (Palaneeswaran, 2006; Ajayi and Oyeyipo, 2015). Change as one of the main sources of rework typically is generated from contract deviation (Love et al., 2005). Changes mostly result in variation and have the potential to raise disputes. An extensive literature review indicated that little research exists on the sub-topic of change and its relationship with rework (Love et al., 1999; Love et al., 2002; Mahamid, 2016b; Kermanshachi et al., 2018). In contrast, many researchers have studied the sub-topic of error as the other significant sources of rework.

Identifying and classifying the rework causes is the first step in rework management (Hwang et al., 2009). Some of the research that employed underpinning the theories for the in-depth study of rework causes was able to identify causal factors that explain how rework occurs (Love et al., 2010b; Aiyetan, 2013; Hwang et al., 2014; Forcada et al., 2017). Other studies that have provided a list of single casual factors have not explained the relational aspect of rework causes and have been unable to develop a mitigation framework (Li and Taylor, 2014). Introducing the concept of "rework cycle" and using system dynamic tools led the other studies to a better understanding of rework interactions (Hegazy et al., 2011), then several studies were conducted to identify rework causes. Rework causes then were classified to facilitate the proposed correction actions (Zhang et al., 2012). Depending on the research scope, several classification methods have been appearing for categorising, measuring, and quantifying the identified rework cause. All introduced and used classification methods have typically been sorted in terms of the organisational body such as, client, consultant, designer, contractor, and subcontractor; or the key elements of the project such as, people, project, and organisation; or stages of the project such as, design, planning and scheduling, construction; or management factors such as, project management and communication, site management, quality management, and contract management; or other aspects such as, process and changes, technical, machines, materials, external factors, and technology.

Throughout the past three decades, numerous rework causes have been introduced based on a review of a number of studies (Josephson et al., 2002; Love et al., 2009a; Enshassi et al., 2017; Ndwandwa et al., 2017; Ajayi, 2017; Eze et al., 2018b; Safapour et al., 2019). Apart from that, using various versions of identified causes in different settings over the years, a long list of root causes has been compiled. Providing a list of all the identified rework root causes requires a systematic literature review and further content analysis. Consequently, there is a considerable amount of effort involved to identify rework causes at different stages of projects, so a general measure to prevent rework has not been defined yet (Ma et al., 2019a) because it is believed that rework studies cannot be compared due to a lack of uniformity (Palaneeswaran et al., 2008). The comparison of various introduced classification methods showed that the cluster titles are the same, but most of the root causes under each cluster vary, as each study follows different definitions.

2.6.2 Factors affecting rework

This group of studies has identified and assessed certain factors to determine whether the extent of rework occurrence is affected or not. Understanding the factors affecting rework helps researchers to provide better models and solutions for rework management. Searching the affecting factors of rework is an appropriate way to find opportunities for improvement. Most of the researchers in this group have first conducted literature reviews to determine the factors and then assessed them through question surveys and interviews. This group of papers has evaluated the factors affecting rework through various civil, construction and residential building projects. An extensive literature review into this study area indicated that research on factors affecting rework covers only a small portion of possible variables so more investigations are required. The following factors have been assessed under rework circumstances; site supervision (3 studies), project type (2 studies), procurement method, organisation size and the use of quality assurance, systems organisational learning, contract documentation, labour controls, change order, organisational culture, work ethic culture, labour productivity, visualisation, BIM and technology (each in one study). However, three more factors from other study areas can be added to the list of factors affecting rework such as, waste material, the role of project team members, and the role of the supply chain.

Despite the initial finding that showed no relationship between project type and selected procurement method with cost and time performance (Love and Edwards, 2005), there is some evidence confirming that rework is influenced by project type, location of the project, and the type of contract (Forcada et al., 2016). For instance, civil infrastructure projects experience less rework compared with building projects (Love et al., 2010b), and rework in green building projects is lower compared with other conventional building projects (Hwang et al., 2016; Salihu and Babarinde, 2020). The application of technology also is the other factor that has been the core of discussion and debates over the years. However, advanced technology, such as BIM and visualisation may reduce design errors (Li and Love, 1998); their implications need to be assessed within a clear perspective and defined project management process (Love et al., 2016b). Therefore, using technology without considering the other conditions of the project may not ensure the reduction of rework. In other words, this topic still requires more investigation in future studies.

2.6.3 Rework impacts

This group of papers has mainly focused on rework effects by quantifying and measuring rework impacts such as time overruns and cost overruns. Rework plays a critical role in the construction industry as it deals with the performance of projects. From this point of view, many studies have connected their research on project performance or construction performance, mainly through means of cost, time, and quality. However, while a critical review of the selected papers showed many concerns around this area of study, only those papers that directly assessed or analysed the impacts of rework have been clustered in this group. In addition to the time and cost impacts of rework, several other factors also have been identified as the consequences of rework that affect people, projects, and organisations. The other identified effects of rework are listed below (Love and Edwards, 2004b; Love et al., 2004; Palaneeswaran, 2006; Aiyetan, 2013; Eze and Idiake, 2018a):

1) Psychological well-being of individuals such as, employees' demotivation, stress, the dissatisfaction on the part of the project team, the low morale of workers, absenteeism, fatigue, and dissatisfied customers.
2) Projects measures such as, quality degradation, unsafe structures, poor contract management, contractual claims and disputes, additional materials and resources, wastage handling, loss of profit/revenue, and lower performance.
3) Organisational factors such as, battered reputation, reduced market share and loss of business, increased professional fees and financial difficulties, inter-organisational conflict, litigation, extra charges due to additional workforce and supervision of manpower, turnover of management, and lower productivity.

Each of these three groups of effects has an interaction on the others and, most importantly, each has cost impacts that are not measured by the organisations. Therefore, the total rework cost in construction projects remains relatively unknown (Love et al., 2019a). Due to the nature of the performance-oriented construction industry, most of the research in this area of study has focused on measuring the two crucial factors of cost and time. An extensive review of the literature indicated that various costs and time reports could be found within the selected papers. The broad range of rework costs reported in both types of residential building projects and civil and construction projects is due to the diversity of rework definitions, which affects the scope of rework consequences and a variety of measuring methods (Love and Curtin, 2019; Zhang et al., 2018). The indirect cost of rework has not been included in many of the reported costs. Taking this proportion of rework cost into account depicts how rework influences the performance of the project. More details of all previously reported rework costs are presented in Table 2.3.

In addition, the time impacts of rework have been reported in different ways and so their results are diverse. There is a difference in the reported delay that originated from rework as each research study follows different methodologies; for instance, a case study is showing a 4.1% delay of project duration while the question survey shows a 5.18% delay (Anjum and Azam, 2019). Another question survey in the construction of building projects between 2005 and 2015 in Nigeria reported an average of a 7.35% impact on the initial delivery time (Eze and Idiake, 2018b). Case studies in Sweden have indicated that 7.1% of the total work time is required for correcting the rework (Josephson et al., 2002), while a single case study in Uganda showed 8.42% as the mean percentage of the rework-related impact on the project schedule (Kakitahi et al., 2016). Reports from 226 projects indicate more than three weeks' delay as the impact of client-related rework regarding time (Hwang et al., 2014). Besides, the contribution of rework in schedule growth was reported as 25% from 32 companies (Hwang and Yang, 2014), while the mean schedule growth reported by Love (2002) was 20.7%. A study in Malaysia has also shown that the scheduled growth due to rework is from 5.1 to 10 percent (Yap et al., 2017). Analysis of a project schedule through a simulation model confirms that lengthening house completion times incorporate rework influences (Arashpour et al., 2014).

Table 2.3: Summary of reported rework cost from literature

Rework cost	Method of measure	Type of project	Country	Type	Source
2.0% to 3.2% of the total project costs	**QS, 100 projects	High-rise building	Indonesia	A	Alwi et al., 1999
3.15% & 2.4% of the project contractvalue	2 Case studies	Residential and industrial warehouse	Australia	A	Love and Li, 2000
4.4% of the construction values	7 Case studies	Construction projects	Sweden	A	Josephson et al., 2002
6.4% (direct) and 5.6% (indirect) of the original contract value, 12% "Total rework cost (TRC)"	QS, 161 projects	Construction projects	Australia	A	Love, 2002b Love et al., 2004
5% (direct) of the total construction costs	Online questionnaire, 359 projects "database"	Buildings, Heavy and light industrial, Infrastructures	_	A	Hwang et al., 2009
10.29% of contract value	QS, 115 projects	Civil infrastructure	Australia	A	Love et al., 2010b
5.06% of the completion cost	Database of 25 projects	New Building	Nigeria	A	Oyewobi et al., 2011
3.23% of the completion cost	Database of 25 projects	Refurbished building	Nigeria	A	Oyewobi et al., 2011
2.93% (direct) and 2.20% (indirect) of the contract value, 5.12% (TRC)	QS, 78 firms' participants	Construction projects	South Africa	A	Simpeh et al., 2011
11.30% of original contract value	QS, 276 projects	Construction and engineering projects	Australia	A	Love and Sing, 2013
10% to 15% of the original contract cost	QS, 86 contractors	Residential building	Palestine	A	Mahamid, 2016b
0.5% to 3.7% of the total work value	QS, 47 housing	Residential building	Sri Lanka	B	Dahanayake et al., 2016
4.08% increase in total cost of the project at 76% completion of duration	Single case study	Construction projects	Libya	B	Al-Zanati and Bajracharya, 2017
2.75% of the original contract value	Case study	Building projects	Spain	B	Forcada et al., 2017
0.39% of contract value	Case study, 346 projects	Construction projects	Australia	B	Love and Smith et al., 2018
1.85% of the construction cost [a] 2.1% of the construction cost [b]	Case Study [a] QS, 22 projects [b]	Residential buildings	Iran	B	Anjum and Azam, 2019
4.95% of the total project cost	Multiple case studies, 6 projects	Residential building	China	A	Liu et al., 2020

A: project rework, which includes scope changes and manufacturing errors off-site. In this case, rework is presented as a cost to the 'project', and no distinction is made to who pays for the repeated works. B: construction rework, which excludes scope changes and manufacturing errors that arise off-site and focuses on the costs to the contractor. QS: Questioner Survey

Table 2.4: List of employed techniques in rework management papers between 1990 and 2020

Method	Aim	References
Regression analysis (RA) and Multiple regression:	-to identify the main causes of change orders, determine the factors affecting rework, determine the effects of change orders on rework,	Mahamid, 2016b
	-to understand the relationships among contributing factors and to develop a model for rework prediction,	Forcada et al., 2017
	-to determine the significant variables that contributed to rework	Love et al., 2004
	-to determine a model that leads to reduction of total rework cost,	Love and Edwards, 2004b
System Dynamics (SD):	-to measure the effects of work ethic culture on rework,	Kiani et al., 2018
	-to reduce design errors and rework,	Love et al., 2000a
	-to develop a series of influence diagrams and conceptual casual loop model,	Love et al., 1999
	-to describe how changes can impact the project management	Love et al., 2002
Fuzzy set theory-based model:	-to prevent rework in projects with BIM implementation,	Hwang et al., 2019
Theoretical conceptualization of error causation:	-to understand rework causal setting and why it remained an on-going issue for organizations contracted to deliver an asset,	Love et al., 2019b
Generalized Pareto distribution:	-to calculate and analyze the probability of rework,	Simpeh et al. 2015, Love and Sing, 2013
Artificial neural networks (ANN):	-to predict and classify of problems and to map the causes and effects of rework,	Palaneeswaran et al., 2008
Analytical Hierarchy Process (AHP):	-to identify the effective factors on rework, classification, evaluation, and prioritizing them,	Aljailawi and Shariatmadar, 2017
	-to select rework measurement methodology,	Brito et al., 2018
Action Research (AR):	-to investigate the problems faced by the companies and to develop an improvement plan,	Taggart et al., 2014b
	-to assist SME in eliminating and reducing rework and defects,	Taggart et al., 2014a
Cognitive mapping (CM):	-to model the complexity and dynamic nature of rework,	Love et al., 2016b
Dependency structure matrix (DSM):	-to identify tasks that are likely to drive rework within a project,	Flanagan et al., 2008
Multivariate statistical technique:	-to achieve meaningful insights into the rework occurrences in construction projects,	Palaneeswaran et al., 2014
Overlapping Strategy Matrix (OSM) with the genetic algorithm (GA):	-to eliminate unnecessary rework,	Hossain and Chua, 2014
Importance Index (IMPI) such as FRI (Field Rework Index)	-to give warning that rework occur or not,	Shah and Sharma, 2016
Critical chain design structure matrix (CCDSM):	-to quantify and visualize rework and its impact,	Ma et al., 2019
	-to develop a schedule in construction projects,	Ma et al., 2019
	-to mitigate rework risks and protect projects delay,	Ma et al., 2019

2.6.4 Theories and techniques

This group of studies deals with theories and some techniques to identify rework causes or measure their impacts in the project's design and construction stage, with the purpose of better understanding the nature of rework. Using theories and implementing some tools and techniques commenced in 1999, it is still a concern. Current evidence of the recent articles on this study area shows that researchers are still exploring various techniques to acquire more details about the nature of rework in the construction industry (Ma et al., 2019b; Hwang et al., 2019). The increased number of publications in this area is attributed to the need to acquire deeper knowledge around rework.

The identified theories and techniques have been implemented and tested in both civil construction and residential building projects. The core methodology used in this group of studies depends heavily on the questionnaire survey and interview followed by case studies. The more frequently employed tools and techniques in rework papers include system dynamic (SD), regression and multiple regression analysis (RA), analytic hierarchy process (AHP), and action research (AR). Some of the techniques that have been utilized along with their implications in rework papers are listed in Table 2.4. The other tools and techniques used include cause and effect, multi-domain matrix, retrospective sensemaking, partitioning algorithm, tipping point dynamics, and the functional stupidity theory.

2.6.5 Models and solutions

The core of study in this group of papers has concentrated on design models and proposed solutions that mostly attempt to mitigate rework. The proposed models and solutions can be found in 17 papers on construction and civil projects, and seven papers on residential building projects. The effectiveness of the proposed models has been tested over the years by monitoring various project aspects such as, supply chain, design, quality, risk, technology, and learning process. All the submitted models that are listed in Table 2.5 provide an entire picture of what has been done to date. The proposed solutions throughout the reviewed articles also are presented after the table:

Table 2.5: List of rework management models over the period of 1990-2020

References	Applied models and their purposes
Love et al., 1999	**The conceptual model** for benchmarking and reducing rework throughout the quality-chain and to develop a series of metrics for the causes and costs of rework using different procurement methods in building construction projects
Love et al., 1999	**The conceptual model** for improving the effectiveness of the supply chain and minimizing the incidence of rework in building construction projects
Love et al., 1999	**Conceptual causal loop model** to identify the major factors that influence rework and understand the casual structure of rework influences
Love et al., 2000a	**Design construction reduction model (DECOREM)** to understand the factors that influence the occurrence of design errors
Love and Edwards, 2004a	**Reduction model** that leads to reducing of the total rework cost
Love and Smith, 2003	**Generic framework** for benchmarking rework at interfaces of the project's life cycle
Love et al., 2004	**Holistic reduction model** to determine the significant variables that contributed to rework in building construction projects
Love et al., 2005	**Pragmatic model** for reducing the incidence of rework by the development of TQM culture in a structural steel supply chain of residential buildings
Palaneeswaran et al., 2006	**Artificial neural network model** for mapping rework related impacts
Sommerville, 2007	**Analytical model** to characterize, evaluate and inform decisions about defects and rework in new houses
Love et al., 2008	**Systemic causal model** for design-error-induced rework in a commercial construction project
Love et al., 2009a	**Generic structural model** to identify the most significant causes of rework
Zhang et al., 2012	**Generalized model** for rework reduction program (RRP) by managing a continuous improvement loop with four functional processes
Forcada et al., 2014 and 2016	**Rework generic systemic model** to categorize causal variables adopted through project, organization, and people
Simpeh et al., 2015	**Rework probability model** to determine rework before the commencement of construction
Ji and AbouRizk, 2018	**Simulation model** to quantitatively assist decision support systems in quality induced rework cost estimation
Zhang et al., 2018	**Conceptual rework management learning framework (CRMLF)** which consists of people, approach, process, tool and project environment to the analysis of rework management learning process
Rezahoseini et al., 2019	**Model of TQM and BIM** to identify the capabilities of BIM that can reduce rework in the projects

- The set-based concurrent engineering approach to mitigate design rework risk (Arundachawat et al., 2009).
- The risk classification matrix that provides a frame of reference to mitigating future rework in complex projects (Love et al., 2011, Love and Edwards 2013) and risk management approach (Puspita et al., 2019).
- The time-cost trade-off to an optimum overlapping degree of design activities reduces change and rework (Dehghan and Ruwnapura, 2014).
- Conceptual learning framework for program alliances confronted with rework (Love et al., 2015).
- Preventive Planning Tool (PPT) to identify rework causes and to plan preventive actions (Hamilton et al., 2018).

Recent evidence shows that the occurrence of rework has not been reduced effectively over the past few years even though various models and solutions have been proposed. A reduction model works effectively if organisations quantify rework impacts in advance (Love and Edwards, 2013). In terms of quantifying the impacts of rework, organisations must willingly acknowledge that rework occurs in their projects (Love and Smith, 2018). Thus, proposing models and solutions in future studies must focus on those aspects of rework management that facilitate identifying and controlling rework. Specifically, more attention needs to be focused on the early project stages such as, design and contracting and it should also consider human resources factors with a higher priority.

2.6.6 Management and strategies

This group of studies comes with recommendations that are usually considered the organizations' strategy to manage rework. There is an increasing rate of published papers on management and strategy during the years 2015 to 2020 compared to earlier years. More than 50 % of papers in this area of study have been published in the last five years after 2015. The lack of effective proposed models and solutions has motivated researchers to shift their minds towards management and strategies. Publishing papers on the study area of management and strategies between 2015 and 2020 is higher, about twice that of the study area of models and solutions. In terms of project types, research in this area of study includes both civil construction and residential building projects. The nature of the suggested management and strategies differs widely in scope and content. The strategies used for the reduction or elimination of rework are very diverse. Hereafter, based on the review of the literature the most emphasised strategies and management practices to tackle the rework issues have been presented.

Quality management practice, benchmarking system, reinforcing supply chain relationships, lessons learned, risk management, change management, safety management, authentic leadership, error management, constructability, multidisciplinary design team, procurement strategies, learning from error, cost management, organisational learning, integrated design process, pre-project planning, front-end planning, materials management, dispute prevention and resolution, utilising building information modelling (BIM), design scope freezing, value management, use of information technology, supervisors’ training, management commitment, the involvement of subcontractor/suppliers during the design stage, using relational contracting, and use of the Last Planner System approach, checking design drawings and verification. Some of these strategies have been implemented practically in previous studies and some need to be tested. While there was considerable interest in identifying rework causes and determining their consequences in the last several decades, it is time to think about developing the best strategies for managing rework.

2.7 Discussion and research gaps

Research on the various aspects of rework in the reviewed articles illustrates the complexity of rework issues that is a consequence of a faulty activity or process. The initial result of the comprehensive review showed that rework had been studied with different perspectives. Thus, it can be concluded that rework is an essential topic for the construction industry. Results showed that identifying the sources of rework is the most interesting sub-topic that generally ends with a classified cause of rework. The variety of presented categories of rework causes has pointed out that there is no commonly used classification method in the construction projects. Since there is no systematic literature review on rework causes, performing a comprehensive review to unify all identified root causes of rework under a comprehensive classification model in the project life cycle is necessary. Studies that address the impacts of rework also provided insights into the implemented theories and techniques. Due to the inter-related influences of rework, several methods have been used in rework papers. Frequently used methods include regression analysis (RA) and multiple repression, system dynamic (SD), action research (AR), and the analytic hierarchy process (AHP). The implementation of more technical methods is of interest in recent years. Various data collection techniques were used to identify rework causes, while analytical methods were rarely implemented for assessing the impacts of rework due to their difficulty of use in practice (Dallasega et al., 2021).

The analysis of reviewed articles also revealed a range of proposed models and solutions for rework reduction and defined strategies for rework management. Part of the suggested models have been tested using case studies, yet the required level of project performance has not been achieved as rework is persisting in construction. Thus, the research moves towards implementing strategies rather than proposing models based on new project management concepts and advanced technologies. Contract documentation is one of the concepts of project management that covers the entire project life cycle. While there is some research that has studied procurement methods and contract documents in rework events (Love, 2002b; Love et al., 2006) the conditions of the contract under rework confrontation have not been explored in the previous studies. Thus, employing a strategy that evaluates the clauses of the contract in rework circumstances would bring novelty and will contribute to the body of knowledge. A contract is a legally binding document that governs all stages of a project and shares responsibilities between all project participants, so it is assumed that it plays a critical role in the process of reworking in an integrated manner.

It is important to understand what has been done regarding the contracts in the previous rework studies. An in-depth review of the sources of rework revealed that the contract document can be a potential source of rework occurrence (Love et al., 2003; Palaneeswaran et al., 2008; Forcada et al., 2014). As such, in the study by Love et al., (2006), they conducted research to investigate the effects of contract documentation in the incidence of rework. The main focus of the conducted research is on the quality of contract documentation/s in relation to the design consultants. Another research on the effects of rework in urban renewal projects in Colombia concluded that the type of contract is one of the triggers in rework occurrence (Forcada et al., 2017). While all this evidence shows the importance of the contract in rework incidences, up to now, as far as we can tell, few, if any, studies have assessed the conditions of the contracts in construction projects in order to tackle the rework phenomena. Based on a further review, factors affecting rework showed that very few studies have attempted to evaluate the influences of procurement methods on rework in construction projects. The result of the study conducted by Love (2002), indicated that the cost impacts of rework do not vary significantly among different procurement systems. Other studies that were conducted later claimed poor procurement methods as one on the main contributing factors of rework (Aiyetan, 2013; Oyewobi and Ogunsemi, 2010; Oyewobi et al., 2016). It is expected that, the evaluation of contract conditions as the main output of a procurement system may result in a better understanding of rework.

Regarding the impacts of rework, many research studies have studied the cost impacts of rework as illustrated in Table 2.3. The value of the construction contract is affected by rework up to 15 % or even more as reported in some cases. Having in-depth knowledge of rework costs may encourage researchers to investigate further how the causes of rework could be eliminated. Current evidence shows how the research on the cost and time impacts of rework has saturated studies while measuring and quantifying the other rework effects has received less attention. Some of the other important rework effects, such as contractual claims and disputes, human influences, and safety, need to be considered more in the future. Furthermore, even though rework influences contractual claims and disputes, the literature shows that there is a scarcity of studies that assess rework in relation to claims and disputes (Palaneeswaran et al., 2006). Lack of such studies may arise from the reluctance of the contract parties to scrutiny, which is referenced as uncomfortable knowledge in the study done by Love et al. (2019b). Thus, the assessment of the contract clauses of the construction projects in terms of addressing rework and its causes may result in fewer numbers of claims and disputes.

In addition, all the proposed models and solutions for reducing or preventing rework have been utilised during the design and construction stage of the project. Some studies pointed out that the proposed models and solutions can reduce the impacts of rework or predict the probability of a rework occurrence. They mainly cover the two stages of design and construction separately or jointly and in a few cases include the procurement stage of the project. The results revealed that none of the proposed models and solutions in the literature deal with the contract directly. Thus, a framework that deals with the conditions of the contract to tackle rework could prevent rework occurrence due to the early identification of the causes. Such a model also reduces the number of contractual claims and disputes in construction projects. Contract management is used as a tool for achieving quality of work in construction projects (Coleman *et al.*, 2020). Similarly, contract can be used for processing rework, even though it has not been employed and tested in the previous studies as listed in Table 2.5. A list of strategies that can deal with rework management has also been extracted from the literature. Among all the identified strategies, change management, dispute prevention and resolution, procurement system and relational contracting are linked to the construction contracts. The Construction Industry Institute (CII) has defined these strategies as the best practice to improve the performance of the project (Safapour and Kermanshachi, 2019). While some research has studied change management to mitigate rework (Mahamid, 2016b; Kermanshachi *et al.*, 2018; Love *et al.*, 2019a), the content analysis revealed that the rework literature lacks implementation of the contracting-related strategies. All the evidence from a comprehensive review of the rework literature confirms that studying rework further in the contract documents is required.

Despite many efforts made to explore rework in construction projects, some gaps were identified through the literature review. Future studies will extend the existing knowledge, so further attempts to analyse any of the identified gaps will provide a higher understanding of rework processing and cover the research shortcomings. Some of the other gaps that were identified during this study are listed as follows:

1) The lack of integrated research on rework in construction projects is one of the areas that needs more attention. Rework causes are very complex and interrelated, therefore proposing a

solution that is only relying on rework causes in one stage does not cover the project life cycle. Thus, integrating all rework causes into a platform consisting of the parties involved and all project stages could be an efficient way to conduct rework management in construction projects. Such studies can be started with a systematic literature review on rework causes to assess and unify previous classification models. Previous studies have adequately reviewed rework in the construction and design stages of a project but studying rework in procurement or tendering is very limited. Poor contract documentation has been identified as a major contributing factor to the occurrence of rework (Love *et al.,* 2006). Assessment of contract documents to discover how a rework situation can be linked with procurement activities may fill the existing gap.

2) The comprehensive literature review revealed that the number of studies on rework management across the construction supply chain is limited only to six papers. The rework process incorporates different project players, including client, consultant, designer, contractor, subcontractor, and supplier (Hwang *et al.,* 2019). The collaboration of all these parties to achieve effective rework management is required. Thus, there are vast opportunities available for the future study of rework based on the perspective of the supply chain management. Moreover, even though several theories, tools, and techniques have been employed in the rework literature, some of the concepts within the supply chain of construction projects still need more investigation such as, off-site construction, modular and prefabrication, lean construction tools and techniques, risk assessment and contract management strategies. The contract is a key element of supply chain management, and the contract conditions have not been studied under rework events yet. Only a few researchers have studied the interconnection of rework and contract documents. None of the study areas

of rework dealt adequately with contract and it is highlighted as a knowledge gap, while rework has adverse effects on contracts by generating claims and disputes.

3) Future research can also work on the study of critical success factors and barriers. During the last 30 years, different models and solutions of rework management have been tested. Nevertheless, based on a review of the literature, no study could be found that has examined the critical success factors of the proposed models, therefore it is a suitable time to study these factors. Better implementation of future solutions will be possible once CSFs and barriers are identified.

4) Many studies are still researching the traditional way for rework management, and there are very few if any studies that could be found using innovative solutions. Research on rework is expected to be incorporated with advanced tools and technologies. In recent years, BIM as an innovation management model shows great potential to decrease rework. However, such results need to be validated at least through some case studies. Exploring advanced technologies such as using a cloud-based information flow or concurrently using BIM and other IT applications in future research is recommended.

5) Transferring lessons learned from previous projects to the next project can prevent the occurrence of rework (Oke and Ugoje, 2013). Lessons learned activates the process of learning, which will enable the organisations to prevent rework (Love et al., 2015). Rework reduction in program alliances is an example of a successful model and can be used as a lesson learned. Program alliances facilitate learning through an organisational culture (Love et al., 2016a). Providing such cultures for cooperative learning instead of focusing on rework reduction may result in better achievement. Thus, future research could bring attention to learning theories and human resources, as rework basically is a product of human errors. Figure

2.2 shows the identified gaps and their relations to the construction contracts which need to be explored and validated in future studies.

Overall, the discussion section highlights the point that assessment of rework in the contract as the main output of any procurement system will result in a better understanding of the rework process by contract parties. It also will allow contract administrators to manage their contracts through rework-related provisions under the conditions of contract. As such, a model that deals with various clauses of the contract can be proposed. This model will reduce conflicts as it gives more awareness to the contract parties at the early stages of the project, and therefore, the consequent claims and disputes will be appropriately managed. The same approach has been employed in some previous studies to manage change orders (El-adaway et al., 2016), safety issues (Abdul Nabi et al. 2020), back to back relationships (Assaad et al., 2020), disputes (Saseendran et al., 2020), time and delays (El-adaway et al., 2020). All these studies have investigated the conditions of the different standard forms of contract by comparing various clauses. The most commonly reviewed clauses of the contract in these studies are the extension of time, changes, claims and dispute resolutions, payments, suspension and terminations, obligations and responsibilities, defects, and the engineer's power. Following a similar approach, the initial review of the commonly used standard form of contract in New Zealand showed that rework is linked to the clauses of variations, time extension, the engineer's power, defect liability, payments, disputes, and general obligations. However, more investigation by conducting surveys and professional interviews will validate such preliminary impressions. Therefore, further studying rework under contract conditions is suggested to achieve more details of the relations between rework and the targeted clauses of the contract.

2.8 Conclusion

The research aims to provide information on rework studies and identify knowledge gaps for further research in construction contracts through a comprehensive review. Based on a four-step literature review, rework papers from 1990 to 2020 were selected and analysed in terms of research interests and their contributions to the body of knowledge. Hence, it has provided a platform to gain more useful information about rework concerns. The results showed that rework had been studied within six distinct research areas. The published papers mainly cover rework effects on project performance, rework causes and rework factors classification, strategies to manage rework either through reduction or prevention modelling, risks of rework, and recently the focus has moved more to safety concepts, learning, and human resources. A considerable proportion of rework studies have focused on rework root causes, explaining that a great effort has been made to understand the nature of rework. Although identifying the sources of rework is the constant theme during the reviewed period, proposing models and solutions and implementing new strategies within a diverse perspective has attracted more interest in the most recent rework publications. A research model or commonly used solution for controlling rework cannot be generalised due to the variety of presented approaches. The analysis of rework research helps practitioners looking for further collaborative research opportunities.

The paper has also identified some gaps for conducting future rework studies such as, the lack of an integrated method of mapping rework in the project life cycle, a lack of rework research in the procurement stage of the project, a lack of study on the critical success factors and barriers of suggested rework models, and there are also some other limitations. Therefore, new strategies are expected to emerge. Evaluating rework causes within the contract conditions could be a novel way to manage rework as the contract is an integrated document among the stakeholders of a project.

It is suggested that rework needs to be considered at the early stages of the project as contract parties plan for the construction. Overall, construction commences after procurement, once the contract between parties is signed off. Conditions of contract is an area that has not received much attention in rework research studies. Furthermore, due to the standard form of contract in most construction projects, the improvement process as it relates to contract conditions seems to have been neglected in the industry. Thus, considering the importance of rework issues at the time of contract preparation could be an effective way of monitoring rework. This paper suggests further studying of rework at the procurement stage of the project and contract is the main output of this stage. Rework also is a contributing factor to contractual claims, disputes, and conflicts among contract parties. Thus, rework can be used as a trigger for contractual improvement by providing a framework to manage contractual claims and reduce disputes. In other words, rework circumstances can be assessed in the conditions of the contract. Such assessment can cover the main related clauses such as variations, time extension, defect liability, payments, engineers' power, and general obligations. The result of the contractual assessment provides recommendations for revising the contract's clauses and minimising the loss in value that originates from the necessity to rework. Furthermore, the framework serves as a guide for adopting the condition of the contract. It also facilitates the development of more efficient approaches by decision-makers in the early stages of the project.

In sum, the approach used in this study is not without limitations. The lack of using the complex combination of similar keywords is the limitation of this study. This limitation can be justified by the inapplicability of studying all related publications in one review study. The main focus of the study is on the matters related to rework. Thus, the results are subject to the limited keyword of rework. The criteria for selecting the keywords may seem narrow for the unit of analysis, but the cross-check approach within three databases provided a wide range of related publications. The identified 140 papers included in the content analysis were deemed reasonable for extracting required information. Nonetheless, the employed approach is considered appropriate according to the study's aim to be aligned with the construction contracts.

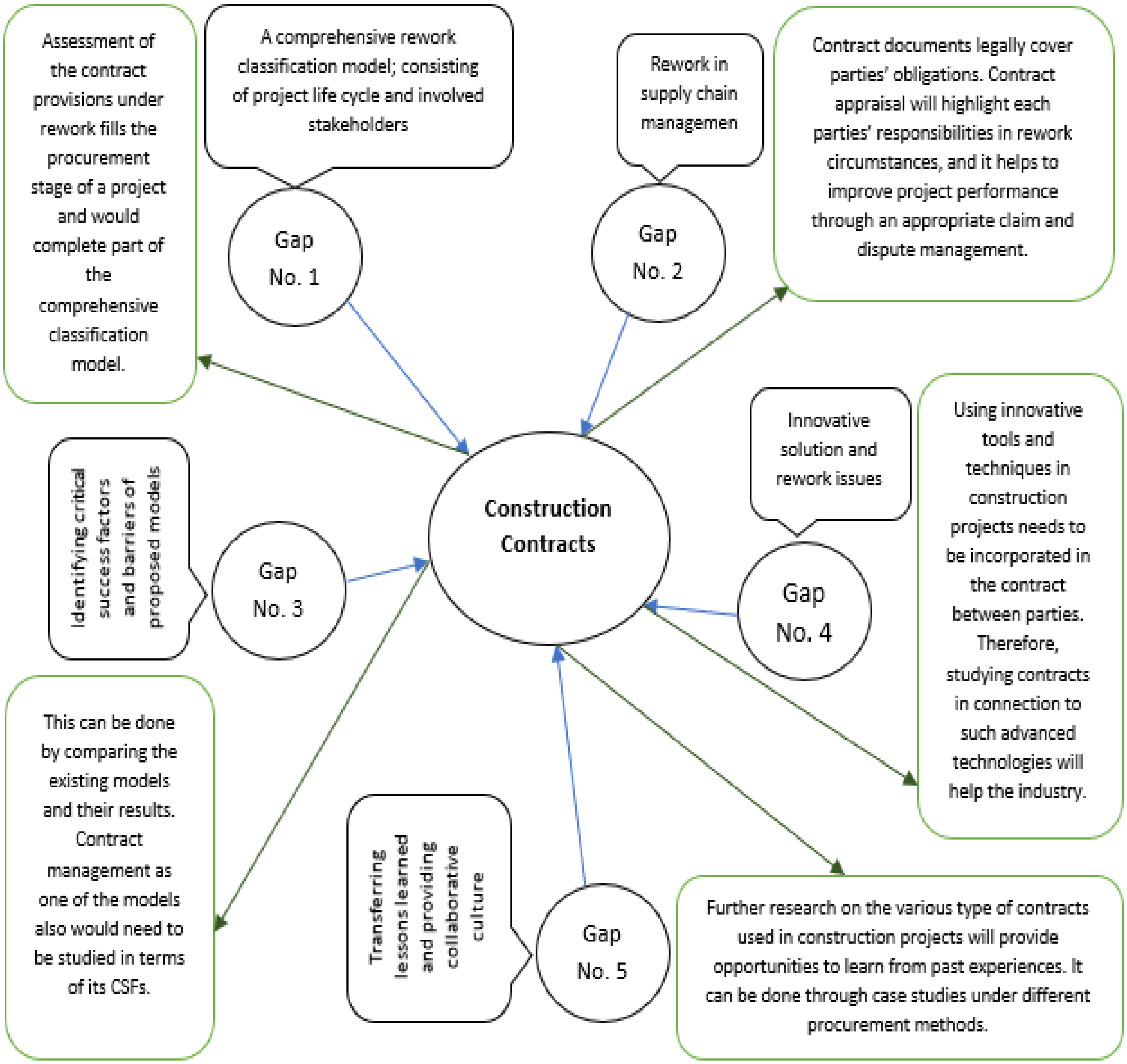
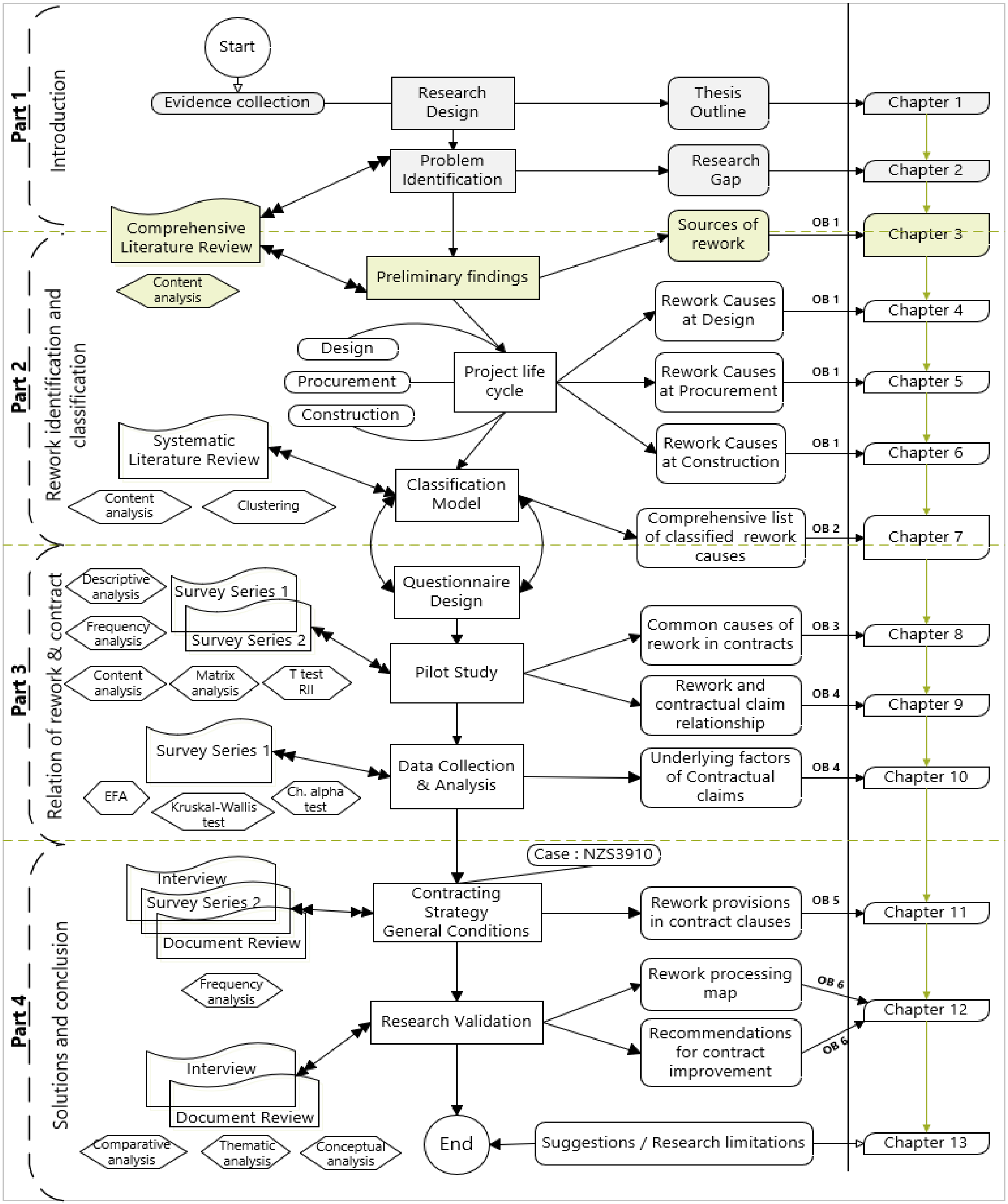


Figure 2.2: *Identified gaps and their relations to construction contracts, a diagram for future studies*

2.9 Epilogue

This chapter presents the key concepts of previous study areas and some theories and strategies around rework. It categorizes the study areas of rework in five clusters through a comprehensive review. Various models are outlined following the concepts of rework reduction and prevention. This chapter also sheds light on the main impacts of rework overall. The fundamental outcome of this chapter highlights several knowledge gaps surrounding rework. It proposes the drivers for further studying of rework in contraction contracts. Thus, the conceptual outlines for further rework studies in the contract and the procurement stage of the project are required to be carried out. As such, in the next chapter, the practices and policies for rework management will be reviewed within the perspective of the project life cycle to present an overview of rework root causes in three main stages of design, procurement, and construction.

Thesis-at-a-Glance / Chapter 3



Chapter 3. Rework management in life cycle of project: An outline for construction contracts

3.1 Prologue

The past practices and studies on rework and the currently used form of contracts in New Zealand are examined in this chapter. More focus on the root causes of rework in this chapter will be carried out based on the main concepts extracted from the literature in the previous chapter. New Zealand construction industry experiences using the various standard form of contracts. The evaluation of the contract terms would require the identification of relevant problems in the construction industry. This chapter will look at rework as one of the current construction issues. Thus, the first step of rework causes identification is reviewed in more detail to give an overview of rework root causes throughout the project's life cycle. Overall, the chapter discusses the number of root causes in each project stage with liable contract parties to bring attention to the contractual terms and conditions. As such, the chapter summarises the current legal forms of contract in New Zealand and then categorises rework causes in a designed classification model including both sides of the contract. It concludes the necessity of further concentration on the project's procurement stage by providing evidence from the literature.

This chapter is based on the following published paper:

Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2020). Rework management in life cycle of project; an outline for construction contracts. *Proceedings, 6th New Zealand Built Environment Research Symposium (NZBERS 2020)*, ISSN 2463-4905.

3.2 Abstract

This paper presents classification of rework root causes (RRC) in the life cycle of projects. Rework is one of the main causes of cost and time overrun and affects project performance. Higher project performance will be achieved by reduction of rework through addressing rework root causes. The research investigates international and local past experiences on construction rework, possible associated standards and relevant regulations and policies for implementation. Through literature review of selected papers from the academic journals and conference papers, the causes of rework are identified in three stages of design, procurement and construction as the key elements of project life cycle. Analysis of rework root causes in the literature over a designed classification model in methodology section was the method used for the results of this study. Critical reviews on each stage are presented by distributing rework root causes in five categories of process, human resources, material and equipment, technical and other related factors. Contract conditions and clauses of NZS3910-2013 as the main used standard document for contracting in New Zealand are evaluated based on this classification. This paper provides a base for industry to bridge the identified knowledge gap between contracting and construction rework. The paper recommends that rework can be managed though contract documents.

Keywords: Classification, Construction, Contracts, Life cycle, Rework,

3.3 Introduction

Project performance is measured with the parameters of cost and time. When time overruns causes delay and cost overruns changes the budget, project performance is experiencing fluctuation. Rework is the key factor that mostly responsible for causing these overruns in projects (Hwang et al., 2009). It has been confirmed that rework is a predominant and persistent problem in construction projects. Nonetheless, construction industry has not been investigated well enough as research results still are inadequate in this area. Since construction firm's reputation is affected indirectly with the consequences of rework, the occurrence of rework is not announced willingly by the industry (Love et al., 2016a). Institute of Construction Industry has proclaimed the average cost of rework is equal to five percent of total construction cost. In addition, a strong correlation between time overruns and rework has been reported in previous research studies. Thus, rework in construction industry can be considered as a practical issue that influences project performance.

Project performance can be altered with some other triggers. Procurement and contracting strategy are among those key elements that play a vital role in the success of construction projects. The structure of cooperation amongst project participants is founded on contract documents as a final output of procurement. The potential change of contract conditions and necessity of revising the form of contracts have obviously repeated over again among studies of legal various contract frameworks (Chan and Chan, 2017). Contractual relationship development between construction practitioners will result in an acceptable level of construction performance improvement. Conventional way of project delivery almost makes conditions to debate in relationships. When projects are more complicated, relations of contractor and client need to be coordinated precisely to avoid contractual disputes (Pesamaa et al., 2009). New contracting strategies can decrease such interference of relations through defining the common goals among construction parties (Construction Industry Review Committee, 2001). Furthermore, collaboration of construction participants will be improved when ambiguity has been removed in contract conditions.

Rework research has contributed to the body of knowledge mainly through identifying rework causes, measuring rework impacts and proposing rework reduction models. On the other hand, research results on different features of contract in recent years have shown a trend towards shifting from traditional procurement system to contractual models. Industry practices show the same tendency for using standard type of contracts. Thus, literature review in this paper will be on two aspects of; Rework as an identified weakness in construction industry and contracts document as the final output of procurement stage. Theories around rework, guidelines for optimizing the impacts of rework and the methods of rework reduction will be presented in the first part of the literatures, and the second part would be on different type of contract, standard contracts and its documents.

3.4 Literature review

3.4.1 Section 1: Rework

Rework can be defined as an effort for redoing an activity or a process that was implemented incorrectly for the first time (Mahamid, 2016a). Despite various interpretation of rework in the literatures there is a common understanding that relays on repeating a work due to nonconformity with the requirements (Hwang et al., 2009). Such nonconformance can be raised from different sources such as project specifications, client requirements or contract documents (Oyewobi et al., 2011). Rework in construction industry is considered as waste as does not add extra value to the process, while it uses time and other resources (Bhatl et al., 2016). Measurement of rework impacts to determine cost and time will not be accurate when there is no difference between rework, changes, defects, errors, fault, failure and deviations (Forcada et al., 2017). The success rate of rework reduction drops by using these replace words among practitioners instead of rework (Aiyetan and Das, 2015; Hwang et al., 2014; Kakitahi et al., 2014; Taggart et al., 2014).

Construction industry is not able to manage rework when the main sources of rework remained unknown (Ye et al., 2015). Rework causes identification is the first step towards rework management. Rework can arise from complicated characteristics of construction processes (Hwang et al., 2009) such as errors, omissions, failures, damage, and change orders (Mahamid, 2016a). Since rework occurs at field many of previous rework methods and definitions have not been succeed in addressing the exact causes of rework. Thus, various rework classification models have been emerged in construction industry for categorizing identified rework causes and measuring their impacts.

3.4.1.1 Classification of rework

Despite the various points of view on classifying rework root causes, having a model to manage rework consequences is essential when sources of rework were identified (Hwang et al., 2009). Following by some rework classification approaches in past few years the most recent system for classifying rework causes have typically been arranged in groups of "Engineering and reviews, Construction planning and scheduling, Leadership and communications, Material and equipment supply, Human resource capability" (Zhang et al., 2012) and "Client related, Design related, and Contractor related factors including subcontractor and site management" (Aiyetan, 2013). Some more details for above mentioned factors that have been classified by previous scholars have been presented as follows;

- Design related factors: It has been emphasized that the numbers of originated rework at design stage are higher than construction. Inaccurate detailing, incorrect specifications, legislations, inadequate coordination, poor communication, lack of supervision and constructability are the factors that attributing to rework at design stage (Aiyetan, 2013). Errors and omissions are the most significant root causes of design related factors (Hwang et al., 2009).

- Contractor related factors: The contractor related factor can be considered under site management related factors and subcontractor related factors (Aiyetan and Das, 2015) as mentioned hereafter.
- Site management related factors: Poor planning and coordination of resources and ineffective use of quality management practices are the most primary causes of rework in site management. Furthermore, the extensive reliance on traditional approaches and non-availability of specific IT for rework tracking is also known as other important contributing factors in this category (Ahmed and Naik, 2016).
- Subcontractor related factors: Inadequate managerial and supervisory skills and the carelessness by subcontractor are the primary factors that contribute to rework (Aiyetan, 2013). Multi layered subcontracting, low skill level of laborers in subcontracted works and poor-quality material used by subcontractors have identified as highly contributing factors of rework as well (Aiyetan and Das, 2015).
- Client related factors: Material replacement and change of plans and scope are the most contributing client related factors. Since change orders are the major source of rework in construction projects, all identified causes of change can be replaced as the main causes of client related rework factors (Hwang et al., 2014). Lack of experience, lack of allocated funds, lack of involvement, poor communication and shortage of contract documentation are the other major client related factors of rework (Ahmed and Naik, 2016).

3.4.1.2 Causes of rework

Designing a classification model that shows all relevant categories of rework root causes can be founded on identified causes of rework from literature. A model with considerable flexibility for various construction groups will cover many of identified construction weaknesses that are originated from rework. A classification system that consists of all identified rework causes can be used for any consequent required action in process. To achieve this goal all identified causes of rework from literature need to be sorted in a comprehensive list. More details of preparing this list have been presented in methodology section of this paper. Here are some samples of rework causes from literature.

Owner change and design error and omission, (Hwang et al., 2009). Site management and subcontracting, project communication, project planning and resourcing, design time management, client changes (Love et al., 2009b). Errors, omissions, failures, changes and poor site practice (Oyewobi and Ogunsemi, 2010). Supervision, workmanship, subcontractor selection, work protection and sequencing (Wasfy, 2010), poor effective use of information technologies, excessive involvement of client in project, lack of clearly defined working procedures, poor communication, ineffective leadership and changes initiated by the contractor to improve quality (Love et al., 2010b), damage due to carelessness, poor planning, coordination of on-site resources and use of low quality materials (Aiyetan, 2013).

Interpretation of drawings and specifications, use of superseded drawings and specifications in the supply chain, lack of supply chain coordination, poor employee training, low skill level of subcontractors, lack of on-site inspection (Taggart et al., 2014a), poor information (Simpeh et al., 2015), Non-Conformance (Maheswari et al., 2016), schedule pressures, reduction of motivation to work, communication between clients and design consultants (Mahamid, 2016a), poor project documents and ineffective decision making (Enshassi et al., 2017). Lack of understanding for end-user requirements, poor contract documentation and low consultant fees, lack of a quality focus, design audit and review, interface management, unrealistic schedule, poor project governance, staff turnover and lack of scope definitions (Wilson and Odesola, 2017).

Table 3.1: An overview of total rework cost from literature

Total rework cost	Direct cost	Indirect cost	Type of project	Year	Authors
10.29% of the contract value	5.07% of the contract value	5.22% of the contract value	Civil infrastructure projects	2010b	Love et al.,
3.47% of the contract value	9.88% as total cost overruns	-	Building project	2011	Oyewobi et al.,
5.06% of the contract value	-	-	New Building	2011	Oyewobi et al.,
3.23% of the contract value	-	-	Refurbished building	2011	Oyewobi et al.,
16.5% of the contract value	-	-	Civil infrastructure projects	2014	Forcada et al.,
3% to 6% of the contract value	-	-	Construction	2017	Yap et al.,

3.4.1.3 Rework cost impacts history

Impacts of rework in construction projects are mainly cost and time overruns and degradation of contractors. Positive relationship between rework costs and variation as well as time overrun implies that an increase in rework cost will give rise to an increase in variation cost and project duration (Oyewobi et al., 2011). Cost growth and schedule overruns are significantly correlated with direct rework costs, which suggest that rework can adversely influences project performance (Forcada et al., 2017). Project time overruns and delay reduces contractors' credential and the unpleasant cost impact of rework is damaging contractor's reputation (Love et al, 2016). Table 3.1 shows various reported cost of rework (Wilson and Odesola, 2017; Forcada et al., 2017; Love and Smith, 2018).

3.4.1.4 Rework reduction strategies

Different methods have been used to control of rework occurrence and mitigating its impacts as it has been shown in Table 3.2.

Even though studies of different construction and design processes have successfully contributed to rework management, they have failed to provide strategic directions for rework management with the perspective of project life cycle. Construction rework research normally have focused on the general issues of reduction models, rework impacts and allocating of resources to solve the problem partially and separately in design or construction stages. In other words, rework root causes have not been fully examined within the life cycle of project yet and this would be considered as a research gap. Furthermore, among various rework studies in the literature, there is no approach has been proposed to incorporate rework with contract documents under context of project management. Since investigating contract documents of construction projects based in New Zealand has not been explored yet, looking for an optimize approach of rework management through contracting process is the novelty of this research.

3.4.2 Section 2: Contracts

3.4.2.1 Trend of changes in using different types of contract

Contractual agreement for construction projects does as a permit to start the practical work after completing the procurement stage. Contract that is a confirmed document between parties is crucial as it determines the overall construction framework including responsibilities structure for each party, stakeholder’s authorities, covering risks and any other relevant issues, which may happen during the execution of construction project. Construction projects are mostly complex process as it generally involves long period with participation of many stakeholders and ambiguous contractual relationships (Oyegoke and Dickinson, 2009).

Table 3.2: Methods and strategies on rework reduction and mitigation

Focus "Supporting Tool"	Reference	Year
The effect of BIM	Hwang et al.,	2019
Regression model	Forcada et al.,	2017
Motivations and leadership	Love et al.,	2016a
Supervision	Shinde and Kulkarni,	2016
Rework probability model	Simpeh et al.,	2015
System dynamics methodology	Li and Taylor,	2014b
Role of supply chain	Taggart et al.,	2014a
Overlapping strategy matrix of design and construction	Hossain and Chua	2014
The probability of rework occurrence (risk control)	Love and Sing,	2013
Rework reduction program (RRP)	Zhang et al.,	2012
Stepwise multiple regression	Love et al.,	2010a
Rework cycle	Rahmandad and Hu,	2010
Pre-project and quality management plans	Hwang et al.,	2009
Characterizing the sensitivity of downstream construction activities	Blacud et al.,	2009
Using AAN method	Palaneeswaran et al.,	2008

Most of the projects were completed under the traditional system of lump sum contracts and this trend continued to middle of twentieth century except for some private sector that developed design and build model to improve relationship, schedule and cost by approaching contractors. Following by that, construction management terms (CM) began to start and soon after fully developed in United Kingdom. Simultaneously the other method of consultative design and build was developed, but client's request to complete complex projects in a more efficient ways caused emergence of program management in 1980 and onwards. During the late 1990s and early 2000s other types of management approaches such as (FA) framework agreement based on teamwork concept, collaboration arrangement and integrated teams became more predominant (Oyegoke and Dickinson, 2009).

3.4.2.2 Common contract models in construction

Some of the most applicable contract models in construction industry are as the following:

- Traditional lump sum contracts: This contractual model is very common within industry. Most of contractors and clients have familiarity with this model. The consequences of this flow are design development, tendering, contract awarding and then delivery of construction. It is expected that design stage to be finished before tendering to get a fixed price of construction cost. In most construction projects design is not completed when construction starts, and it provide opportunities for contractor to ask for variations and claim for extra pays. Thus, one drawback of this model is to prepare ground for confrontational approach over disputes.
- Build, Operate, Own and Transfer: BOOT is a group of models that is common for PPP "Public Private Partnership" and PFI "Private Finance Initiative" type of projects. This model provides a way for governments looking for finance in private sectors. According to this model advocated for schemes such as railways, tolled roads, tunnel and bridges (Zuo, 2010). Contractor as part of a consortium is taking all responsibilities of design, construction plus operation and client is taking lower cost risk. However, client that in most of cases is government cannot use this model for small projects without future stream of payback.
- Design and Build: In this model an organization, which is usually a contractor will be fully in charge of two major parts of design and construction of project. The contractor can subcontract or have a joint venture with a design firm to manage the project.
- PM/CM and on call contracting: In both case client hires a master contractor to get consultant and manage the project. In combined project management and construction management "PM/CM", an organization that called "management contractor" will do three main steps of representing to client, leading a design team and giving advice to contractor's team while they

are performing construction processes as work packages. PM/CM takes a contractual agreement that carries financial risk within. On call contracting is the same method with slightly deference in executing the last part of processes. In this model, the whole work is divided into task. Task orders are smaller in scope and have more details compare to work packages in PM/CM. The approach of task order removes the uncertainty as it enables the project to be well defined, planned and controlled on budget as mini contracts are involved. Administrating too many subcontractors in this model in compare to PM/CM is one of the disadvantages.

- Guaranteed maximum price (GMP): In this model all parties “Client, Consultant and Contractor” will agree on a negotiated maximum sum that will be paid by client with a reimburse method, so any overspending of this agreed figure “GMP” due to mismanagement of contractor and consultant will be under their responsibilities. Thus, the risk of cost for the client is very limited. Relationship in this model is almost the same as D&B, but the major difference between them is that the design is fixed, and it used as the negotiated price limit with open book reimbursement from the client side.
- Full cost reimbursement: In this model contractor is chosen to take the project under a cost reimbursable base with an agreed allowance of overhead and having profit. This model takes the concept of GMP with development to another level as full cost reimbursable instead of using open book for partial. The cost risk for client in this model is the highest among all models. Auditing system is a critical element of this approach as client needs to be confident about both contractor and design team performance.

Evidences indicate that while trends toward using the traditional general contracting has decreased over the past few years, other type of contracts such as design and build contracts and cost reimbursable contracts have been used more frequently in contrast (Oyegoke and Dickinson, 2009).

3.4.2.3 Standard contracts

Various parts of construction industry have developed different groups of standard contracts for a variety of reasons such as meet the specific purpose, distributing risk among parties and making it suitable based on used contractual models. There are some international standard contracts are commonly used as well. The most well-known international standard contracts are, FIDIC, NEC and JCT. Apart from international standard forms of contracts there are numbers of contract standards are using in New Zealand as listed as the following,

- NZS 3910: This is one of the most commonly used construction contracts, which is used for building and civil engineering construction.
- NZS 3916: Conditions of contract for building and civil engineering construction-Design and construct
- NZS 3917: Conditions of contract for building and civil engineering construction-Fixed term
- MBS Standard Contracts
- NZIA SCC: Has a leaning towards protection of the architect involved in the project
- RBC1: (NEW BUILD): Prepared for use by Registered Master Builders and it is available for use on building contracts
- NZIA NBC-G
- NZIA NBC-MW
- NEC3

Among all above mentioned contracts the standard form of NZS3910 is the most common used document in New Zealand (Ali and Wilkinson, 2010) that will be the core of evaluation in terms of classified rework root causes obtained from this research study.

3.5 Methodology

Rework management is complex and dynamic throughout the project life cycle of design, procurement and construction stages. Knowledge gaps for further research can be identified by the means of literature review (Bao et al., 2018). Although there is an increase of interests in reviewing rework topics over the years, a systematic literature review of rework from the perspective of the project life cycle has not been available. In this study the review was conducted through papers relevant to the topic of rework in construction projects to classifying rework root causes into distinct stages of project to facilitate future study on links between rework and contract documents. Choosing an effective strategy to manage rework will be simplified by better understanding of where the main problems are from a project life cycle perspective.

Table 3.3: Overview of journals and selected papers

Source of papers "Title of Journals"	Number of reviewed papers
Journal of construction engineering and management	8
Civil engineering and environmental systems	3
Journal of management in engineering	3
Production planning and control	3
International journal of project management	2
Construction management and economics	2
Journal of Construction Project Management and Innovation	2
Structure and Infrastructure Engineering	2
International Journal of Sustainable Construction Engineering & Technology	2
Conference papers and thesis	7
Other journals	29

To find out more about rework root causes details in each stage of project, the papers published between 2005 and 2019 were reviewed in this study. Reference to the method used by (Bao et al., 2018) rework literature published in above mentioned years obtained and analyzed through the following approach. Rework papers in relevant journals were selected by using keywords of “rework” in paper titles within suitable search engines. Over 63 papers were directly relevant to construction projects and were selected to review including 56 journal papers from 38 different sources and 7 conference papers and thesis. More details of used papers have been presented in Table 3.3. All identified rework root causes were listed by reviewing the selected papers in the next step and then distributed in each stage of project life cycle based on the following classification model.

3.5.1 Design a classification model

Since this research would provide the base of further study on rework management through contract documents in each stage of project life cycle, a classification model to cover all future requirements need to be designed. Therefore, the following model including three levels has been developed in which all similar identified causes can be categorized in a single section.

3.5.1.1 Level 1: contract parties

Different organizations may involve in executing of a construction project, but to make this model simpler only two direct parties of a contract have been customized. Client and all subsidiaries working for client such as consultants or other legal entities have been set in one side and contractor and all relevant subsidiaries such as subcontractors and suppliers have been set in the other side of contract.

3.5.1.2 Level 2: Project Phases

According to PMI "Project Management Institute" a life cycle of project is consisted of developed sequences from initiation to closing. In construction industry this definition will hold three main stages of design, procurement "tendering" and construction. Accordingly, all identified rework root causes have been categorized in these three stages. In this level of classification model, the following steps were considered to maximize the accuracy of assigning each cause to each stage of project:

- Identify rework root cause of relevant paper designation as precisely as possible
- Match this information with project stage details to find a direct relation in between
- Merge similar rework root causes in each stage to simplify and optimize the result

3.5.1.3 Level 3: Root causes

Investigating of rework causes classification in the main used references for this paper indicated that each author has applied a certain model that is vary from each other. To reach an integrated classification model considering two pre-mentioned levels, this paper has categorized all rework root causes in five subdivisions (Hemanta et al., 2011; Mahamid, 2016a).

- Process related factors
- Human resources related factors
- Material/Equipment related factors
- Technical related factors
- Other related factors including financial and environmental

The ultimate expected output of the research would focus on identifying and classifying the main causes of construction reworks and their roots, which embedded in contracts. The study will come up with development of a comprehensive list of classified rework root causes in each stage of project to find out relations with contract documents.

3.6 Findings

Analysis of papers showed that all identified rework root causes in literature are available in seven most recent studies between the years of 2009 to 2017. Two significant features of these seven papers are; all published in a well-known journal worldwide and all have a list of rework root causes that make them easier to evaluate (Asadi et al., 2019). All distributed rework root cause from literature at first level of designed classification model showed a total number of 374 as can be seen in Table 3.4 and Table 3.5. Following the steps at each level of deigned classification model will result in a total of 316 items including internal and external root causes of rework in life cycle of project (Asadi et al., 2019). It shows that the total numbers of 58 items have been repeated at the time of distributing rework root causes among the classification matrix. Repeating items were containing of 34 items in design and 24 items in construction stage.

3.7 Discussion

To better management of rework in construction projects this study has provided details information of rework root causes through literature review. Based on search method and three level of classification model, a total number of 374 rework root causes were identified and classified through distributing within project life of cycle. Identifying the connections between rework root causes and stages of project may benefit the construction industry as it depicts where problems need to be considered in a certain area. Analysis showed that while distribution of rework root causes is seen within life cycle of project each level of classification model holds different numbers of rework root causes. Since all records in Table 3.4 and Table 3.5 of finding section are counting the numbers of rework root causes for each section, the subsequent results are discussed just in terms of quantity regardless of rework impacts.

Table 3.4: Numbers of classified rework root causes in client and contractor side of contract

Category	Client	Contractor
Process	39	31
Human resources	22	45
Material and Equipment	2	22
Technical	61	86
Others	32	34
Total	156	218

In terms of contract parties in first level of classification model the total number of 218 rework root causes have been allocated to contractor while this figure for client side is showing as 156 root causes. The Construction stage includes the greatest number of causes of 220 among all tables, while the procurement stage consists of the lowest number of 18 causes. In third classification level, technical related factors with the total numbers of 147 are showing as the most contributing causes of rework. In contrast, Material/Equipment related factors with total numbers of 24 have been ranked as the lowest. The highlighting of procurement stage for holding the lowest number of rework root causes is understandable as this stage is only limited to a few months of tendering and will be closed after contract issuance. When figures of Table 3.5 are judged individually the sum of three specific factors nearly are calculated as the half of the total identified rework root causes. These figures show that process related factors in design stage following by technical related factors in design and construction stages can be considered as critical areas for rework management.

3.8 Conclusion

Rework and reduction strategies of rework impacts have received extensive attention in recent years; nonetheless rework is suffering construction industry probably because projects are measured out of the project life cycle context (Xue et al., 2010). This study has provided a platform to give more insights to the matter of rework with the perspective of project life cycle. Although rework has been reviewed as the core of this study, it is acknowledged that this review is only limited to the identification of rework root causes. Considering all identified rework causes from literatures and classified their roots, a comprehensive list of rework root causes for each stage of project is prepared as the main result of this paper. Classification of rework root causes at this level may allow projects to be managed more efficient. However, the analysis of literature over 63 papers showed enough evidences to cover all stages of project life cycle, more study on rework management specifically in procurement stage will be recommended in future.

Table 3.5: An Overview of distribution of rework root causes in life cycle of project

Stage	Design			Procurement			Construction			
Factors	Client	Contractor	Total	Client	Contractor	Total	Client	Contractor	Total	Total RRC*
Process	25	17	**42**	4	3	**7**	10	11	**21**	70
Human resources	20	14	**34**	0	0	**0**	2	31	**33**	67
Material/Equipment	1	0	**1**	0	0	**0**	1	22	**23**	24
Technical	30	16	**46**	5	2	**7**	26	68	**94**	147
Others	11	2	**13**	3	1	**4**	18	31	**49**	66
Subtotal of	88	48	**136**	12	6	**18**	57	163	**220**	**374**

*__RRC__ is abbreviation used for Rework Root Causes

The outcomes of this research inspire more studies around rework management by focusing on project stages or even more detailed on each stage that have been previously underestimated. Particularly, this research suggests that contract document which is the final output of procurement stage as well as starting point of construction needs more investigations in terms of rework management. A preliminary study on covering of rework root causes by the contract clauses and its attachments will prioritize the importance of each related factors based on project stage. The paper suggests that better rework management will be attained through revising contract clauses and its attachments. The results of this paper will consist of independent variables for further research to find relations of rework and contract documents. Searching for this relation can be implemented based on a list of Rework Root Causes (RRC) against clauses of contract for each stage of project through a questionnaire. Details of this questionnaire after removing repeated causes among various papers and unifying the same themes are structured as 48 RRC in design stage, 15 RRC in procurement stage (Asadi et al., 2019) and 47 RRC in construction stage.

3.9 Epilogue

This chapter identified rework root causes in three stages of the project and investigated the distribution of rework causes on each side of the contract. It is observed that the project's construction stage carries the majority of rework causes followed by the design stage. Compared with these two stages, only a few numbers of rework cause incorporated into procurement. In construction, most of the causes rely on the contractor side of the contract, while it primarily relies on the client-side in the design stage. In general, root causes of rework can be grouped into five clusters of process, human resources, material/equipment, technical, and others "general/external." The result also showed the highest rework causes under the technical group, while material and equipment encompass the lowest rework causes.

Further investigation of rework in the contract would require the identification of rework root causes. The identification of rework causes can be achieved through a literature review in each stage separately. The following chapters cover more details of rework root causes in design, procurement, and construction with liable parties of the contract. The project's life cycle generally starts with design, so rework in this stage of the project will be reviewed in the next chapter to identify the root causes that can be addressed for the assessment and improvement of the contracts.

Part two

Classification of rework in contracts

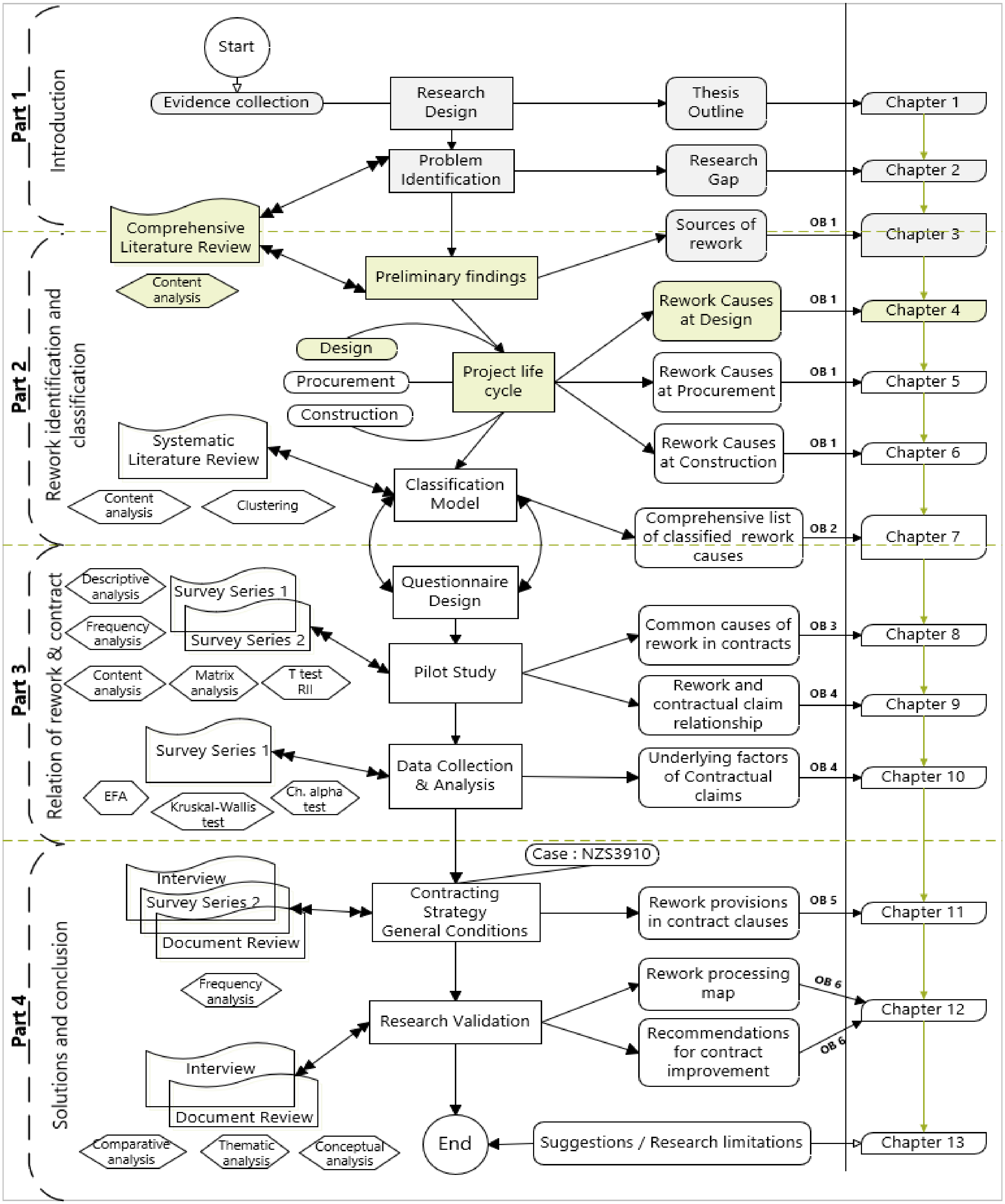
Chapter 4. Classification of rework root causes in the design stage of projects for contract assessment

Chapter 5. Contract documents appraisal and rework root causes classification in tendering stage of project

Chapter 6. Contracts evaluation through classified rework root causes in the construction stage of projects

Chapter 7. Rework classification model in the project life cycle with liable parties of the contract

Thesis-at-a-Glance / Chapter 4



Chapter 4. Classification of rework root causes in the design stage of projects for contract assessment

4.1 Prologue

This chapter reports the root causes of rework from a literature review focusing on the design stage of the project. The results of this chapter partially meet Objective 1 outlined in the first chapter of this thesis. The project's design stage is an important part of the project life cycle that generates most of the preliminary required documents of the contract for construction projects. The critical effects of design in the construction rework occurrence have been discussed and emphasized in previous studies. In this chapter, an introduction to rework in design is initially presented, followed by a detailed review of the sources of rework in the design process and some strategies to manage rework. It then analyzes the causes of rework in this stage and categorizes identified causes according to the previously mentioned classification in two sides of the contract. Classified causes of rework are then subjected to discussion by comparison between the number of causes in each side of the contract. Further discussion on the results of rework causes under the project's design stage is presented at the end of this chapter.

This chapter is based on the following accepted paper:

Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Classification of rework root causes in the design stage of projects for contract assessment. *CIB World Building Congress (2022).* ID: 9.

4.2 Abstract

Rework is one of the leading causes of cost and time overruns that primarily affect project performance. The performance of construction projects can be elevated with the implementation of rework moderation strategies. Identifying rework root causes is the first step of rework management followed by a mitigation approach, reducing or preventing strategy. As the contract is the core connection between clients and contractors, using a rework management approach in the contracting process allows participants to be aware of rework impacts before the project's commencement. Selecting the best approach for rework mitigation depends highly on the causes of rework and their classified roots. Thus, the paper classifies rework root causes in the design stage of projects to provide a platform for contract documents assessment. The method used to classify the identified rework root causes into five categories was designed based on the literature. Results from collecting secondary data indicated all categories in the design stage of the project, consisting of technical, human resources, process, material/equipment, and other related factors. The next step of the study is to assess contract documents through a questionnaire based on these classified factors in search of a connection between rework, contractual claims, and clauses of the contract. The paper recommends that assessing contract documents can be used as a new approach for rework management.

Keywords

Classification system, construction performance, contract documents, design, rework causes.

4.3 Introduction

The construction industry has been criticized widely for poor performance and inefficient output as it has faced significant problems of unappropriated financial performance. The other main construction problems are the high cost of project delivery and the inability to complete projects on time. One of the major factors contributing to these problems is reworking. Rework has been identified as a significant factor contributing to poor project performance by construction professionals (Love and Edwards, 2004a). An appropriate strategy for reducing the impacts of rework cannot be effectively implemented with little familiarity with the rework background. Rework can remain a fundamental problem when there is not enough knowledge about the causes of rework (Ahmed and Naik, 2016). Thus, a full understanding of the contributing factors in rework occurrence will be an essential part of rework management studies.

However, rework occurs for different reasons and affects construction projects; few industry standards exist for defining, quantifying, and classifying rework root causes. Selecting and specifying a general preventing measure by comparing the results of previous rework studies is not an easy decision (Forcada et al., 2017). There is no uniformity of collecting data in previous studies (Love and Smith, 2003) and their interpretations are almost different (Palaneeswaran et al., 2008), so collecting data on rework is usually difficult. To understand more about the causes of rework, various type of rework needs to be classified first. Previous studies have designed and applied several classification systems at different levels based on their research needs as follows.

- Three levels of activities, causes, and rework sources (Burati et al., 1992)
- Five categories followed by cause & effect diagram (Robinson et al., 2004)
- Three groups of client, design, and contractor (Love and Edwards, 2004a)
- Four groups of contractors, client, consultant and environmental (Mahamid, 2016a)

There are some differences between design rework and construction rework (Hwang et al., 2009). Design rework occurs with client changes in scope and specifications, design, and procurement errors, while construction rework results from a lack of implemented techniques and poor construction management policies. More studies after this conclusion in 1986 showed that the causes of rework in each stage of the project are not limited only to these items, and the list of rework causes was completed gradually by more investigation of different types of projects. In line with this progress, this study aims to identify and classify the underlying causes of construction rework in the design stage of the project, and then it explores the relations between contract clauses and rework through an investigation on contract documents. These objectives can be achieved by preparing a comprehensive list of all identified rework root causes and developing a model for classifying them in the design stage of the project. The results of this study are systematically accomplished through literature as described in the methodology section of this paper.

4.4 Literature Review

4.4.1 Design Process

The employed design process approach affects construction projects (Sacks et al., 2009) as common delays are mostly linked with drawings and other design deliverables (Hossain and Chua, 2010). The design process is a major source of issue for the following stages; as an instance, design changes make construction more complicated, and tender deficiency in the procurement stage rises with design incompetency (Mazlum and Pekericli, 2016). Unlike the manufacturing process, design in construction projects is not duplicating, so the applied model in a design project cannot be developed for the other one. In addition, the design process of a project involves various disciplines, activities, and resources in which all design variables are dependent. These dependencies vary for each construction project and are prone to make design errors that reach rework at the end (Hossain and Chua, 2010). Rework as an important waste in construction projects is mainly addressed to unclarified and disordered design tasks when the project starts (Mazlum and Pekericli, 2016). Process models that enable projects to determine the location of rework causes in design activities will assist in preventing rework occurrence. Dependency relationships of the design activate model is an example that has been examined to minimize the negative effects of the design process (Hossain and Chua, 2010).

4.4.2 Rework in Design Stage of Projects

The construction of a facility is highly dependent on design; therefore, any error or omission in the design documents can affect the construction process (Love, 2002b). A suggestion was given for extending the same methodology to the design stage of projects when all objectives of the rework pilot study for field construction have been achieved (Rabinson et al., 2004). This suggestion consented that rework in the design stage of projects can be measured and reduced by modifying and expanding a similar approach. Design-related causes of rework were investigated later with other studies to uncover the causes of rework (Love et al., 2011; Hwang et al., 2014). Causes such as change requests by the design team and contractor, change orders in design by a client after undertaking work on-site, and design error and omissions originate significant rework in the construction stage (Palaneeswaran, 2006; Hwang et al., 2009; Love et al., 2011). Imposed pressure by clients on design firms to provide design details and an unclear communicated requirement to designers are the main reasons for design error. Also, tight design schedules make incomplete information, leading to design omission (Wilson and Odesola, 2017). Effective communication between the project team and client can mitigate part of these changes and design errors.

4.4.3 Design changes

Changes are part of the exploratory nature of design as the content and structure of design activities are dynamic (Pilehchian et al., 2015). Change in design may continue even after the starting construction stage. Design changes often make unexpected side effects such as delay, defects, and cost overruns, and sometimes it may become a source of project failure. Design changes are often discovered when the practitioners are adjusting or looking for an alternative way of correction, though design change impacts are mostly overlooked. With such an attitude, the consequences of changes cannot be evaluated (Pilehchian et al., 2015); however, identifying and analyzing design change consequences on time is essential for a construction project to succeed.

The design change is the most influential factor between the number of causes that make changes in construction projects. All identified causes of design change have been classified into two groups of internal and external. Client, designer, consultant, and contractor are among the internal sources of causes and natural environment, economic, politics, third party and advanced technology are among external sources. Empowering clients in the design process is an effective way of rework reduction (Love et al., 2004) as a client has the most influence on the design change occurrences (Yana et al., 2015). Less involvement of the client at the design stage is probably caused by the addition or removal of the work from the main contract, which is called scope changes. When scope change happens after completing the work, it may lead to major rework with extra cost whereas, it may consist of lower-cost impacts when it is announced before the commencement of construction (Vachara and Cheang, 2015). According to Vachara and Cheang, change issues in the design stage are:

- Scope change by owner,
- Design function change due to client's requirement,
- Change due to design errors by designer,
- Change in specifications by designer,
- Change due to poor and incomplete design by designer,
- Design change due to inconsistent site conditions,
- Change in design initiated by a supplier,

4.4.4 Design errors

Errors due to human limitations may occur independently of the skill, education, and experiences, even sometimes the most detrimental error happens by highly trained and the most capable person (Han et al., 2013). The direct cost of design error is about 6.85, and indirect is about 7.36 percent of contract value (Lopez and Love, 2012). Rework occurrence is inevitable when there is an error in design, so errors often involve rework that requires extra time and resources and finally affects project performance. Errors in the design are prioritized amongst top sources of construction rework (Hwang et al., 2009). Findings show that design error causes up to 79 percent of rework cost (Hossain and Chua, 2014); however, the extent of rework is highly dependent on when it happens within the project life cycle. Some factors such as inefficient quality assurance, design team poor integration, inadequate training, and ineffective coordination strongly make errors in design (Love et al., 2009a). Findings of research done in construction to address causes of design errors show that the cost of design errors has not been recorded as much as change orders and claims so, little is known about design error costs as firms rarely measure their actual costs (Lopez and Love, 2012).

Errors in design can delay the project schedule and put pressure. This pressure will transmit the negative impacts of such errors to construction activities, even those indirectly linked. Underestimating these negative impacts will enable practitioners to count errors number precisely. A study on the process of design documentation to understand how the design error occurs in construction projects showed that short term strategies such as recruiting external resources and paying low salaries to designers are not effective practice and take an appropriate method of design review, audit and verification are required in the long run (Love et al., 2000a; Han et al., 2013).

4.4.5 Design and Construction Interface

Three main problems associated with design management are design quality, design standard, and constructability (Oyewobi et al., 2011). Design and construction are dependent on each other, and their dependencies also differ from project to project. Attentions to the design process management have been raised as a design-related factor such as lack of coordination among specialists, mistakes in drawings or specifications, and less knowledge of construction have increased the number of difficulties in construction (Hossain and Chua, 2014). The model of the feedback mechanism between design and construction showed that hidden rework in the design stage would reduce the quality of construction work as they are revealed during the execution of the project (Parvan et al., 2015).

Constructability is the only interface of design and construction. Constructability is detected during construction without design details or even after the task has been accomplished. Lack of constructability would result in higher costs and a longer delivery period (Oyewobi et al., 2011). It has been claimed that this challenge in the construction industry is getting more complicated due to the increase of participants and their relations (Sohi et al., 2016). When the project is segmented, each participant tries to maximize its interests, so project managers receive different information from different sources (Liu et al., 2017). These complex interconnections have been the core of the research studies. Thus, some solutions have been proposed to maximize the constructability of projects.

4.4.6 Design Management Strategies on Rework

Rework is time-consuming and costly, and any balance between the delayed time and total amount of rework cost depends on project priorities and the competitive market (Hossain and Chua, 2014). Rework causes are mostly associated with design development. Choosing an appropriate strategy to manage rework in the project's design stage practically depends on the complexity of construction, project size, and the number of involved entities. The priority for selecting a strategy can be altered based on where the most design problems are raised. Poor design management is due mainly to lack of coordination, design complexity, inefficient information flow, and obtaining compliance permissions. Research findings indicate that design-related rework can be minimized by implementing the following strategies.

When design error and changes originated from a lack of coordination creates a higher rate of rework, moving towards a workable mechanism to bring all participants together is the best choice (Oyewobi et al., 2011). Otherwise, involving the contractor at the early design stage to reduce error and mistakes would be encouraging. This can be achieved through a quality assurance system that enhances the project's buildability and elevates the compliance rate. When errors and changes are originated from complex design or poor information flow, applying information modeling techniques such as BIM to reduce waste is recommended (Tribelsky and Sacks, 2011; Mazlum and Pekericli, 2016).

4.4.7 Collaboration of design and construction

Generally, construction is started the following design, and each part is executed separately by different team members. This Method lengthens the overall time of project completion (Hossain and Chua, 2014). On-time completion of projects in the construction industry is an important criterion in assessing contractors' qualifications. To achieve this aim, design disciplines and construction activities are integrated. Working with contractors, owners, designers, and other parties for many years together is evidence of this integration to gain the project goals (Liu et al., 2017). Integrating design and construction is assumed to be a solution and achieving this integration would be possible by adopting several methods (Hossain and Chua, 2014). However, the strength of this integration has not been evaluated yet (Parvan et al., 2015). To get reasonable performance in collaborating with design and construction, strong communication between contractors and designers plays a critical role, and trusted relationships among participants pushed it to the ultimate rate. Nonetheless, entities are unwilling to do that because of their financial benefits and leadership (Liu et al., 2017).

Rework in construction projects can be eliminated if the design process is improved and all involved entities are well coordinated (Simpeh et al., 2015). This refers to the design and construction links as any disconnection will be the root of consequent problems in the construction industry (Oyewobi and Ogunsemi, 2010). Projects operate more effectively due to the accuracy of transferring information at the time of collaborating between design and construction. A collaboration between these two stages of the project will be more effective when the knowledge and values of the project are defined precisely by the client or end-users (Jorgensen and Emmitt, 2009). One way to achieve such collaboration is by inviting construction expertise in the early design stage to improve constructability concepts (Hossain and Chua, 2014). To involve construction in the design stage, BIM as a technological tool can be employed. Building information modeling works by sharing information across the participants to make better decisions, remove rework and reduce unnecessary wastes in the process, whereas design and construction firms do not need to make a significant change in their organizations. However, evidence shows that BIM is not a perfect option to integrate design and construction; it can be used partially to achieve collaboration (Liu et al., 2017).

4.4.8 Overlapping design and construction activities

Due to the high demand for shorter completion of projects, various methods of schedule compression have emerged, such as overlapping phases of projects and acceleration of schedule. Overlapping is a well-known technique to complete construction projects faster. Other terminologies such as concurrent engineering, parallel engineering, and phased construction have been used in the literature as the replacement word for overlapping (Dehghan and Ruwnapura, 2014). The project management body of knowledge (PMBOK) has called this technique fast-tracking. In the overlapping technique, some activities that normally are performed by a sequence can be performed in parallel. This technique is used for large-scale projects in which construction starts before completing the design stage. However, this technique shortens the completion of projects, and it has some disadvantages. It probably makes rework in construction activities, specifically when the final design differs from the early design. In addition, feedback from construction cannot be addressed to design activities (Hossain and Chua, 2014) so, implementing this technique needs to be considered with care.

Pena Mora's study on overlapping in construction projects in 2001 was among the most contributing research on this topic. The evolution of upstream tasks and the sensitivity of downstream tasks were selected as the study's main concepts to generate a framework for construction activities. The framework was applicable for any type of overlapping to minimize rework risk (Dehghan and Ruwnapura, 2014). The other approach of minimizing re-design in downstream activities was applied on overlapping later, and then the provided framework was completed through characterizing downstream tasks (Blacud et al., 2009) to address part of activities. Scheduling model of overlapped design activates based on information dependency made progress in the field; however, none of the studies was able to propose an optimum way of overlapping as all just have considered one dependency between upstream design tasks and downstream construction activities (Hossain and Chua, 2014).

Since overlapping performs with the expense of rework, it increases the cost of the project. An optimum overlapping strategy needs to be found to make a balance between the time saving on one side and rework cost on the other side (Dehghan et al., 2015). In search of an optimal overlapping strategy, the dependencies between rework probability and overlapped activities were assessed with two assumptions, predefining costs to minimize time and vice versa. Then cost and time impacts of overlapping on the project performance were quantified. Results showed that the reduction of both impacts of time and rework's cost is closely correlated to the accuracy of early information. In other words, rework will be reduced with provided accurate information at the early design stage. The other dependency was construction sensitivity to change. The higher sensitivity of construction activities will increase the rework amount. Moreover, unplanned overlapping may result in unexpected design and construction rework as well (Hossain and Chua, 2014).

4.4.9 Design and Technology

Lack of modern technology implementation may result in project inefficiencies such as imperfect communication and poor transmitting of information (Mollasalehi et al., 2016). Adapting technology in the construction industry lagged far behind others (Hwang et al., 2009). Technology, people, and process are the three main components of a successful collaboration in any context (Liu et al., 2017). People and process effects on project collaboration will be less in the absence of the third component. The construction industry tends to keep working with traditional approaches, but improvement can be seen by the emergence and use of information technology in all stages of projects (Taggart et al., 2014a). Up to 80 percent of construction problems at the site can be attributed to delayed and missed information (Bertelsen and Koskela, 2004), so employing technology to facilitate timely information delivery is an essential part of decision making (Abbaszadegan and Grau, 2015).

Research results have shown that inefficient use of information technology in the design stage of projects contributes to rework (Love et al., 2010a). Design documentation processes, design checks, and reviews are managed more accessible when information technology is used. Implementing BIM in the collaboration of design and construction context to find the effects of technology is an example that has been set as a core in recent studies (Parvan, 2012; Chen and Luo, 2014; Mollasalehi et al., 2016). Evidence indicates that rework is reduced in the vision of BIM even though the source of information between design and construction is the same (Liu et al., 2017).

4.5 Methodology

To achieve the research aims, a four-step methodology has been considered and implemented in this paper.

4.5.1 Comprehensive Review

In the first step, a comprehensive review was carried out on rework literature in construction projects to select relevant sources that were published in journals and conferences. Through conducting a literature review based on an in-depth assessment of the available articles on rework only in the construction industry, this research was able to find more than 80 sources with the keyword of rework in their titles. All selected papers were then analyzed in detail, considering the following content. The investigation of rework-related factors has been attempted worldwide, and many variables as rework root causes have been identified. Since identified items in previous research were repeated in different ways, this study constrained the next step for collecting more reliable data. It follows PRISMA main steps of identification, screening, eligibility and included documents.

4.5.2 Refinement from literature

For the second step, the most recent rework studies in various regions of the world that contained a list of identified rework causes and covered at least one of the stages of the project life cycle have been chosen to explore all possible root causes of rework and make a comprehensive list without missing any items from the previous step. After several refinements in search of the first step, it was clear that all identified rework causes could be found in the following sources as listed here:

- [A]: Divergence or Congruence? A Path Model of Rework for Building and Civil Engineering Projects, Peter E. D. Love, David J. Edwards, Jim Smith and Derek H. T. Walker, 2009,
- [B]: Factors influencing rework occurrence in construction, L.O. Oyewobi and D.R. Ogunsemi, 2010,
- [C]: Construction small projects rework reduction for capital facilities, Di Zhang, Carl T. Haas, Paul M. Goodrum, Carlos H. Caldas and Robin Granger, 2012,
- [D]: Using system dynamics principles for conceptual modelling to resolve causes of rework in construction projects, Olatunji Ayodeji Aiyetan and Dillip Das, 2015,
- [E]: Analyzing causes for reworks in construction projects in China, Gui Ye, Zhigang Jin, Bo Xia, and Martin Skitmore, 2014,
- [F]: Analysis of rework in residential building projects in Palestine, Ibrahim Mahamid, 2016a,
- [G]: Factors Contributing to Rework and their Impact on Construction Projects Performance, Adnan Enshassi, Matthias Sundermeier, and Mohamed Abo Zeiter, 2017,

Analysis of these articles resulted in preparing a list of 316 identified rework root causes with details of; 42 items from source [A] in the direction of the client and contractor related items with a focus on design, 77 items from source [B] mostly oriented on technical and human resource in all stages of a project,18 items from source [C] with processing evaluation in all stages of a project, 39 items from source [D] on both client and contractor side in design and construction stages of a project, 39 items from source [E] covering all stages of a project with no order, 43 items from source [F] considering consultants and environmental factors in the construction stage and 58 items from source [G] both client and contractor side assessing different internal and external factors.

4.5.3 Categorizing of Rework

In the third step, a model for the classification of all identified rework root causes has been designed. It is used to categorize and simplify the list of causes based on the needs of this research. Previous criteria and concepts used by other researchers were considered in the proposed classification model to avoid missing or duplicating identified factors. Identified rework root causes are distributed between two major parts of the contract as client and contractor in this model. To simplify this matrix, all other organizations that work with the client have been merged on the client-side. The same approach is considered for the contractor side. More details of this step are the same as the applied model for studying of Procurement "tendering" stage of the project (Asadi et al., 2019).

4.5.4 Classification of root causes

In the last step, all identified rework root causes were entered into the matrix with three dimensions of contract sides, project stages, and rework root categories. Depending on the defined scope for each identified item, one or more matrix spaces can be allocated. Distributing of identified rework root causes within the designed classification model is used as the base for the results of this paper. More details on the obtained result can be found in the finding and conclusion sections.

4.6 Findings

However, the overall research covers all stages of the project life cycle; this section presents only the result of the project's design stage. The second step of methodology in the presence of rework showed 102 items that attribute to design activities (Asadi et al., 2019). Allocating 102 items into the distribution matrix in the third step of methodology raises this figure to 136 for both contract sides. In other words, there are 34 common items between client and contractor that have been repeated among different sources of literature. Providing a descriptive list of allocated items in each matrix line indicated that some of the causes are the same content, and some can be considered the same as their terminology almost transmits the same meaning. For example, modification, revision, and change in spec and scope for any reason can be classified in one general item, as can be seen in the table.

Since rework impacts are not measured in this study, the following classified rework root causes have been sorted in no order. Thus, each item has no priority in terms of importance, and the table only shows the number of classified root causes. Results showed that the distribution of causes over the categories is not in balance. Technical-related factors with 16 items are the most frequent category involving rework, followed by human-related factors that contribute to 15 root causes. Process-related factors illustrate eight root causes of rework equal to the total items of the other related factors category. Lastly, material and equipment-related factors were found as the lowest frequent category, with only one involving item as a root cause of rework. After fully reviewing and unifying the contents, rework root causes in the project's design stage can be listed as 48 items, as shown in Table 4.1.

4.7 Conclusion

This study reveals that more efficient rework management can be achieved by packing a series of rework root causes into unified components. The findings suggest that rework causes in the design stage of a project have appeared in all five designated categories; however, human resources and technical-related factors are among the highest number of rework root causes compared to the other categories. In contrast, material and equipment-related factors in this project stage contribute to the lowest number of causes. The results of this paper as rework root causes in the project's design stage can be summarised as the following items.

- Changes in any order, errors, and omission in any form and lack of control documents for both client and contractor are the major items under process-related factors.
- Conflict of interest regarding client staff, manpower experiences, labor shortage, low skilled level, poor knowledge, various personal attitudes, lack of motivation, and the absence of job security for both client and contractor team members are categorized under human resources-related factors.
- Material and equipment related factors just consist of non-compliance to the specifications and standards for the client-side of the contract
- Lack of attention to quality management, deviation and failure, poor technology application use, ineffective communication system, inefficient management and decision making, weak planning of workload, shortage of work procedures, and the inability of forecasting field conditions are highlighted as technical-related factors in both sides of the contract.
- Financial issues, low payments, lack of involvement, time pressure, unclarity of authority and unanticipated consequences of change from client-side and constructability problems, and low proposed price by contractors are the other related factors that may result in rework.

Based on secondary data from the literature review, the presented model in this paper offers a list of rework root causes as a platform for future studies. Thus, the results of this paper can be used for further studying the relation between rework and contract documents through an evaluation model. The evaluation model reviews all clauses of contract condition and their attachments against the classified rework root causes in search of any relation for rework management. The likelihood of rework occurrences can be managed more effectively when project participants can check the causes of rework at the time of contracting. The classified rework root cause in each stage of the project will provide this opportunity for checking contact documents to assure that possible impacts of rework are covered thoroughly. Rework management through implementing this mechanism will result in more awareness of contract parties, and higher project performance may achieve when both sides of the contract recognize the benefit of this approach.

Table 4.1: Classification of rework root causes in design stage of project

Part		Process related factors	[A]	[B]	[C]	[D]	[E]	[F]	[G]
Client	1	Changes, modification, and revisions in design "spec, scope and construction method" in any order to improve in quality, constructability, etc. and late design change	3*	3*	*	2*	3*	2*	-
	2	Error in design, drawings and specifications by consultant due to complexity and time boxing	-	*	-	*	*	2*	-
	3	An omission in design, drawings, spec by consultant due to incomplete design or lack of attention to details	-	*	2*	-	-	*	-
	4	Lack of documents control such as inadequacies in contract documentation	-	-	*	-	-	*	-
Contractor	5	Design changes in any form	6*	*	*	-	*	-	*
	6	Design errors in any form	-	*	*	-	-	-	*
	7	Any omission in design process due to incomplete information for design	-	*	*	-	-	-	*
	8	Lack of document control including subcontractor's documents	-	-	*	-	-	-	-
Part		**Human resources related factors**	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**
Client	9	Lack of experiences and personal expertise in design team members of consultant	*	-	-	*	-	2*	-
	10	Inadequate supervision staff due to manpower turnover	-	-	-	-	-	2*	-
	11	Insufficient skilled level manpower for specific design	-	-	*	-	-	-	*
	12	Lack of education and poor knowledge due to nonsufficient personal training	*	-	2*	-	-	-	*
	13	Lack of employee motivation and rewards	-	-	*	-	-	-	*
	14	The absence of job security and other safety rules	-	-	-	-	-	-	2*
	15	Conflict of interest	-	-	-	-	-	-	*
	16	An inappropriate personal attitude such as unfollowing work instructions or failure to the adhesive to policies due to disturbances in personal planning	-	-	*	-	-	-	2*
Contractor	17	Lack of experiences and personal expertise in design team members	*	-	-	-	-	-	*
	18	Insufficient skilled level manpower	-	-	*	-	-	-	*
	19	Lack of education and poor knowledge due to deficiencies in personal training	*	-	2*	-	-	-	*

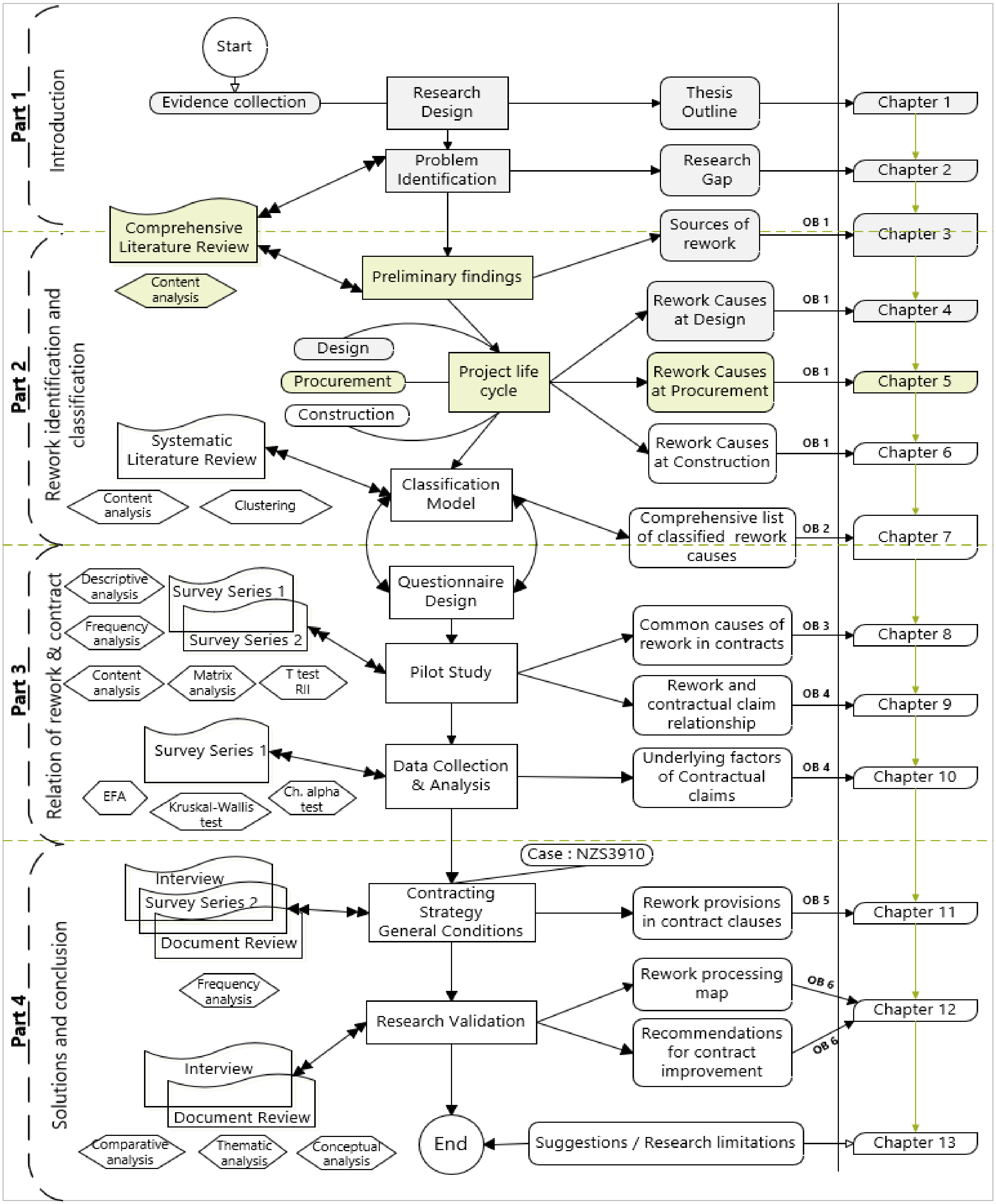
Part		Factor	[A]	[B]	[C]	[D]	[E]	[F]	[G]
	20	Lack of employee motivation and rewards	-	-	*	-	-	-	*
	21	An inappropriate personal attitude such as unfollowing work instructions or failure to the adhesive to policies due to disturbances in personal planning	-	-	*	-	-	-	2*
	22	The absence of job security and other safety rules	-	-	-	-	-	-	2*
	23	Inadequate manpower due to staff turnover or reallocation to other projects	*	-	-	-	-	-	-
Part		**Material and Equipment related factors**	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**
Client	24	Non-adherence to material specifications or non-compliance to standards	-	-	-	*	-	-	-
Part		**Technical related factors**	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**
Client	25	Ineffective use of quality management practices and lack of attention to quality	*	*	-	-	-	-	-
Client	26	Deviation and failure due to poor monitoring, control, and quality inspection or non-compliance to the standards/specification and project requirements	-	4*	*	-	-	-	-
Client	27	Ineffective or lack of information technology and poor technology application use	*	*	-	2*	-	-	-
Client	28	Poor communication system and ineffective coordination and integration between different design team members and consultant	*	-	*	*	-	2*	2*
Client	29	Inefficient management and decision-making due to poor information and poor contractual relations	-	*	*	-	-	-	*
Client	30	Poor planning of workload and poor scheduling of construction resources	-	-	2*	-	-	*	-
Client	31	Inability in development of realistic work procedures due to constraint in carrying out activities and ambiguous instructions	-	2*	-	*	-	-	-
Client	32	Inadequate brief to prepare detailed documentation and deficiencies in forecasting field conditions	*	-	*	-	-	-	*
Contractor	33	Ineffective use of quality management practices and lack of attention to quality	-	*	-	-	-	-	-
Contractor	34	Deviation and failure due to poor monitoring, control, and quality inspection or non-compliance to the standards/specification and project requirements	-	4*	*	-	-	-	-
Contractor	35	Ineffective or lack of information technology and poor technology application use	-	2*	-	-	-	-	-
Contractor	36	Poor communication system and ineffective coordination and integration between different design team members	*	-	*	-	-	-	-
Contractor	37	Inefficient management and decision-making due to poor information and ambiguous project process	-	*	*	-	*	-	-
Contractor	38	Poor planning of workload and poor scheduling of construction resources	-	-	*	-	-	-	-

	39	Inability in development of realistic work procedures due to constraint in carrying out activities and poor project documents such as late design input	-	-	*	-	-	-	*
	40	Deficiencies in forecasting field conditions by contractor	-	-	*	-	-	-	-
Part		**Other related factors**	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**
Client	41	Financial issues such as lack of funding allocated by the client for site investigations or inadequate money spent on the briefing process	2*	-	-	-	-	*	-
Client	42	Low payment fees for design works	-	-	-	-	-	*	-
Client	43	Lack of client involvement in the project or late user involvement in design process	*	*	-	-	-	*	-
Client	44	Time pressure due to fixed time for design tasks and lack of time	-	-	-	*	-	*	-
Client	45	Unanticipated consequences of change	-	*	-	-	-	-	-
Client	46	Unclear line of authority	-	-	-	-	-	-	*
Contractor	47	Non-attention to constructability problems raised at early stages	-	-	-	-	-	-	*
Contractor	48	Competitive or low design fees proposed by contractor	-	-	-	-	-	-	*

4.8 Epilogue

This chapter investigated the causes of rework regarding clients and contractors related to the construction projects' design stage. Selected strategies to improve rework in the design stage generally depend on the construction projects' complexity and nature. The finding of this chapter revealed the existing rework causes with their liabilities to the contract. The results showed that rework's root causes contribute to both sides of the contract being slightly more reliant on the client. It also enables construction practitioners to improve the contracts' initiatives by searching the relationship between clauses of the contract and the identified root causes of rework. While this chapter provides the basics for rework root causes identification in the design stage, a great deal is still required for further research with a larger sample of studies to recognize and summarize relevant causes of the construction contracts comprehensively. The final list of rework root causes under the client and contractor sides of the contract is discussed further in chapter seven. The same approach is used to identify the causes of rework under the procurement stage of the project in the next chapter.

Thesis-at-a-Glance / Chapter 5



Chapter 5. Contract documents appraisal and rework root causes classification in tendering stage of project

5.1 Prologue

Investigation for the identification of rework root causes in the project's life cycle continues in this chapter by focusing on the tendering stage of the project using the literature review method. This chapter also aims to cover part of the requirements for Objective one in this research. The same adopted structure for identifying and classifying the root causes of rework used in the previous chapter is followed to present and analyze similar results in the procurement stage of a project. After rework definitions, this chapter introduces different types of contracts and the most used standard form of contract in New Zealand. The definition of rework is presented in the first part of the chapter, and then identifying root causes in contract documents as the main output of the procurement stage will be discussed. This chapter develops an understanding of how rework occurs in the procurement stage of a project and proposes a model to evaluate rework in construction contracts. Findings in this chapter reveal that the project's procurement stage encompasses the lowest number of rework root causes compared with the other stages of the project life cycle. A flowchart to evaluate the conditions of the construction contracts in rework events is introduced in this chapter. The main concept behind this flowchart is used for the other chapters to understand whether further assessment of the contract is required or not.

This chapter is based on the following published paper:

Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2019). Contract document appraisal and rework root causes classification in tendering stage of project. *Proceedings, 43rd Australian Universities Building Education Association Conference (AUBEA 2019)*, ISBN: 978-1-921047-51-0.

5.2 Abstract

This paper aims to identify rework root causes during the tendering stage of construction projects. Rework is a common issue for construction projects and companies are struggling to manage rework effectively. Rework has significant impacts on performance due to its influences on cost, time and quality. Rework factors are identifiable and can be used to develop a reduction model for avoiding negative impacts. Rework can be minimized by addressing their main sources. Using rework reduction approach in contract documents could enable project managers to have a better understanding of how rework occurs. This paper identifies rework causes in order to understand how they can be controlled through appropriate condition of contracts. Data analysis of rework root causes through the literature together with evaluation of contract documents was the method used for the result of this paper. Identified rework root causes from literature have been categorized and assessed in tendering stage as one of the major phases of project. Classification of rework root causes appears in the following categories of process, human resource, material/equipment, technical and other factors such as environmental and financial. Clauses and conditions of contract documents NZS3910:2013 are evaluated based on this classification. The paper suggests that rework can be managed through contracts.

Keywords, Rework causes, Contracts, Classification system, Construction projects, Tendering, NZS3910

5.3 Introduction

Time and cost overruns have been experienced in numbers of construction projects in which rework is mostly the key factor responsible for these poor performances (Hwang et al., 2009). Construction Industry Institutes (CII) has conducted various research and studies about performance and the results show that the average direct cost of rework is about 5 percent of construction total cost. The number of studies and obtained results on relation between rework and performance in construction projects specifically in building industry are inadequate but majority of them have claimed that rework is the main cause of time and cost overrun (Love et al., 2004; Hwang and Yang, 2014). Thus, rework can be one of the main factors that influence construction performance in terms of costs and time. Mainly sources like changes, errors, omissions, failures and damage are the origins of rework. Rework also includes some changes in form of additional or missing of scope and some errors due to contractor and designers' mistakes in design stage or in construction process (Love et al., 2004).

The research on construction rework has become a core theme and contributed to the body of knowledge in construction management for recent years. Studies conducted in this field so far have focused mainly on aspects such as factors affecting rework, rework causes and impacts, mitigation and reduction models. Zhang et al. (2012), in their research say that investigated rework causes by other researchers have been mostly considered with two perspectives. Some believe that rework is generally linked with quality issues such as non-conformance (Abdul-Rahman 1995), deviations (Burati et al., 1992; Davis et al., 1989), failures (Barber et al., 2000) and defects (Josephson and Hammarlund, 1999). Some others such as Mc Tague and Jergeas (2002), and Hwang et al. (2009), have focused on rework impacts in project performance, construction practices and workforce assessment at the activity levels. In both categories rework as a non-value adding activity that seriously affect project performance are neglected by the construction industry (Ahmed and Naik, 2016). Recently rework has been identified as a major problem that has constant contributions to schedule and cost overrun, productivity reduction, weak performance and increasing the likelihood of incidences related to safety issues in construction job sites (Love et al., 2016a).

The two key factors that influence the development of construction industry are technology and management. Even though numbers of approaches in project management have emerged to improve construction performance, it is increasingly argued that the traditional approach to project management is no longer effective (Hertogh and Westerveld, 2010; Priemus and Wee, 2013). Even though complexity and uniqueness are the most common known characteristic in construction industry, most of current projects still using methodologies that underestimate the dynamic environment influences (Sohi et al., 2016). Thus, considering a new management methodology to help construction industry coping with problems such as rework which is raised from the nature of these kind of projects is required. Furthermore, "since last 40 years, although some new advanced technologies have been applied to some of the construction projects, still the industry's efficiency remained low" (Koushki et al., 2005; Guo, 2009). Obtained results from previous research simply shows that implementing an appropriate new technology is not enough solely and it should be accompanied by contemporary management concepts (Aziz and Hafez, 2013).

According to (Horvath, 2004; Fearne and Flowler, 2006; Cheng et al., 2009) construction sector is one of the largest industries in most of countries with the least integration compared to other major industries. Such disintegration is maybe resulted from applying traditional approach of project management (Isnaini et al., 2015). Many of current contractors are performing modern projects and to deal with raised challenges it is time to shift from existing traditional concept to modern project management. One way to improve this situation can be attained by using standard type of contract documents and the current study will consider this key element of project to find out any relation between rework and contract clauses and its attachments. Limited evidences that initially focused on the rework causes and consequences in contract documents can be found in the empirical research literatures and it would be considered as a research gap, specifically with the viewpoint that says rework is known as an acceptable or regular feature in construction projects. This gap in the literature shows that not enough is known about the contractual terms and conditions for rework in construction projects.

On the other side, studies done on the legal contractual framework in deferent types show a potential need to make some changes in the form and condition of contracts and its relationships to improve construction sector performance. Procurement and contracting strategy play a vital role in the success of construction projects as it establishes the foundation for cooperation amongst project parties (Chan and Chan, 2017). Contractual agreement for construction projects acts as a permit to start the practical work after completing the procurement processes. Contract that is a confirmed document between parties is crucial as it determines the overall construction framework including responsibilities structure for each party, stakeholder's authorities, covering risks and any other relevant issues, which may happen during the execution of construction project. As a result, two aspects of the literature review that need to be carried out are construction contracts originated from procurement system and construction rework as a drawback in processes.

Shaik Ayaz Ahmed (2016) believes that little is known about the background and sources of rework and it has remained as an intrinsic problem. Several rework studies to identify and classify the main root causes of rework have been done and despite the facts that rework has a great impact on the project performance there are few concrete results have been reported comparatively (Hwang et al., 2009). In order to manage the impacts of rework on performance, rework root causes need to be identified and classified at the beginning of the project. However, most of construction companies are reluctant to acknowledge the existence of rework in their projects as it affects their reputation (Love et al., 2016a). Hwang states that it is very important for project managers to recognize the various impacts of rework specifically when the cost is affected. There is a great need for project managers to minimize rework through a model that can effectively address main sources of rework (Hwang et al., 2009). Thus, proposing a reduction strategy without fully understanding of contributing factors related to rework occurrence will not be an effective way and to overcome this issue a comprehensive list of all identified rework root causes to make improvement is required. By using the new concept of project management this paper sets out to combine the literature on matters of construction contracts, including the terms and conditions “clauses and attachments of contract”, and construction rework altogether in order to propose a practical contracting framework to manage rework in construction projects.

5.4 Literature Review

5.4.1 Contract definitions

Totterdill (2006) simply defines construction contract as a legally binding agreement between two parties, the owner that sometimes called employer or client and the contractor. In one side client defines the project, decides for the project requirement, gives instructions, supervise the whole processes, pays for the construction cost and finally possess the completed project. In the other side, contractor works on the project to build it and be paid for the job done. This agreement works as a guideline for controlling the relation of client and contractor. Contract specifies required procedures details, and changes may happen to work compare to the contractor’ offer and the payment method from the employer side. It clearly refers to the bodies that have to be taken the responsibility of any unexpected problems that mostly results in delay and over budget. A contract needs to be clear without any uncertainty for parties; it should clearly define what is needed to be done, how schedule to be controlled and how much have to be paid for the project (Zuo, 2010).

5.4.2 Contracts type

Typically, a standard contract is including the following parts "Tender documents, offer, agreement, letter of acceptance, contract conditions, technical documents such as drawings, spec, bill of quantities, etc". Based on Broome's model there are two general sections of traditional contracts and relation contracts. When client specify all requirements of project not only including practical issues but, all individual participants, which is a purely traditional contract. This type is common in New Zealand known as standard contract condition of NZS3910 (Henderson 2004). Basically, non-traditional contracts' attention is on relation rather than other aspects. Henderson' survey (2004) showed 58 percent of New Zealand construction projects were commonly on traditional method of tendering, but later on Shestakova (2005) revealed a trend towards using procurement strategies with more relationship between partners.

5.4.3 Main standard contracts in New Zealand

NZS3910 - Condition of contracts for building and civil engineering construction, which is used as a current basic document for contracting in New Zealand construction industry is known as NZS3910 issued by Standards NZ and first published on August 2003. The main aim of this standard document is to produce a straightforward flexible document which includes all essential commercial provisions, and which may be used for all types of engineering and building work with a variety of administrative arrangements. Different industry institutions have made some variations on NZS3910 for special purposes. New Zealand Registered Master Builders Federation (MBF) has raised the prompt for establishing such a standard contract variation to refer the contractual situation on comparatively straightforward projects with the absence of the engineer role. As an instance NZS3915 is a standard document for building and civil engineering construction when an architect, surveyor and other suitable person either a direct employee or another one is not available to act as Engineer to the contract. In addition to these two common standards for contracts there is three main other contracts developed by New Zealand Institute of Architects (NZIA) known as SCC "the standard condition of contract", NBC-G "the national building contract, General" and NBC-MW "the national building contract, Minor work".

5.4.4 Rework definitions

Oyewobi et al. (2011) say that rework has represent a new terminology in construction dictionary and it happens when an element of work fails to meet customer requirements, or when the completed work does not conform to the contract documents. According to (Love, 2002a) there are various interpretations of rework in the construction management literature, including quality deviations, nonconformance, defects, and quality failures, which all vary. Mills et al. (2009), reported that a lack of differentiation between these terms "error, fault, failure, defect, quality deviation, non-conformance, quality failure, snag and rework" can lead to inaccurate, incomplete measurements and cost determinations, and possibly inappropriate strategies for reducing their occurrence (Forcada et al., 2017). Therefore, there is a little evidence of a reduction in rework mainly because these terms are used interchangeably to describe imperfections in construction projects (Aiyetan, 2013; Hwang et al., 2014; Kakitahi et al., 2014; Taggart et al., 2014a; Jingmond and Agren, 2015).

Some of the given definitions of rework by previous researchers are presented as the followings chronologically. "The process by which an item is made to conform to the original requirement by completion or correction or doing something at least one extra time due to non-conformance" (Ashford, 1992). "Unnecessary effort of redoing a process or activity that was incorrectly implemented the first time" (Love et al., 2000b). Activities in the field that have to be done more than once in the field, or activities that remove work previously installed as part of the project (Rogge et al., 2001). The same definition has been given by Robinson et al. (2004), with excluding change orders and scope changes by the owner. Activity that must be redone, because it was not done the first time following by the requirements (Hwang et al., 2009).

5.4.5 The nature of rework

Sommerville (2007) says that in construction industry, rework has become a norm and some researchers have looked at it as a right, which is inevitable and acceptable, however Hwang et al. (2009), believe that there is generally an absence of systems within projects to monitor and control rework. Although some innovative approaches have been developed to manage and control rework occurrence, rework in construction projects has nonetheless continued persistent (Simpeh et al., 2015). Despite the significance of rework, there are few industry standards available for defining, quantifying and classifying field rework. To find out more about rework root causes different perspective and breakdown structures have been used by previous studies. In most of them, rework root causes have been classified through conducting a quantitative analysis using statistical state for measuring rework impacts on performance and there are little common aspects have been addressed to find an appropriate rework mitigation approach (Zhang et al., 2012).

In addition, according to (Love et al., 2004) there have been numerous government initiatives such as Australian Procurement and Construction Council (APCC) reports that have criticized the industry for its fragmented nature, lack of coordination and communication between participants, adversarial contractual relationships, lack of a customer supplier focus, price-based selection, and ineffective use of technology. Such poor organizational and management practices have contributed to time wastage, unnecessary costs, increased errors, and misunderstandings, which have invariably resulted in rework occurring in projects (Abdul-Rahman 1993; M. Cnudde, 1991;

Josephson and Hammarlund, 1999). Meanwhile construction tasks are typically divided between two or more groups such as professional and trade entities like contractors and subcontractors, which frequently operate independently of each other. Such an environment provides the ground for rework occurrence and construction organizations should give more attention on improving the processes that affecting rework.

5.4.6 Sources of rework

The discussions presented by Love et al. (2005) about flow of project information suggest that the major cause of rework is uncertainty. Koskela and Huovila (2000) emphasized that this uncertainty is generated by poor information, the information which often is missing, unreliable, inaccurate and conflicting (Simpeh et al., 2015). Another major source of rework is Non-Conformance that defined as deviation in terms of quality during construction. Whenever there is a deviation in quality, a non-conformance report (NCR) is issued. This report leads to rectification, repair or rework of an activity that ultimately result in time and cost overrun (Maheswari et al., 2016). Numbers of reasons and items have been identified as rework causes since the year 1988. More detail of each of these items for tendering stage with reference to the most recent studies in last ten years will be presented in this paper to provide a comprehensive list of identified rework root causes for that particular phase of project.

5.4.7 Impacts of rework on project performance

Love (2002) reported that the costs of rework in civil and heavy industrial engineering projects have been source of worries for construction stakeholders because the costs are gradually increasing. The adverse consequences of rework include reduced profit, loss of market share, damaged reputation, increased turnover of management and workforce, lower productivity, higher costs, and finally, costly litigation between participants over responsibility for overruns and delays (Love et al., 2004). Rework is produced as a result of poor management practices and week organizational structures and these unwanted organizational and management practices have contributed to time wasting, unnecessary costs, increased errors and misunderstandings, which have invariably resulted in rework occurring in projects (Abdul-Rahman, 1993; Josephson and Hammarlund, 1999; Love et al., 2004). Such rework may result in overtime, additional hiring of resources, schedule slippage, or reductions in project scope or quality. Palaneeswaran et al. (2006) argued that the direct impact of rework on the project is identified to consist of: additional time to carry out the rework, additional cost to rectify the occurrence, more materials for rework and wastage, as well as consequential increase in labor cost to fix the defect plus related extension of manpower supervision. In addition, Wasfy (2010) believes that rework leads to clients and contractor's dissatisfaction and Oyewobi et al. (2011) in reference to many reported cases claim that rework has a negative impact on the performance of projects in terms of cost overrun, time overrun and dissatisfaction of the participants in the project.

5.4.8 Rework classification systems

According to Hwang et al. (2009) analysts have suggested that rework is often due to the complicated characteristics of the construction processes. Many of vary methods and definitions of rework extracted from previous studies did not address how construction rework is identified as it happens in the field. Occurrence of rework in construction industry is very common and significantly project success is affected by this phenomenon and construction companies are not able to control this issue mainly because rework reasons and causes have been remained unknown (Ye et al., 2015). Robinson et al. (2004) claimed that having a precise field rework definition in construction projects and an industry wide standard in order to classifying and measuring rework impacts is required.

To classify identified rework and its root causes, different approaches have been used in recent years. For example, Burati et al. (1992) have proposed a system including main project activities like design, construction, fabrication, transportation and operability at first level and rework causes and its source at second and third level. Following by that Robinson (2004) presented a rework classification system based on Cause and Effect (CE) diagram in five categories consisting of engineering, construction planning, leadership and communication, material and equipment, and human resources. Furthermore, another classification system shows rework root causes in three categories of Client related, Design related, and Contractor related factors, including subcontractor and site management (Love and Edwards, 2004a). Similarly, Ibrahim Mahamid (2016a) conducted a study in the west bank in Palestine to analyze rework and identify most influential rework causes in residential building projects. He has classified the causes in 4 groups of contractor related causes, client related causes, consultant related causes and environmental causes.

5.4.9 Rework reduction strategies

Love et al. (2005) claimed that the occurrence of rework in construction is system orientated, and until rework is eliminated, attention must be given to preventing it from happening. In addition, organizations should focus attention on improving the processes of affecting rework. Thus, managers need to accept that rework will occur, but the extent to which it occurs must be controlled and minimized. As a result, project management roles can provide an effective means for tracking rework occurrences and thereby implementing suitable management measures to reduce the impacts on productivity and project performance (Palaneeswaran, 2006). Hereafter some of the strategies and methods applied by previous researchers in order to reduce or minimize rework in construction industry have been presented that will consist of some important scholars from 1989 to 2017.

Burati et al. (1987) argued that rework can be significantly reduced or eliminated when total quality management (TQM) is applied in conjunction projects with reward schemes. Then (Fearne et al., 2006) reported that effectiveness of efforts in planning within contractor and its subcontractors and suppliers pushes projects to be more succeeded because design related rework in the form of change orders is the major source of rework in construction projects. Sterman used system dynamics models to captures the change in projects through the rework cycle formulation and later on Love et al. (2000a) at the same year employed the causal loop diagrams to gain insight into the cause and effect relations between scope changes and construction project outcomes (Parvan, 2012). A Design and Construction Rework Minimization (DECOREM) model had been developed and applied by Love et al. (2000) to simulate a number of practical scenarios that can be used to reduce design errors and rework. DECOREM aim was to provide an insight and better understanding of the factors that influence the occurrence of design errors in contracts documentation. Pena-Mora and Li, (2001) proposed a framework to overlap two sequential activities to minimize the risk of rework in downstream activity using the concept of upstream evolution rate and downstream sensitivity to change in upstream parameter (Hossain and Chua, 2014). To reduce rework in projects, Love et al. (2004) proposed number of design and production management strategies such as understanding client requirement, auditing contract documentation, implementation of quality management practices and use of last planner approach. Furthermore, Blacud et al. (2009) described a framework of characterizing the sensitivity of downstream construction activities to minimize the risk of construction rework. In the same year Hwang et al. advised that pre-project and quality management plans should be drafted with an understanding of the causes of rework in order to minimize its impact.

In the year of Zhang et al. (2012) developed a generalized conceptual model for a rework reduction program (RRP) to reduce rework by managing a continuous improvement loop with four functional processes of tracking and cause classification, evaluation of rework and its causes, corrective action planning and integration of changes into the total management system. Hossain and Chua, (2014) conducted a research to propose an optimization approach leading to minimize rework by choosing a strategy on overlapping design and construction activities incorporating early information sharing in design phase. Li and Taylor, (2014b) by implementing system dynamics methodology examined the impact of design rework on construction project performance as it clearly illustrates the dynamics of design error induced rework in the construction project development process. In the same year Taggart et al. (2014a) conducted an action research approach about the role of the supply chain in the elimination and reduction of construction rework and defects as an action research approach. The results of their research indicated that the supply chain participants, when adopting more collaborative and proactive approaches, can identify root causes and suggest possible cost-effective solutions to avoid future repetition. In addition, Love et al. (2016a) emphasized that by having an authentic leadership as well as actively engaging with contractors and focusing on continuous improvement rework could be significantly reduced. Following by that Forcada et al. (2017) used regression model for rework prediction based on original project conditions which enabled them to put strategies in place prior to the start of construction. This helped them to minimize uncertainties and reduce the impact on project cost and schedule, and thus improve productivity and performance.

To summarize and in order to having minimum of rework occurrence or to reduce it in construction projects some actions can be taken such as changes controlling, value management, use of information technology, design scope freezing, supervisors training, quality control plan, and project inspection (Wasfy, 2010). Meanwhile, to prevent rework, various approaches are being used, which include visualization enabled technologies (building information modeling (BIM), modularization, lean construction, constructability reviews between design and construction teams, and relationship-based procurement (RBP) (Love et al., 2016a). Although much literature exists concerning rework reduction, there is a need for further analysis, validation, and improvement of rework reduction methods (Zhang et al., 2012). With this background it can be mentioned however, different methods have been used to control rework, yet investigating contract process and its documents to manage rework has not been fully explored and this paper will open this new angle to provide initial bases for future studies by the following of the method that is offered in methodology section.

5.5 Research methodology

To find out more details of rework root cause within the life cycle of projects all previous research approaches around the subject of rework were reviewed throughout literatures published from 1988 to 2018. All identified rework causes, and their roots obtained from various perspectives were combined together to provide a comprehensive list of rework root causes. Since some of the identified rework root causes had been repeated over again in different ways only seven of the most recent published in last ten years have been considered for current study based on two key criteria of:

1) Paper has been published in a well-known academic journal in the fields of construction and engineering. These papers were chosen from Journal of Performance of Constructed Facilities, Journal of Building Performance, Journal of Construction Engineering and Management, Journal of Construction Project Management and Innovation, Journal of Management Engineering, Jordan Journal of Civil Engineering, International Journal of Sustainable Construction Engineering and Technology

2) Papers that showing lists of rework root causes in various classification systems consisting of different phases of project. List of specific sources used in this paper are as follows indicating with abbreviations of R1 to R7.

R1: A path model of rework for building and civil engineering projects (Love et al., 2009a)

R2: Factors influencing rework occurrence in construction (L.O. Oyewobi and D.R. Ogunsemi 2010)

R3: Construction small projects rework reduction for capital facilities (Zhang et al., 2012)

R4: Using system dynamics principles for conceptual modeling to resolve causes of rework in construction projects (Olatunji Ayodeji Aiyetan and Dillip Das 2015)

R5: Analyzing causes for reworks in construction projects in China (Ye et al., 2015)

R6: Analysis of rework in residential building projects in Palestine (Ibrahim Mahamid, 2016a)

R7: Factors contributing rework and its impact on construction project performance (Enshassi et al., 2017)

However, these sources have been considered to provide a comprehensive list of all identified rework root causes throughout the life cycle of project, this paper only shows related items in tendering stage. More details of applied methodology for connecting rework root causes with contract documents of NZS3910 are explained in the following sections.

5.5.1 Selection of a model for rework classification

From the life cycle perspective of project, the main study analyzed all those literatures that covered any of three main phases of Design, Procurement/tendering and Construction. The numbers of identified rework root causes from selected literatures were about 316 items. The first priority for analyzing all these causes was to design a classification system in which same items could be categorized in one section. In order to achieve such system first the approaches used in previous research were assessed and then to cover all identified items a classification system was proposed. The main classification approaches from seven selected sources in this paper are listed hereafter.

Design cost, Client, Design team, Site management, and Subcontractor causes (42 items in the source R1); Technical, Quality management, and Human resources factors (77 items in the source R2); Process, and Human performance groups (18 items in the source R3); Design related, Client related, and Contractor related factor (39 items in the source R4); Source R5 are including 39 items without following a certain classification system; Client, Consultant, Contractor, and Environmental related causes (43 items in the source R6); Human resources, Construction process, Material/Equipment supply, Client, Design, Contractor, and External environment rework impact (58 items in the source R7)

Level 1	Contract parties	Client
		Contractor
Level 2	Project phases	Design
		Procurement / Tendering
		Construction
Level 3	Rework root causes classification	Process related factors
		Human resource related factors
		Material/Equipment related factor
		Technical related factors
		Other related factors

Figure 5.1: *Model of applied rework classification*

In order to cover comprehensive list of identified rework root causes within life cycle of project a model that is shown in Figure 5.1 was used in current study. Other related factors in this classification system can be included as financial, environmental, governmental policies and etc. This model has been designed following by the combination of the most recent studies contents mentioned in this section and adjusted based on some other diagrams from previous literatures such as Robinson et al. (2004).

5.5.2 Propose a model for evaluation of contract documents

To find out either the contract document of NZS3910:2013 covers the groups of classified rework root causes, the study was customized through the following steps to provide a conceptual framework for investigating connection areas between the contract documents and the subject of rework.

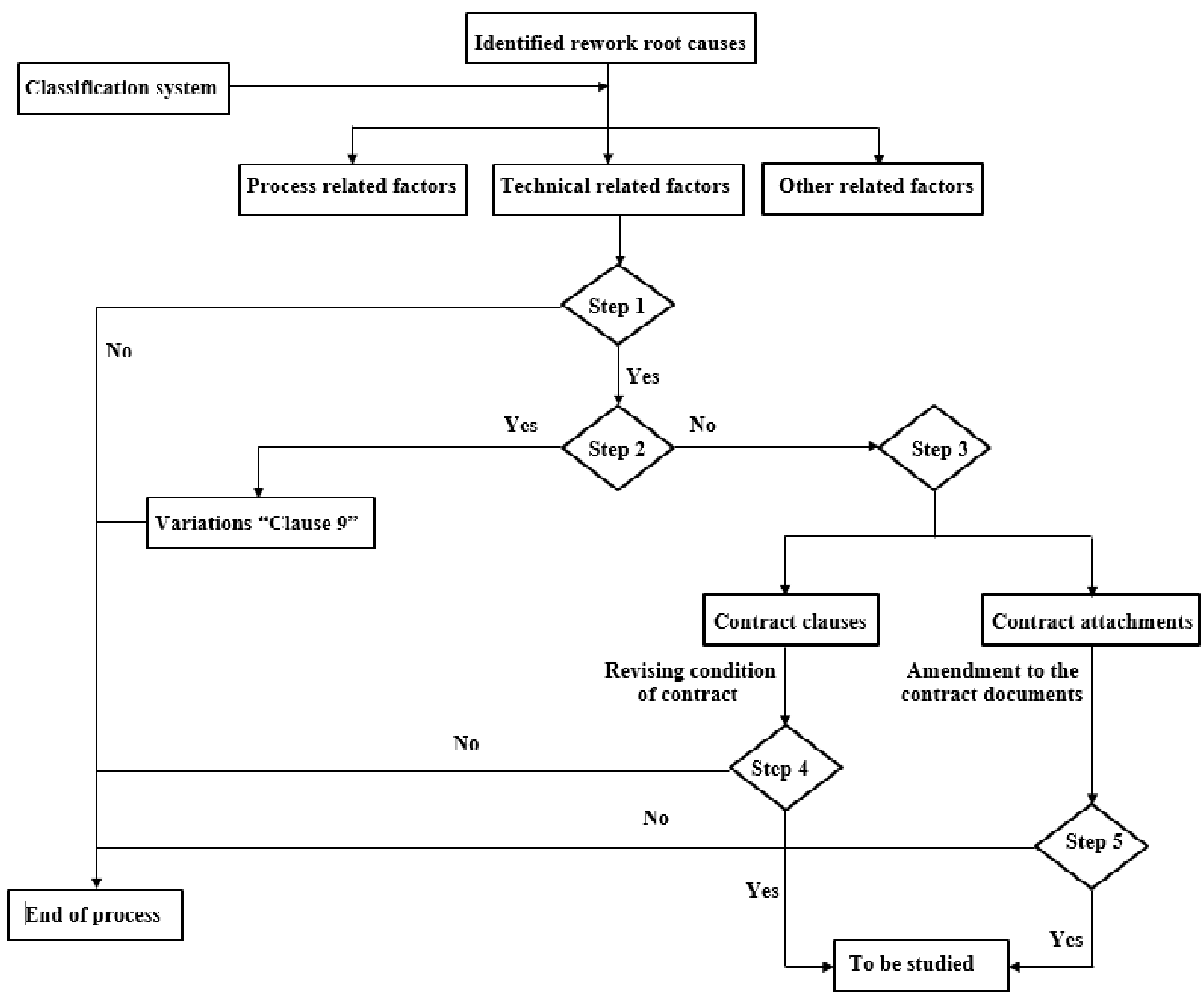


***Figure 5.2**: Flowchart of rework root causes and evaluation of contract documents*

Step 1- Checking whether these rework root causes be considered as contractual issue or not?

Step 2- Dose this group of causes led to variations “Clause 9 of contract condition”?

Step 3- Which contract clauses or attachments of contract is related to this group of rework root causes?

Step 4- Dose revising the relevant contract clause will cover this group of rework root causes?

Step 5- Dose making change in the attachments of contract will cover this group of rework causes?

A conceptual model to show all these steps is presented in Figure 5.2 that finally is pointed to a research study for developing a new approach to manage rework in construction projects based on contract documents of NZS3910.

5.6 Findings

According to the initial results on the basis of chosen methodology, the total identified rework root causes in the life cycle of project were 316, which are presented in Table 5.1.

Table 5.1: Overview of identified rework root causes distributed within the project life cycle

Project Phase / Stage	R1	R2	R3	R4	R5	R6	R7	Total in phase
Design	17	15	15	10	6	17	22	102
Procurement (Tendering)	5	4	0	1	4	3	1	18
Construction	20	58	3	28	29	23	35	196
Total numbers of root causes	42	77	18	39	39	43	58	316

After reviewing the literatures and employed the classification model in tendering stage of project the total numbers of 18 identified rework root causes were presented in Table 5.2 as the major outputs of this paper. Since there were 3 items common in literatures and to avoid repeating their contents the final total numbers of rework root causes of tendering stage in Table 5.2 is shown as 15.

Table 5.2: List of identified rework root causes from the literatures with referencing to relevant resources

	Classification of rework root causes in tendering stage	R1	R2	R3	R4	R5	R6	R7
Process related factors								
	Client side							
1	Incomplete design at the time of tender	√	-	-	-	-	√*	-
2	Procurement method	-	√	-	-	-	-	-
3	Contractor selection method	-	√	-	-	-	-	-
	Contractor side							
4	Inadequate procurement methods	-	-	-	-	-	-	√
5	Improper subcontractor selection	-	-	-	-	-	√	-
6	Poor contract execution	-	-	-	-	√	-	-
Technical related factors								
	Client side							
7	Errors made in the contract documentation	√	-	-	-	-	-	-
8	Omissions of items from the contract documentation	√	-	-	-	-	-	-
9	Poor quality contract documentation	-	√	-	√*	-	-	-
10	Incomplete documentation at the time of award	-	√	-	-	-	-	-
	Contractor side							
11	Lack of clear definition of contract documentation for working content	-	-	-	-	√	-	-
12	Ambiguity of items from contract documentation	-	-	-	-	√	-	-
Other related factors								
	Client side							
13	Payment of low fees for preparing contract documentation	√	-	-	-	-	-	-
14	Insufficient time to prepare contract documentation	√	-	-	-	-	√*	-
	Contractor side							
15	Payment of low contract fees or delay in paying contract fees	-	-	-	-	√	-	-

5.7 Discussion

Each contract generally has minimum of two parties and all relevant tasks and responsibilities will be divided between these two parties. In this paper client and all subsidiaries organizations such as consultants' companies have been set in one side of contract and the main contractor and all relevant subcategories such as subcontractors and suppliers have been considered in the other side of contract. In the main study of conducting current research, previous identified rework root causes within the whole life cycle of project are categorized in three major stages of design, tendering (procurement) and construction. The standard contract document of NZS3910 as common used contract document in New Zealand are assessed among all identified rework root causes to find out which items will be covered by contract clauses and contract attachments. However, the term of rework has not been mentioned in contract documents, some part of rework root causes such as changes can be covered by clause 9 of contract condition as “Variations”. In other words, rest of rework root causes still need to be looked over. In this paper only tendering stage of project has been assessed, so the paper only has identified and classified the construction rework root causes under tendering stage of project. Results from the assessment of the rework root causes that embedded in contract documents of NZS3910 will be presented in anther paper. Thus, further study to understand what possible contractual changes are required to manage rework in construction projects is suggested. Apart from the summarized factors in conclusion part of this paper, assessing other general factors of tendering stage in future research projects would probably make a new contribution to the body of knowledge, factors such as “lack of manpower, staff motivation, inadequate knowledge and experience from category of human resources factors, lack of information technology use and lack of attention to quality from category of technical factors in addition to political effects from category of other related factors”.

5.8 Conclusion

In total, Investigation and analysis of a construction rework within a set of contract documents together with a suggested model of rework management to achieve higher performance will contribute to the body of knowledge. Results of this research more likely lead to development of professional practice in contracting step of construction projects. Under each stage of project life cycle, rework root causes are classified in five major factors as process, human resource, equipment/material, technical and others. Based on the obtained evidences from literature reviews of this paper, all identified rework root causes in tendering stage can only be classified in three categories of process related factors, technical related factors and other related factors. As the paper result indicates there are no items can be classified under human resources related factors and material/equipment related factors which more likely are acceptable as these two categories are not involve in this stage of project directly but needs more investigation. The summary of other three categories as the final output of this paper are presenting as the followings. This summary would be the fundamental structure for the future study of evaluating contract documents in relation to the matter of rework in tendering stage of project.

1) Process related factors are those items that involving in practical work. These factors are included procurement method, contractor selecting process and incomplete design at the time of tender by client, improper subcontractor selection method by contractor and poor contract execution by both parts.

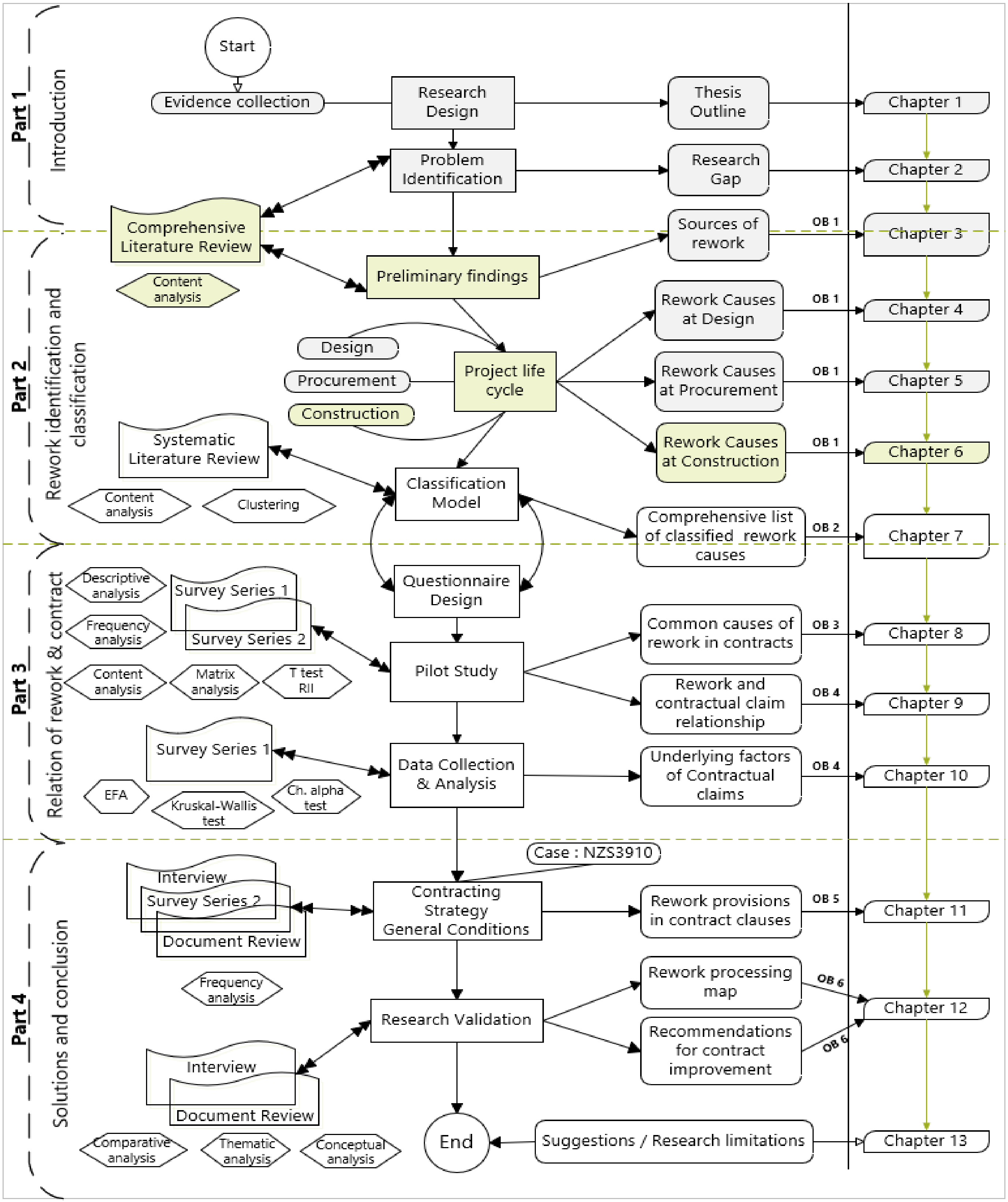
2) Technical related factors are among those items that are not essential part of practical work but can affect the process directly. Poor quality of contract documents prepared by client such as ambiguity due to lack of clear definition for working content, errors and missing contractual parts due to incomplete design documentation, any deviation and errors in proposal documents prepared by contractor are among those major technical items that has the potential of rework.

3) Other related factors that can be categorized under this stage of project are included financial issues such as payment of low fees for preparing contract documentation, payment of low contract fees or delay in payment to contractor plus insufficient time to prepare contract documentation by client and consultant.

5.9 Epilogue

This chapter focused on the project's procurement stage while investigating the causes of rework with liable parties of the contract, including client and contractor. The previously proposed strategies based on the identified rework root causes in the procurement stage mostly rely on the contract documents. The finding of this chapter revealed that rework root causes contribute to both sides of the contract being slightly more reliant on the client. There are no identified rework root causes under the two categories of human resources and material/equipment, while contract documentation is the core of attention among several studies. Thus, more focus on the contract preparation as the main output of the procurement stage is critical for rework management. Construction practitioners can improve the contract conditions through a direct link between design and construction stages. This chapter recommends the assessment of the commonly used standard form of contract in New Zealand to understand if rework is addressed adequately in construction contracts or not. Therefore, the list of rework root causes under the project life cycle needs to be completed. The remaining rework root causes under the construction stage will be discussed in the next chapter.

Thesis-at-a-Glance / Chapter 6



Chapter 6. Contracts evaluation through classified rework root causes in the construction stage of projects

6.1 Prologue

This chapter aims to explore further the causes of rework in the last stage of the project through the literature. The root causes of rework in the construction stage with liable to the client and contractor side of the contract are identified and classified into five categories. In this chapter, a discussion on the causes of rework will be concentrated on the post-contract level issues. The number of rework root causes at this stage of the project should be higher than the other two previously discussed stages as it involves practical activities. Previous studies also have proposed various reduction and prevention models and strategies at this stage, but proposing a model only considering this stage of the project cannot be a comprehensive approach. The findings of this chapter classified different types of rework root causes in the same way as the previous two chapters with liable parties of the contract. This type of classification will allow the next step of research to be linked to the contract. By applying the developed classification model on the project's life cycle, rework causes in all three stages can be assessed based on their relations to the contract conditions. The chapter finishes with an extensive list of causes that heavily rely on the contractor. This result recommends early involvement of the contractor in contract preparation to address these causes in the contract conditions.

This chapter is based on the following published paper:

Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2020). Contracts evaluation through classified rework root causes in the construction stage of projects. *Proceedings of International Structural*

Engineering and Construction, *7(2)*, Emerging Technologies and Sustainability Principles, ISSN: 2644-108X.

6.2 Abstract

Rework occurs across the life cycle of projects and has significant impacts on construction project performance. A rational approach to managing rework is by identifying the main sources of rework, and then mitigation measures can be implemented to enhance performance on projects. Rework has been widely studied within the construction industry, but the link between rework and contract conditions remain unexplored. This study identifies and classifies the root causes of rework at the construction stage of projects. It then examines the relationship between the conditions of contracts with the identified root causes. A comprehensive list of rework root causes was determined through the review of literature, which was categorized into five classified factors. The classified factors include process, human resource, material/equipment, technical and other related factors such as environmental and financial. The next step comprises a questionnaire survey designed to determine relationships between rework and contracts. The result of the study is presented descriptively for ease of understanding. The results show that rework could be managed more efficiently through contracting processes, which ultimately benefits construction projects' performance.

Keywords:

Classification, Contracting, Equipment, Human resources, Material, Process, Technical, Root-causes

6.3 Introduction

The construction industry debatably has the least integration among other major industrial sectors (Isnaini et al., 2015). Rework has been recognized as a non-value adding problem that seriously affects the construction project's performance and is primarily ignored by the construction industry (Ahmed and Naik, 2016). According to the given definition by Love, rework is "Doing something at least one extra time due to non-conformance to the requirements." Despite the considerable amount of research that has been undertaken to date, there is little evidence can be found on rework reduction in projects (Jingmond and Agren, 2015), and future work is required to determine the underlying factors that contribute to rework. Regarding the origins of rework (Burati et al., 1992) introduced five major areas, including design, construction, fabrication, transportation, and operability. Then (Love and Edwards, 2004b) classified the causes of rework into design-related factors, client-related factors, and contractor related factors. Five other proposed categories were human performance, instruction, communication, design and engineering, planning and scheduling, material and equipment supply (Robinson et al., 2004), and recently an environmental causes group has been added to previous classification models (Mahamid, 2016a).

Evidence shows that new technologies make improvements, but they cannot effectively reduce construction problems. Advanced technology must be employed with a contemporary management concept (Aziz and Hafez, 2013). One of the most influencing processes in which each participant's precise role has been defined is through contracting. Lacking focus on customers and creating adversarial relationships as per contract plays a major role in the weak reputation of the construction industry (Love et al., 2005). The construction industry's performance can be improved through numbers of project management approaches and contracting management as one of those contemporary concepts has the potential of generating the highest value as it covers the life cycle of a project.

6.4 Background of the study

In construction projects, it is well established that rework contributes to the cost and schedule overrun (Love et al., 2010b). The broad range of research is evidencing that schedule delay and cost overruns are the rules rather than the exception in the construction industry (Han et al., 2013). Previous research results have shown that adopting and implementing effective approaches to identifying rework root causes will positively affect project performance. Hereafter are some of the applied strategies and methods by previous researchers to reduce or minimize rework in the construction industry: “Design scope freezing, Value management, Information technology use, Subcontractor’s involvement at the design stage, Integration of design management and project management, Supervision, Quality management, System dynamic models, Change management, Proper handling of materials.” However, different methods have been used to control rework, investigating the contract process, and their document to manage rework has not been thoroughly examined yet. The possible ways of interaction between rework and contract can be studied via searching rework root causes within contract documents. This paper classifies the root causes of rework as a base for further study on the contracting process through defined methodology in the next section.

6.5 Methodology

This paper is part of a research study that explores rework management in construction projects' contracting process. Identifying the causes of rework is the key priority of the study as it is used to evaluate contract documents. One way to provide a comprehensive list of identified rework root causes is through searching the published articles. As a result, the literature review method was used to fulfill the initial research requirements in the first step of the study. The sequences of implementing this method consist of identifying research by generating a strategy, criteria selection for including and excluding studies, collection of relevant articles, quality assessment of the collected studies, data extraction, and result summarization (Mohiuddin, 2011). After defining the search scope, the following arrangements were established in compliance with the current study's employed method. A critical review of a selection of criteria for the methodology used in this paper was completed as the following five arguments:

- Including academic studies in the research area of rework in the construction industry
- Updating the knowledge of rework management, particularly on root causes of rework
- Demonstrating the coverage of recent research over the previously published papers
- Assessing the quality of previous work through publications in respected journals
- Justifying a model for classification of extracted data to provide more reliable reports

The first step of this review was to answer this question of what are the rework root causes in the construction stage of projects? Based on this setup, the publications' search scope was defined through the keyword of rework in the paper titles. Rework is a broad term that is widely used in many research fields. In this order, a search was restricted only to the construction industry, and the rest of the other areas were excluded; after following these steps, the numbers of papers reached over 80 relevant publications. All collected publications were reviewed thoroughly to find out the causes of rework. Narrowing down to this specific target with careful consideration of the quality of provided documents led the authors to the point that all identified cause of rework can be found in some recent publications. Assessment of the publication's quality was determined through the criteria of being published in well-known journals. Total numbers of 7 publications, as shown in Table 6.1, were selected for final consideration, covering different regions over the world, such as Australia, Nigeria, Canada, China, and Palestine. These publications also have covered a broad range of construction projects such as residential buildings, infrastructures, industrial plants, highways, etc. For covering the last step of the designed method on reviewing the literature, an extra strategy was developed to generate a suitable report on extracted data as described below.

Table 6.1: List of selected articles following the strategy and criteria of methodology section

	Publication Sources	Authors	Year
A	The Journal of Performance of Constructed Facilities	Love et al.,	2009a
B	Journal of Building Performance	Oyewobi and Ogunsemi,	2010
C	Journal of Construction Engineering and Management	Zhang et al.,	2012
D	Journal of Construction Project Management and Innovation	Aiyetan and Das,	2015
E	Journal of Management in Engineering	Ye et al.,	2015
F	Jordan Journal of Civil Engineering	Mahamid,	2016a
G	International Journal of Sustainable Construction Engineering Technology	Enshassi et al.,	2017

The total identified rework root causes exceed 316 items for a project's life cycle on both sides of the contract (Asadi et al., 2019). The next research step to find relations between contract documents and rework would be more complicated with the long list of 316 identified causes. Furthermore, the pre-mentioned list showed that some of the endorsed contents in various publications are the same. Thus, a model for categorizing identified rework root causes was designed. The proposed model comprises five broad areas, and each area included more details to give a full explanation about rework root causes. This model was adjusted by combining four previous classification concepts mentioned in the introduction section and adopted based on current research needs in three levels. The first level shows two major parties of contracts as client and contractor, the second level consists of project stages as the research is covering the life cycle of a project, and level three distributes between areas of the process, human resources, technical, material and equipment and other related factors (Asadi et al., 2019).

Table 6.2: Classified rework root causes in the construction stage of project

Process related factors	Side	Source
1,2- Changes in the construction process or after completed work due to officials, additions, omission, removal and modifications in any order	Client & Contractor	A,B,D,E,G
3- Any construction error due to inappropriate construction method, poor design, complexity and incomplete understanding of design intent	Contractor	A,B,D,E,F
4- Omission of some tasks during construction		B
Human Resources related factors		
5,6- Lack of knowledge of construction process	Client & Contractor	A,B,F
7,8- Lack of experience in construction process		A,B,G
9- Labor reallocation, alteration and staff turnover	Contractor	A,B,F
10- Unqualified technical staff and unavailability of skilled labors due to lack of training and inadequate local education		A,B,F,G
11- Insufficient skills in both labor and supervisory levels such as poor teamwork in problem-solving		A,B,F
12- Lack of motivation and care, Carelessness		B,F
13- Poor workmanship approach and attitude such as incorrect interpretation of customer requirements, misreading of drawings or incomplete understanding of design intent		B,D,G
14- Personal issues such as disturbance in planning, attempt to fraud, rigidity to improvement, random human error, lack of trust, and commitment and conflict of opinions between participants		B,F,G
Material and Equipment related factors		
15- Defective materials due to shortage in the market	Client	B
16- Inadequate procurement of quality material or use of poor-quality material such as substandard products and services instead of advance material by subcontractors	Contractor	B,D,E,F
17- Replacement or misplacement of material and equipment in construction sequences due to insufficient functions or technological issues		C,E,G
18- Defective or damaged materials due to poor handling, poor supervision of admission or prefabrication errors		A,C,D,E,G
19- Use of inefficient equipment or altered material due to inadequate resources, shortage in market, emergency conditions or other technological issues		B,D,E,F,G
20- Untimely deliveries of material and equipment		G
Technical related factors	**Side**	**Source**
21,22- Ineffective use of quality management practices and lack of attention to quality or failure to implement QMS	Client & Contractor	A,B,D,F,G
23,24- Deviation and failure due to poor monitoring, audit, control and inspection or non-compliance to standards/specification and project requirements		A,B,D,F,G
25,26- Ineffective or lack of information technology and use of inappropriate construction technology applications		A,B,E
27,28- Ineffective management practice due to poor contractual relationship and poor communication and integration with project participants such as design, construction team members and subcontractor’s coordination		A,B,D,E,F
29,30- Inadequate construction planning and poor planning of workload or unrealistic programs such as time boxing and fixed time allocated to tasks without work separation		A,B,D,F,G
31,32- Conflicting and incomplete information due to poor information flow and inaccurate use of work specification and data		B,D
33- Poor project documents due to the absence of a clear uniform standard, lack of procedures to accept work, and late designer input	Contractor	B,D,E,G
34- Poor site management practice and ambiguous instructions due to lack of support and inadequate supervision, poor techniques implementation and ineffective construction methods use		B,D,E,F,G

Other related factors		
35- Unpredictable factors from different sources such as new request made by end-user during the construction to improve standards or during final inspection and certification,	Client	E
36- Financial issues such as budget compression or increase, cost pressure, and inadequate funding allocated for site investigation and consultation		D,G
37- Lack of constructability because of separation between design achievements and construction conditions		E
38-Changes in government regulations, laws, and policies		E
39- Poor safety considerations and failure to provide protection to the completed works	Contractor	A,B,D,E,F,G
40- Damage or defect by contractor and subcontractors due to construction errors and carelessness		A,B,D,F
41- Poor site condition such as delay in providing water and electricity		B,E,G
42- Delay in paying contract fees and payment of low contract fees due to low contract price		B,E,G
43- Cost pressure and Financial weakness such as inadequate funding and budget compression		B,E,G
44- Schedule acceleration, schedule pressures, excessive overtime, and working under high time pressure due to delay and untimely delivery		B,E,G
45- Adverse natural conditions such as hot weather, rain, cold, earthquakes, and floods and uncertainty of environmental aspects such as soil condition		B,E,G
46- Unpredictable factors from different sources such as government roles		B,F
47- External factors such as social, cultural, political, and economic influences and environmental situation such as the physical condition of a project		E,F,G

6.6 Findings and discussion

Various categories of rework root causes in the construction stage also show an uneven level in terms of quantity. Technical related factors with 14 items are the highest contributing category that produces rework in construction. Following that, the other related factors with 13 items are the second top category. Then human resources factor involving ten rework root causes and is seated as the third category. Material and equipment related factors hold six items of rework root causes, and the lowest number of contributing factors in rework occurrence belongs to the category of the process-related factor with only four items. None of these figures prioritize ranking as the study has not measured the impacts of rework. The sum of 47 classified rework root causes in the construction stage of a project with more details is shown in Table 6.2.

6.7 Conclusion

This paper presents classified rework root causes in the construction stage of projects through a literature review. Following the guideline steps in the methodology section. This review was conducted to categorize existing papers on rework causes. It was discovered that previous studies have mostly focused on the contractor side of the contract. Of the 47 classified root causes of rework in this stage, 33 items are associated with the contractor side, which is about more than 60 percent of all classified root causes in the construction stage. In addition, very few focuses are perceived on human resources factors, particularly in the contract's client-side. Another highlighted fact in the rework analysis is the frequency of repeating some of the roots, as can be seen in the table. Results showed that lots of effort had been put in certain areas mainly because of their impacts on the project or their probability of occurrences, such as deviation and failure by contractor, ineffective management and poor communication of contractor, poor site management practice by contractor, and changes made by the client. Rework root causes in the construction stage of the project will be summarized as the following five categories:

1) Changes by client and contractor, errors, omission, lack of control documents by contractor
2) Knowledge and experience of both the client and contractor's staff, unqualified labor, insufficient skills, poor workmanship approach, lack of motivation and personal issues
3) Defective materials by the client, inadequate supply of material, replacement, damaged material, inefficient equipment uses, and untimely delivery of material by the contractor
4) Ineffective use of quality management, deviation and failure, lack of IT, ineffective management practice, poor planning and incomplete information by both parts of the contract plus lack of procedures and poor site management by the contractor

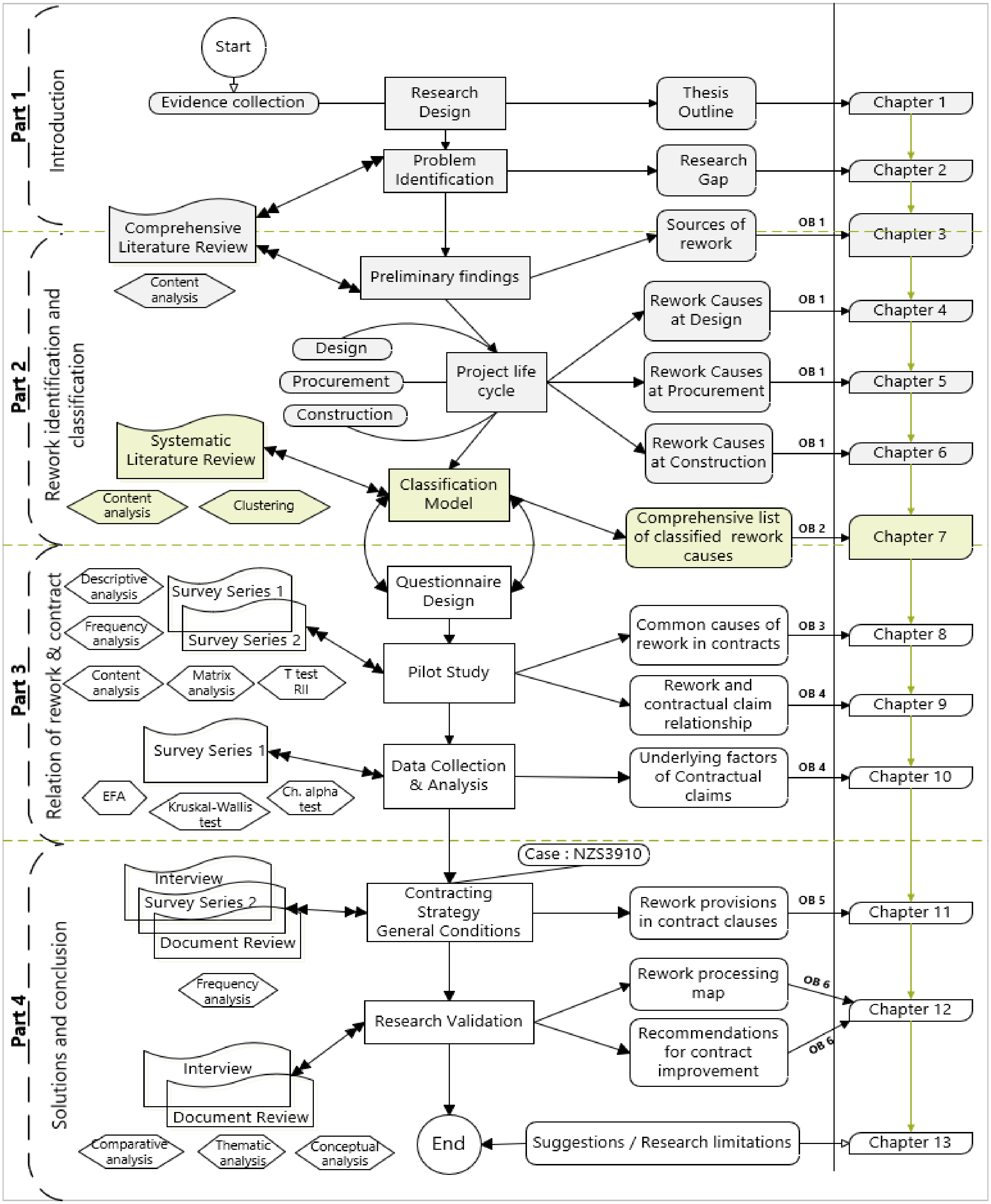
5) Governmental issues and constructability problems by the client, safety consideration, damage or defects, site situations, payment issues, schedule pressure, natural conditions and external factor from the contractor, financial issues and unpredictable factors for both

Contract documents are the core connections of client and contractor, and it defines authorities and responsibilities to cover any probable circumstances. This paper's results can serve as an authentic base for defining a new strategy on rework management to cooperate with the contract. Thus, it can cover the scholar gap searching for integrated rework solutions that affect both contract sides. The evaluation of involved contract clauses and the contract attachments through a questionnaire based on classified rework root causes can reveal the contract documents' weak connection points. Revising and amending contract documents under this perspective will strengthen the construction project outputs, such as performance and productivity. This study relies only on journal papers, so the result may have some limitations as the other conference papers have been excluded from the study's scope, so consider all papers for future studies is recommended. Furthermore, the same approach can be used for evaluating the other stages of design and procurement. Test and analysis of identified rework root causes through a survey among construction firms in future studies also is recommended.

6.8 Epilogue

This chapter reviewed the root causes of rework in the construction stage to complete the list of root causes that can be used to improve the contract conditions in New Zealand construction projects. For this purpose, numbers of previously identified causes of rework in previous studies were extracted and categorized in two parts based on their originated sources, either client or contractor. The classified causes of rework in this stage revealed the importance of the contractor's role in rework events. The provided list also demonstrated that rework occurs in the construction stage more than the other two stages. Thus, the construction stage contributions to the contract conditions in addressing rework root causes is predicted to be higher than the other two stages. Finally, a list of causes with the liability to the contract sides was developed. By completing this chapter, a full list of rework causes under three stages of the project life cycle was provided. The provided comprehensive list of rework causes at this level based on the preliminary literature review needs further validation through a wider range of articles and also requires to be organized in a model that combines similar causes. Thus, the next chapter rearranges all identified causes of rework through a systematic literature review to generate a comprehensive list of rework root causes by proposing a classification model that shows the dimensions of rework in terms of project stages and contract parties. This model helps construction practitioners address such issues directly to the relevant clauses of the contract, and though the condition of the contract can be improved when such evidence is available.

Thesis-at-a-Glance / Chapter 7



Chapter 7. Rework classification model in the project life cycle with liable parties of the contract

7.1 Prologue

This chapter aims to understand various rework classification methods used in previous studies to design and propose a collaborative model for the contract parties that can easily refer to it. To achieve this goal, a comprehensive study was performed through a systematic literature review on the sources of rework. It revealed the key elements required for classifying rework causes overall. The first part of this chapter gives a comprehensive list of rework root causes generated from three previous chapters. Then it follows three steps methodology to conduct a systematic literature review to classify the results throughout the project life cycle. Various applied classification methods in previous studies were then identified and compared. Based on the provided list of rework root causes, a classification model was designed at three levels to address each cause to the relevant stage of the project concerning the contract parties. The proposed model was implemented to the previously identified rework root causes and resulted in six separate tables. Each of the tables shows where needs further investigation. A more detailed discussion on the applicability of this proposed model in the research's next steps will be presented in the summary section at the end of this chapter.

This chapter is based on the following Journal paper:

Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Rework classification model in the project life cycle with liable parties of the contract. *Journal of Construction Management and Economics.* ID: 214526387.

7.2 Abstract

An effective way of improving performance on construction projects is to manage rework. However, managing rework is challenging because of the dynamic nature of construction activities. A rational starting point is the identification of the root causes of rework then a framework for its management can be developed for uplifting construction performance. This paper reviews rework-related studies in the construction industry through a critical review of literature. Through the investigation, a comprehensive list of the main factors affecting rework is identified. A content analysis on the previously proposed classification methods for rework revealed that all rework causes could be grouped under three stages: design, procurement, and construction. It also showed that rework causes could be ascribed to clients and contractors. The current study used a model that incorporates both parties to contracts across project stages to classify the identified rework causes. The developed model also categorised rework causes along typical project life cycle in five constructs: process, technical, human resources, material/equipment, and general/external factors for the two liable parties of contracts. The study findings show variability in rework causes. The procurement stage has fewer items than design and construction stages. Thus, procurement stage of the project needs further investigation. The result also revealed the involvement level of contract parties in rework occurrence can be utilized in further studying of contract management.

7.3 Introduction

In construction projects, the combination of stakeholders work together to execute a complex and unique product. Rationally, each stakeholder prefers to save its own benefit and has no motivation for working collaboratively. Such an attitude has steered projects to split the main work into smaller packages to be accomplished by distinct organizations individually. Thus, the stages of design, procurement, and construction of projects have been performed separately for a long period, and this breakup of the project life cycle has degraded construction success indicators such as performance, productivity, and competitiveness. Rework is a complicated research topic that appears across the project life cycle and has cross-functional impacts (Zhang et al., 2018). Implementing a life cycle philosophy for rework management is critical due to the integrated activities that occur across construction project stages. Rework is defined as "the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time" (Love et al, 2002). This paper introduces rework as part of the construction process, in which both parties to a contract are involved with and can suffer from. To facilitate construction projects' success, identifying rework causes at projects' life cycle and providing solutions to manage rework are required. Choosing an effective strategy to manage rework will be simplified by understanding the main problems throughout the project life cycle.

An effective way to identify the existing knowledge gap and pave the way for future studies is through literature review. The critical part of each research finding can be acquired and shared through publications for further advancement in a specific area (Bao et al., 2018), as publications provide a wider perspective of the topics. Thus, researchers are able to build a new idea by continuing the work of others. As a result, a comprehensive review of published papers identifies the current status and would help researchers to investigate future required research (Ke et al., 2009). In the study area of rework in construction, available literature mostly has focused on general trends of rework topics, and they lack systematic analysis on the causes of rework from a project life cycle perspective. Furthermore, there is no detailed analysis on the identified rework causes and their classification methods to be found in the literature. An extensive literature review on rework causes with a life cycle perspective identifies the knowledge gap in each stage and provides recommendations for further studies to achieve higher performance. The life cycle approach effectively reduces construction project costs (Bao et al., 2018) by managing rework. Thus, the paper aims to identify rework causes and categorize them systematically through an extensive literature review to provide a comprehensive list of rework causes. Hence, the critical review of rework literature in construction projects to address the root causes of rework in a structured way is presented.

7.4 Comprehensive list of rework root causes

The investigation into the sources of rework has taken more attention than the other study area of rework such as rework impacts, reduction models and solutions, proposed strategies and implemented theories. Identifying the root causes of rework has always been an essential part of research around rework as it is the first step towards rework management either through reduction or prevention (Hwang et al., 2009; Ye et al., 2015; Ndwandwa et al., 2017). Rework identification is a necessity in construction projects as the consequences of rework lead to cost overruns and delay, poor organizational performance, and contractual claims (Love and Smith, 2003; Kim and Skibniewski, 2020). Many sources of rework and rework causes have been identified in research studies over the years. Various research have attempted to identify causes of rework in different types of construction projects including residential and commercial buildings, (Oyewobi and Ogunsemi, 2010; Hwang et al., 2014; Ajayi and Oyeyipo, 2015; Yap et al., 2017; Liu et al., 2020; Mahamid, 2020), civil and infrastructure (Palaneeswaran et al., 2008; Love et al., 2010b; Zhang et al., 2012; Palaneeswaran et al., 2014; Enshassi et al., 2017; Hwang et al., 2019), and industrial plants.

The primary sources of rework are deviation from quality or nonconformance, changes, failures, defects and damages, errors, and omissions (Palaneeswarane et al., 2005). Numerous rework causes have been identified in different research by implementing various methods of benchmarking, cause and effect, regression, system dynamic, artificial neural networks, and fuzzy set theory based (Love and Smith, 2003; Robinson et al., 2004; Palaneeswarane et al., 2008; Love et al., 2010b; Aiyetan and Das, 2015; Hwang et al., 2019). The first list of rework causes with six categories (Josephson et al., 2002) was presented as a benchmark rework cost in the Swedish construction industry. In 2004, a full list of rework root causes under five categories was developed in Canada to measure and classify construction field rework using a fishbone diagram of cause and effects (Robinson et al., 2004). The identified causes of rework through the literature had been used for different purposes, for example, providing a framework to monitor rework in building projects (Palaneeswarane et al., 2005) or to determine the cost of rework in civil and infrastructure projects (Love et al., 2010b; Miri and Khaksefidi, 2015; Mahamid, 2016a).

The list of rework root causes has evolved through empirical research and case studies worldwide. In some studies, the list of rework causes was identified and tested over construction projects, and in some others, it has been used for proposing a classification model or developing a framework of rework management (Love and Edwards, 2004a; Love et al., 2009a; Forcada et al., 2014; Aiyetan and Das, 2015; Zhang et al., 2018). Part of the reviewed papers focused on the identification of rework causes from the perspective of their impacts on project performance through measuring contractual claims, time, cost, quality and safety indicators (Palaneeswaran et al, 2008). Previous studies also have provided or used the list of rework root causes for various purposes such as investigating client-related factors (Hwang et al., 2014), minimizing the effects of rework to achieve more effective construction (Shah and Sharma, 2016), reducing design-related causes (Wilson and Odesola, 2017; Salihu and Babarinde, 2020), examining the perception of professionals on the factors that trigger the occurrence of rework (Eze et al., 2018b), prioritizing rework indicators (Safapour et al., 2019; Balouchi et al., 2019), and evaluating the relationship between material waste and rework (Mahamid, 2020).

Despite all efforts to investigate the causes of rework in different projects type worldwide (Ye et al., 2015), there is no comprehensive list in the literature of rework root causes to cover all stages of a project. In most of the selected studies, identified rework causes were largely from one and, to a lesser extent, from two stages of a project rather than from the entire project life cycle. By conducting a critical review of the literature on rework studies and analyzing the most common root causes, this paper provides a comprehensive list of rework causes to fill the identified gap. However, some similarities exist between the list of rework causes from the selected publications; this paper has considered all identified causes to avoid missing any potential item.

7.5 Methodology

This paper is part of a research study that explores rework management in construction contracts. Poor contract management and scope ambiguity in the contract documents creates contractual claims and change orders that leads to rework occurrence (Palaneeswaran et al., 2006; Al-janabi et al., 2020). Thus, identifying the causes of rework is the key priority of the study as it was suggested for further investigation of the contract documents by previous research (Forcada et al., 2014). One way to provide a comprehensive list of identified rework root causes is through searching the published articles on rework in the construction sector. Published papers on the topic of rework from 1990 to 2020 were obtained through the following systematic literature review steps. The reason for the selected period is that rework research has started expanding after the first official definition of rework by Construction Industry Development Agency in 1995 (Love et al., 2018a). A systematic literature review as a scientific activity is more often used for management practices. The sequences of implementing this comprehensive review consist of identifying research by generating a strategy, selecting criteria to include and exclude studies, collecting relevant articles, quality assessment of the collected studies, data extraction, and result summarization (Park and Tucker, 2017). This review was initiated to answer this question of what the root causes of rework in construction projects are. Accordingly, the scope of searching publications was defined through the keyword of “rework” in the paper titles. Rework is a term widely used in many research fields and is interchangeable with several other words (Love and Smith, 2003). To avoid such possible interferences, the keyword used in this paper was confined only to “rework” in the paper's title. The search was further limited only to construction projects with the document type of article and conference papers. Other published papers under the broad categories of editorial, book review, forum, discussions/closures, letters to the editor, articles in the press, index, foreword, introduction, conference/seminar report, briefing sheet, and comment were excluded from the search analysis.

Following the commonly used method in previous studies, suitable search engines of Scopus, Web of Science "WoS," and Google Scholar were employed for searching (Bao et al., 2018; Habibi and Kermanshachi, 2018; Wang et al., 2020). The study began by (a) searching for the rework topics in the Scopus search engine followed by two complementary searching engines, (b) selecting relevant papers and (c) clustering them based on the subtopics, and then (d) detailed analysis of rework causes from the project life cycle perspective. In the first search round, Scopus was utilized as it is widely used for reviewing construction literature. The search was then completed using the Web of Science and Google Scholar search engines (Chan et al., 2020). Using the second and third search engines ensured that no relevant document was missed. The supplementary search engines cover the potential limitations of each other. The following algorithm has been considered to meet the systematic literature review criteria, as described in Figure 7.1.

7.5.1 Comprehensive literature review

The review process of finding relevant journal and conference papers is started when the research requirements are adopted based on the scope of the study (Safapour et al., 2019; Malek and Desai, 2020). The afore-mentioned requirements then are divided into three main steps: defining a search strategy, refining documents for inclusion in and exclusion from the papers, and examining of the documents to ensure that only selected papers are in the study's scope and are not duplicated. The search for rework in three search engines was conducted on the 14th of April 2020 with the following codes:

(TITLE (rework) AND ALL (construction)) AND DOCTYPE (ar OR cp) AND PUBYEAR > 1989 AND (LIMIT-TO (LANGUAGE , "English")) in the Scopus search engine,

(TITLE: (rework) AND TOPIC: (construction), Timespan: 1990-2020. Databases: WOS, BIOABS, CABI, CCC, FSTA, KJD, MEDLINE, RSCI, SCIELO. Search language=English) in the Web of Science search engine and,

(with all of the words (rework) AND (construction) in the title of the article, Return articles dated between, 1990-2010, excluding citations AND search English pages) in the Google Scholar search engine.

The above three search engines resulted in 128 papers in Scopus, 92 papers in Web of Science, and 109 papers in Goggle Scholar. A total of 329 papers were then reviewed to remove the irrelevant documents and repeated papers among three search engines. The selection of more relevant papers will lead to more accurate results. Thus, initially, all paper titles were reviewed carefully to check whether they meet the research scope or not. The papers with titles out of the research scope were removed. Following that, the abstract of all remaining documents was scanned to segregate the relevant papers according to research scope. Besides, all papers with the same titles were identified to avoid duplications. The outcome of all these process steps resulted in 82 papers in Scopus, 10 papers in Web of Science, and 48 papers in Google Scholar. In total, 140 papers remained for further analysis.

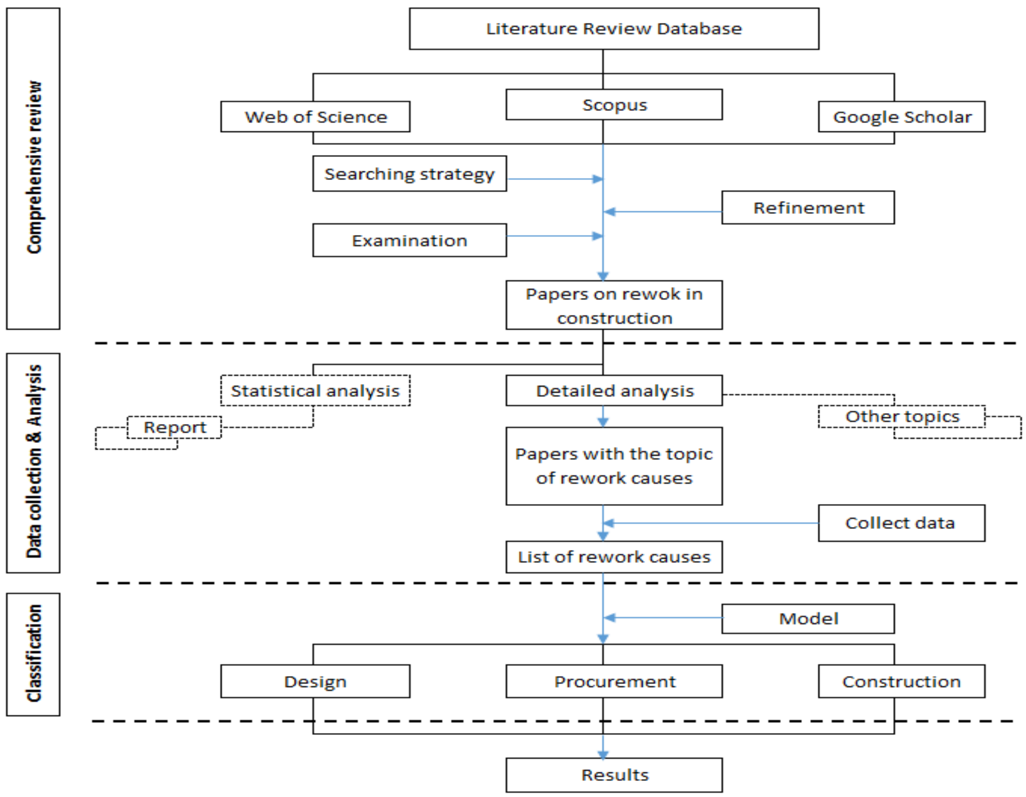


Figure 7.1: *The process of research methodology*

7.5.2 Data collection and analysis

All 140 papers were studied to take out the required data around the causes of rework and provide a comprehensive list of rework root causes that covers both liable parties of the contract in the project life cycle. The following strategy was developed to generate a report on the extracted data. The main criteria for selecting papers were mainly based on discussing the causes and sources of rework. Thus, all papers that contain the list of rework causes were clustered in a separate group for further discussion and providing a report. Of 140 publications, the total number of 35 papers had provided a list of rework causes. Since the paper aim was to provide a comprehensive list of rework causes, all identified causes in the selected papers including their classification methods were transferred to an Excel file for further analysis. Different categories appeared from the extracted data of the collected classification methods. The Excel file also revealed that the number of cases in each study varied and ranged between a minimum of seven items (Hwang et al., 2014) and a maximum of 77 items (Oyewobi and Ogunsemi, 2010). The results and discussion sections of the paper contain more detail about the analysis of causes and their categories.

7.5.3 Classifying the results

Further analysis showed that most previous studies had classified the causes of rework based on their research aims. As can be seen in Table 7.1, various rework classification methods have been used in the construction industry for categorizing identified rework causes and measuring their impacts. Despite the various points of view on classifying rework root causes, having a model for managing rework consequences is essential when rework causes are identified (Hwang et al., 2009). The identified rework causes from the literature can be categorized into different groups based on their similarity and differences. A flexible model for various construction projects can cover all identified rework causes and provide any possible solutions or recommendations. Since this research aims to look at the causes of rework within the project's life cycle, the model needs to contain the main project stages, including design, procurement, and construction. The classified causes of rework will also be used for further studying of the contract (Al-Janabi et al., 2020), so the liable contract parties would need to be included in the classification model. For this purpose, a classification system at three levels in Figure 7.2 was adopted to address all reviewed and analyzed rework root causes from the collected data section. The proposed structure covers all rework causes and addresses each of the root causes to the project stages and liable contract parties.

All identified rework causes were then placed in the adopted classification model as described in the following sections to provide a comprehensive list of rework causes that can be utilized in construction contracts throughout the project life cycle.

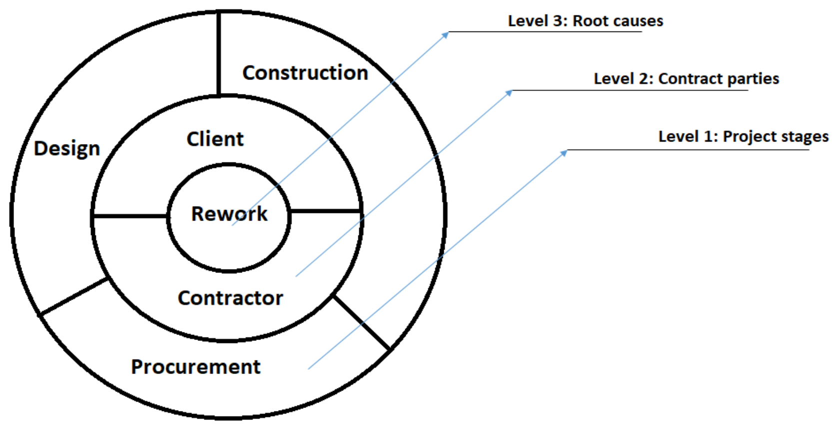


Figure 7.2: *Conceptual structure for rework root causes classification*

7.6. Results

7.6.1 Rework classification methods in the reviewed papers

In previous studies, the list of identified rework root causes has been classified in various methods depending on the study's aim. The classification of rework causes is an essential part of the rework management process (Robinson et al., 2004; Zhang et al., 2012). The root causes of rework are traceable when a classifying method is employed. The classification provides referencing for future rework management and strategies (Love and Edwards, 2013). Table 7.1 presents the rework classification methods used in the reviewed papers. Employed classification methods in the literature indicated that the root causes of the rework could be categorized into various groups, including (a) stakeholders, (b) project stages, (c) organizational factors and activities, and (d) other miscellaneous aspects. Most of studies have classified rework causes based on the initial sources of rework from stakeholders (client, contractor, consultant and subcontractors). Classification based on the occurrence of rework at different stages of the project (design, contracting management and construction) was the second-most used method in the selected papers. The rest of the papers have added some other categories or used a combination of stakeholders and projects stages at the same level in their classified results. A lesser proportion of the papers have not adopted a specific classification method and simply listed the causes of rework. All category names of rework causes used in the classification method of the reviewed papers are listed in Table 7.1. The most used category names among the classification methods were design (21 studies), client (18 studies) and contractor (10 studies).

Detailed analysis showed that the list of rework causes under each category varies among different studies. The lack of a system for categorizing rework causes in construction projects was revealed by reviewing the available classification methods. The lists of rework root causes in most of the studies were adopted based on the research needs, project types and stakeholders' requirements. Therefore, the existing classified groups do not cover a wide range of rework causes comprehensively. Furthermore, the same identified causes are found in different categories from different levels. For example, lack of communication was identified in the category of client (Mahamid, 2016a; Eze and Idiake, 2018b; Trach et al., 2019), contractor (Hwang et al., 2019), and subcontractor (Ye et al., 2015; Liu et al., 2020), and at the same time, under various project stages such as design (Wilson and Odesola, 2017; Liu et al., 2020), construction (Mahamid, 2020), or other categories (Oyewobi et al., 2016; Enshassi et al., 2017). A single cause may occur in different project stages or under different parties, thus same level categorization of causes may unable to show their accurate roots. Lack of knowledge and training is another example that can occur in the design or construction stages (Eze and Idiake, 2018b; Eze et al., 2018a; Trach et al., 2019; Hwang et al., 2019) and can be linked to both sides of the contract, either client or contractor. It also had been classified in the grouping of human resources in some other studies (Zhang et al., 2012; Shah and Sharma, 2016). It can be concluded that despite all the efforts to identify rework causes, there is a lack of a standard classification model to cover all project stages with liable contract parties. A structured classification model including a comprehensive list of rework root causes removes the limitations and summarizes the long list of identified causes.

7.6.2 Classification model

The list of rework root causes needs to be analysed, and for this purpose, an in-depth classification model that could address rework at various project stages and the different sides of the contract was required to be designed and developed. The employed concepts and terminologies in Table 7.1 were used as the basis of the proposed model in this paper. Rework causes can be grouped based on their sources, impacts, occurrence in project stages, and involved parties. The proposed model in this study covers rework causes either from various sources or at different project stages. Since a standard contract in the construction industry is involved with two parties overall, this study has focused on these two main parts - the client and the contractor. The client side of the contract generally encompasses consultants and the contractor side includes subcontractors and vendors. Both parties are involved throughout the project life cycle and therefore both client and contractor at each project stage may contribute to rework occurrences. The proposed model has incorporated contract parties and various project stages at two separate levels to tackle these contradictions. As a result, six clusters appear in the model, namely, design-client (cluster 1), design-contractor (cluster 2), procurement-client (cluster 3), procurement-contractor (cluster 4), construction-client (cluster 5), and construction-contractor (cluster 6). The identified rework root causes from the literature then were grouped into five constructs under each of the clusters in the third level.

Providing a systematic approach for classifying the causes of rework will improve the rework management consequences. Thus, the following proposed model in three levels describes when, where, and how rework occurs. Each stage of the project shows when rework occurs, during the project life cycle. The contract's liable parties indicate where the causes of rework originate. Lastly, root causes of rework can be placed under each of the stages and liable contract sides to explain how they may be initiated. The concept and criteria applied in previous studies have been considered in the following model to avoid missing or duplicating any of the identified causes. Grouping the similar rework root causes is necessary to understand the interdependency of causes and avoid duplications (Siraj and Robinson, 2019). The category names in the proposed model were adjusted precisely to cover all identified categories in Table 7.1. In the case where a category name was found with other similar terms, the more inclusive name has been chosen. For example, the category name of “Contract Management” was replaced by “Procurement” and the category name of “Construction” covers both “Site Management” and “Construction”. Furthermore, “Process” was selected over “Change/Error/Omission” as it covers all the interchangeable names, and “Human Resources” was selected over the other terms of “People and Workmanship”. Some of the category names were required to be combined to avoid missing items. For example, four categories of leadership and communications, planning and scheduling, technical, and quality management that were incorporated as supportive activities were named mutually as “Technical”. Thus, the proposed classification model clearly shows the various groups of rework causes with their liable contract parties in the life cycle of projects.

7.6.2.1 Level 1: Project Stages

According to PMI "Project Management Institute," the life cycle of a project consists of developed sequences from initiation to closing. This definition in the construction industry in overall, consists of three main stages of design, procurement and construction (Habibi et al., 2018), which are sometimes called EPC in megaprojects. The design stage covers cases of rework from previously identified categories of design and engineering reviews. The procurement stage covers rework causes from previous contracting management categories (Coleman et al., 2020), and the construction stage covers previous categories of site management and construction (Palaneeswarane et al., 2005). Rework causes in the category of “Project” are distributed among all stages depending on the nature of the items.

7.6.2.2 Level 2: Contract Liable parties

Since contract documents in construction projects are signed off between the client and contractor, this paper has classified rework causes into these two main groups as described earlier. The client parts cover two previous categories of client and consultants. The contractor parts cover three categories of contractor, subcontractor and supplier from previous classification methods (Assaad et al., 2020). Rework causes under “Organizational factor” are distributed among both parties depending on the nature of the items.

7.6.2.3 Level 3: Root causes

Continuance to the afore-mentioned levels; this paper has categorized the root causes of rework under five distinct constructs: process, human resources, material and equipment, technical, and general/external factors. The group of process-related factors covers the items from the previously classified category with the same title. Human resources-related factors cover the previous categories under the names of workmanship, people, and human resources. The material and equipment related factors cover the same category in previous models plus the machine’s category. The technical-related factors cover the following categories of planning and scheduling, leadership and communication, technical and quality management. The last group of general/external factors covers the previous categories of environmental/external, and other related factors. In this way, all identified causes of rework throughout the literature are allocated to the proposed model.

Figure 7.3 presents a diagram of the proposed model in which the horizontal line has divided it into two similar patterns that may occur on both sides of the contract. The upper section addresses the client and the lower section is for the contractor. This line also has been considered as the border between the two and can be treated as the contract. The contract documents are signed at the end of the procurement stage, while before and after that point are known as pre-contract and post-contract respectively. It also shows how a project evolves from design on the left side of the diagram towards the end of construction on the right side. Each of the five constructs has been placed on both sides and three stages to check the probability of rework occurrence in the entire process. Each box in the diagram contains numbers of rework root causes, as described in Table 7.2 to Table 7.7. Three abbreviations based on the three-level classification system have been allocated for coding of the boxes. The first character of the code shows the project's stage, and includes "D" for design, "P" for procurement, and "C" for construction. The second character shows the liable contract parties in which "E" is used for the client-side and "S" for the contractor side. The third character shows the relevant category of root causes as "P" for the process, "H" for human resources, "M" for material and equipment, "T" for technical, and "G" for general/external related factors. For example, DST means technical related factors that originated from the contractor side at the design stage and may comprise more than one root cause that will be demonstrated as DST1, DST2, and more. Each identified rework cause places in one of these boxes.

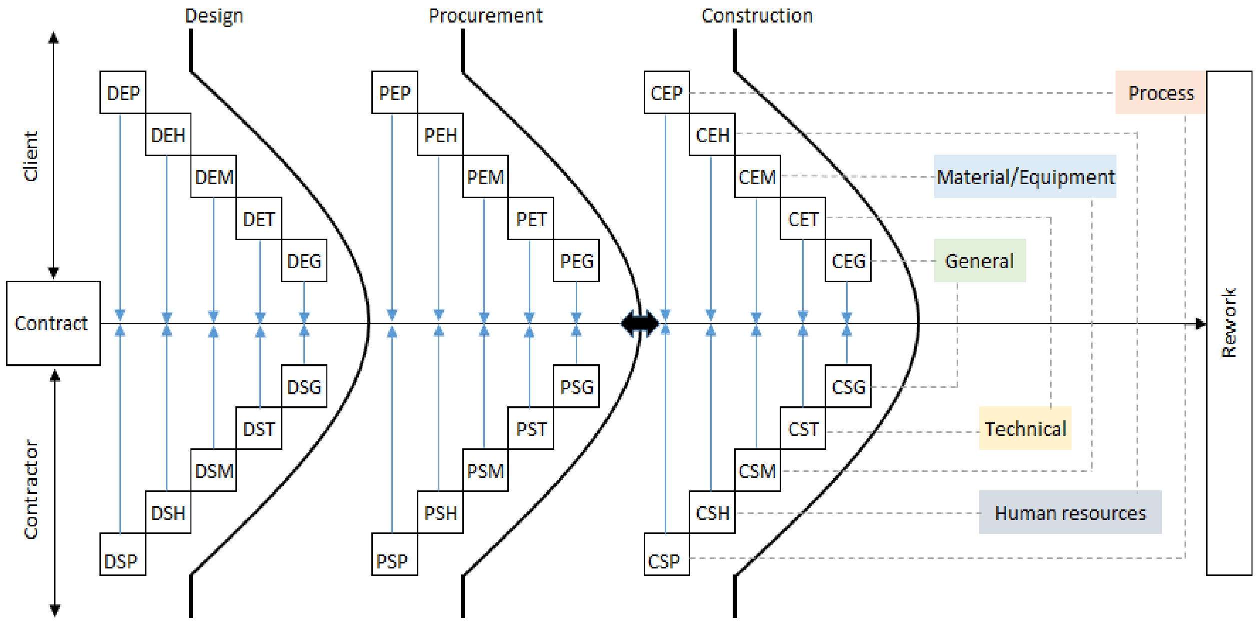


Figure 7.3: *Classification model for rework root causes in life cycle of project with liable parties of the contract*

7.6.3 Rework causes classification and ranking in the project stages

Several research efforts have attempted to identify and classify the causes of rework and quantify its overall extent (Aiyetan, 2013), and each study's outcomes show different results. Engineering and reviews such as unsuitable or faulty design and lack of coordination in the design stage were known as the most significant causes of rework at the design stage (Josephson et al., 2002; Robinson et al., 2004). In other studies, human resources capability, and rework factors related to the contractors were prioritized as the major rework categories that affect the projects' performance (Enshassi et al., 2017; Eze and Idiake, 2018b). The top five rework factors were identified as error and omission, labour skills, inadequate supervision, scope changes, and NCR to the specifications and requirements of the project (Mahamid, 2020). Detailed analysis revealed that various identified rework causes have been classified in different ways. The importance and frequency of these causes vary from one study to another depending on the project type and locations.

Distribution of the identified rework root causes within the proposed classification model is presented in Table 7.2 to Table 7.7. Each table presents a list of classified rework causes in a project stage that can be linked to one side of the contract. The identified causes under each study were analyzed separately to bring together the same items under each Table. The frequency of repeating an item over the studies is indicated in the last column of the tables. This indicator is for ranking of the causes and does not make any priority in terms of severity or probability of rework occurrences. It only reflects the high interest of previous studies on the identified cause and explains how it was commonly used among previous researchers. For making the list of causes in each project stage, the following process took place to maximize the accuracy of referencing from the literature (Chan et al., 2020).

- Provide a list of rework causes under each author name to define the interrelations between causes
- Review the identified cause regarding the relevant paper's title as precisely as possible
- Ensure that categorizations of causes are uniform by comparing the provided lists
- Match the retrieved information with the details of the project stage
- Optimize the results through merging the same items in each stage separately

This processing confirms that all causes have been grouped in the most relevant and correct places. It also reduces the variety of views in providing more general causes that will incorporate easily into the more overall frameworks. Moreover, it would help the identification of more effective response strategies that can be allocated to the appropriate contract party. It finally generates a comprehensive list of rework causes that can be adopted for different projects and both contract parts.

Table 7.1: An overview on the classification methods used in the reviewed papers in this study

	References	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	
	Category / **Country**	Sweden	Australia	Canada	Hong Kong	Hong Kong	Hong Kong	Australia	Nigera	Australai	Canada	Nigeria	Hong Kong	Singapore	Spain	China	Iran	Nigeria	Nigeria	Palestine	India	India	Nigeria	Nigeria	Palestine	South Africa	Nigeria	Malaysia	Nigeria	Nigeria	Ukrine	Singapore	USA	China	Saudi Arabia	Nigeria	Number of occurence
1	Client	√	√	~	~	√	√	~	~	~	~	√	√	√	~	√	√	~	√	√	~	√	~	~	√	~	~	~	√	√	√	√	~	√	~	~	18
2	Consultant	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	2
3	Contractor	~	~	~	~	~	~	~	~	~	~	√	~	~	~	√	~	~	√	√	√	~	~	~	√	~	~	~	√	√	√	√	~	~	~	~	10
4	Subcontractor	~	√	~	√	√	√	~	~	~	~	~	√	~	~	√	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	8
5	Vendor/Supplier	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	1
6	Organizational factors	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	2
7	Design/Engineering review	√	√	√	√	√	√	~	~	~	~	√	√		~	√	√	~	√	~	√	~	~	√	√	√	~	√	~	√	√	√	~	√	~	√	21
8	Contract Management	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	2
9	Construction	~	√	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	√	~	~	~	~	~	~	~	~	~	√	~	5
10	Project	~	~	~	~	~	~	~	~	~	~	~	~	~	√	√	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	√	√	~	~	5
11	Workmanship/People/Human Resources	√	~	√	~	~	~	~	√	~	√	~	~	~	√	~	~	~	~	~	√	~	~	~	√	~	~	√	~	~	~	~	√	~	~	~	9
12	Site Management/Productopn/Operation	√	√	~	√	√	√	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	7
13	Material & equipment/Machine	√	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	√	~	~	√	~	~	~	~	~	~	~	~	5
14	Process/Change/Error/Ommision	~	~	~	~	~	~	~	~	~	√	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	√	~	~	4
15	Technical	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	1
16	Leadership and Communications	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	1
17	Planning and Scheduling	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	2
18	Quality Management	~	~	~	~	~	~	~	√	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	1
19	External/Environmental aspects	~	~	~	~	~	~	~	~	~	~	~	~	~	~	√	~	~	~	√	√	~	~	~	√	~	~	~	~	√	~	~	~	√	~	~	6
	No classification/ General	~	~	~	~	√	√	√	~	√	~	~	~	~	~	~	~	√	~	~	~	~	√	~	~	~	√	~	~	~	~	~	~	~	~	~	7

[1] Josephson et al., 2002; [2] Love and Smith, 2003; [3] Robinson et al., 2004; [4] Palaneeswarane et al., 2005; [5] Palaneeswarane, 2006; [6] Palaneeswarane et al., 2008; [7] Love et., 2009a; [8] Oyewobi and Ogunsemi, 2010; [9] Love et., 2010a; [10] Zhang et al., 2012; [11] Aiyetan, 2013; [12] Palaneeswarane, 2014; [13] Hwang et al., 2014; [14] Forcada et al., 2014; [15] Ye et al., 2015; [16] Miri and Khaksefidi, 2015; [17] Ajayi and Oyeyipo, 2015; [18] Aiyetan and Das, 2015; [19] Mahamid, 2016a; [20] Shah and Sharma, 2016; [21] Ahmed and Naik, 2016; [22] Oyewobi et al., 2016; [23] Wilson and Odesola, 2017; [24] Enshassi et al., 2017; [25] Ndwandwa et al., 2017; [26] Ajayi, 2017; [27] Yap et al., 2017; [28] Eze et al., 2018ba; [29] Eze et al., 2018b; [30] Trach et al., 2019; [31] Hwang et al., 2019; [32] Safapour et al., 2019; [33] Liu et al., 2020; [34] Mahamid, 2020; [35] Salihu and Babarinde, 2020.

Table 7.1: An overview on the classification methods used in the reviewed papers in this study

7.6.3.1 Design Stage

The design stage consists of two main parts: pre-design/conceptual design and detailed design (Yeo and Ning, 2002). The development of this stage has been identified as the most important activity in a project's life cycle (Habibi et al., 2018) as the initial concept of the client's requirement consolidates into a form within this stage. All items under this category from previous research studies were carefully reviewed to combine altogether and make a single list of causes in the design stage. Table 7.2 comprises 24 root causes of rework from the client-side of the contract concerning their code number, references and numbers of citations.

Table 7.2: Rework causes classification in design stage - liable to the client-side of the contract

	Rework root causes	Code	Covered by references	sum
1	Poor communication system	DET1	[2,5,6,7,9,10,11,12,15,16,17,18,19,21,24,27,28,29,30,33]	20
2	Changes, modification, and revisions	DEP1	[1,2,3,4,7,8,9,10,11,13,15,18,19,22,24,25,30,31,33]	19
3	Financial issues and lack of funding	DEG1	[2,5,6,7,9,11,12,13,16,17,18,19,21,24,28,29,30,31]	18
4	Conflicting and incomplete information	DET2	[1,3,5,6,9,11,14,15,16,17,18,19,22,23,24,26]	16
5	Lack of client involvement	DEG2	[2,5,6,7,8,9,12,16,17,19,21,25,26,28,29,30]	16
6	Lack of experiences and personal expertise	DEH1	[2,5,6,7,8,9,12,14,16,18,19,21,28,29,30]	15
7	Lack of education and poor knowledge of team	DEH2	[2,5,6,7,8,9,10,12,16,19,21,28,29,30,32]	15
8	Time pressure to complete design tasks - lack of time	DEG3	[2,7,8,9,11,12,14,18,19,21,23,28,29,30]	14
9	Inefficient management	DET3	[8,10,11,13,17,18,24,31]	8
10	Inadequate planning and poor scheduling of workload	DET4	[7,8,9,10,11,14,18,19]	8
11	Insufficient skilled level manpower	DEH3	[3,8,10,14,17,21,24]	7
12	Defective material, non-adherence to material spec.	DEM1	[1,3,10,13,14,20]	6
13	Ineffective use of quality management practices and deviation or failure due to poor monitoring	DET5	[7,8,9,11,14,18]	6
14	Incomplete design, omission in design, drawings, spec	DEP2	[3,7,8,9,10,19]	6
15	Lack of documents control	DEP3	[3,10,18,23,32]	5
16	Inadequate supervision staff	DEH4	[3,9,14,19,27]	5
17	Error in design, drawings and specifications	DEP4	[7,8,9,15,19]	5
18	Poor technology application and lack of IT use	DET6	[7,8,9,17,18]	5
19	Conflict of interest	DEH5	[11,20,24,31]	4
20	Inappropriate personal attitude	DEH6	[8,10,24]	3
21	Lack of employee motivation and rewards	DEH7	[8,10,24]	3
22	Unclear line of authority	DEG4	[20,24]	2
23	The absence of job security and other safety rules	DEH8	[20,24]	2
24	Unanticipated consequences of change	DEG5	[8]	1

The findings suggest that rework causes in the design stage of a project have appeared in all five categories. However, the distribution of root causes among the categories is not in balance for both sides of the contract. The most frequent category in the design stage is human resources related factors, on both sides following the technical related factors. Overall, the total number of rework root causes at this stage of the project is more likely to slope towards the client rather than the contractor with 24 items against 21. Table 7.3 comprises 21 root causes of rework from the contractor side of the contract concerning their code number, references and numbers of citations.

Table 7.3: Rework causes classification in design stage - liable to the contractor-side of the contract

	Rework root causes	Code	Covered by references	sum
1	Poor communication system	DST1	[1,2,5,6,7,8,9,10,11,14,15,18,22,23,24,25,26,28,29,30,31,32,33,35]	24
2	Inadequate planning and poor scheduling of construction resources	DST2	[1,2,3,5,6,7,8,9,10,12,14,16,20,23,25,28,29,35]	18
3	Design changes in any form	DSP1	[3,4,7,8,9,10,11,15,18,20,22,23,25,28,29,30,31]	17
4	Time pressure to complete design tasks - lack of time	DSG1	[3,5,6,7,8,9,11,12,14,16,23,24,27,28,29,35]	16
5	Poor technology application and lack of information technology use	DST3	[2,5,6,7,8,9,11,12,16,17,18,23,28,29,30,35]	16
6	Ineffective use of quality management practices and deviation or failure due to poor monitoring,	DST4	[2,5,6,7,8,9,10,11,12,14,16,23,27,29,35]	15
7	Design errors in any form	DSP2	[3,7,8,9,10,11,15,22,23,24,25,28,29,31]	14
8	Inefficient management and ineffective coordination	DST5	[8,10,12,15,16,17,24,27,28,29,32]	11
9	Omission in design process and incomplete design information	DSP3	[1,3,8,10,11,15,22,23,24,25,31]	11
10	Lack of experiences and personal expertise	DSH1	[7,8,9,11,14,17,18,23,25,26,32]	11
11	Insufficient skilled level manpower	DSH2	[3,8,9,10,23,24,26,28,29,30,32]	11
12	Lack of education and poor knowledge of team	DSH3	[7,8,9,10,14,17,20,23,24,26]	10
13	Inadequate manpower to complete the task	DSH4	[2,5,6,7,8,9,12,16,25,35]	10
14	Labor reallocation, alteration and staff turnover	DSH5	[2,5,6,7,8,9,12,16,35]	9
15	Lack of document control	DSP4	[3,10,14,22,23,32]	6
16	Poor project documentations	DST6	[10,20,22,23,24]	5
17	Financial issues and lack of funding, cost pressure	DSG2	[17,20,24,25,26]	5
18	Lack of employee motivation and rewards	DSH6	[8,10,20,24,32]	5
19	The absence of job security and other safety rules	DSH7	[8,20,22,24,32]	5
20	Non-attention to constructability problems raised at early stages	DSG3	[5,6,15,23]	4
21	Inappropriate personal attitude	DSH8	[8,10,24]	3

7.6.3.2 Procurement Stage

The procurement stage plays an essential role in the success of construction projects as the project's cost and time are affected by different procurement strategies. Procurement is a stage between design and construction and generally overlaps with both stages leading to higher uncertainties (Yeo and Ning, 2002). This stage is also known as post design and pre-construction that comprises receiving documents from the design stage, tendering, contracting, and in some projects providing materials equipment. In most construction projects, procuring the required equipment and material is part of the contractor's main responsibility (Habibi et al., 2018). All relevant items from previous research studies were carefully reviewed and analysed, then placed in a single list. Table 7.4. comprises seven root causes of rework from the client-side of the contract concerning their code number, references and numbers of citations.

Table 7.4: Rework causes classification in procurement stage - liable to the client-side of the contract

	Rework root causes	Code	Covered by references	sum
1	Poor contract documentations, document omissions	PET1	[2,4,7,8,9,11,12,16,17,18,19,23,25,26,27,28,29,30,31,33]	20
2	Time pressure, insufficient time to prepare contract documentation	PEG1	[2,5,6,7,8,9,12,17,19,25,26,28,29,30,35]	15
3	Incomplete design at the time of tender	PEP1	[2,5,6,7,9,12,19,25,26,28,29,30]	12
4	Financial issues, low fees for preparing contract documents	PEG2	[2,9,12,21,28,29,30]	7
5	Improper contractor selection	PEP2	[8,11,12,21,22]	5
6	Errors made in the contract documentation	PEP3	[2,4,7,9,30]	5
7	Incomplete information at the time of award	PET2	[5,6,8,11]	4

The evidence of rework root causes at this stage revealed that only the three categories of process, technical, and general/external related factors appeared in both sides of the contract, and there is no evidence of studying the other two categories in previous research. An investigation into the categories of human resources and material/equipment from the procurement perspective in the future would benefit the projects. Further studying of the following items will contribute to the body of knowledge: lack of manpower, staff motivation, inadequate knowledge and experience from the category of human resources factors, lack of information technology use and lack of attention to quality from the category of technical factors in addition to political effects from the category of general/external related factors. Similar to the design stage, the total number of rework root causes from the client-side of the contract is higher than the contractor side. Table 7.5. comprises five root causes of rework from the contractor side of the contract concerning their code number, references and numbers of citations.

Table 7.5: Rework causes classification in procurement stage - liable to the contractor-side of the contract

	Rework root causes	Code	Covered by references	sum
1	Conflicting and incomplete information, ambiguity of items from contract documentation	PST1	[5,6,14,15,17,28,29,30,33,35]	10
2	Improper subcontractor selection	PSP1	[4,5,6,8,11,12,19,22,25,34]	10
3	Poor project documents, lack of clear definition of contract documentation	PST2	[5,6,15,23,28,29,30,33]	8
4	Inadequate procurement method, poor contract execution	PSP2	[8,11,15,22,23,24,31]	7
5	Financial issues, low contract fees	PSG1	[7,9,15,33]	4

7.6.3.3 Construction Stage

However, many research studies have emphasized the importance of the design stage in the process of construction projects, yet most problems such as delay, and cost overruns were raised from rework within the construction stage. Construction commencement before design completion affects the project's performance as the overlapping of these two stages transfers the impact of design errors to the job site thus increasing the time and cost of the project (Habibi et al., 2018). The previous classification systems of rework under construction group included contractor-related factors, site management, and subcontractor factors (Palaneeswarane et al., 2005). In this study, all previously identified items under these categories and other related factors were compared to provide the following single list of rework root causes at the construction stage. Table 7.6 consists of 14 root causes from the client sides of the contract concerning their code number, references and numbers of citations.

Table 7.6: Rework causes classification in construction stage - liable to the client-side of the contract

	Rework root causes	Code	Covered by references	sum
1	Lack of knowledge of construction	CEH1	[2,5,6,7,8,9,10,12,14,16,19,20,21,24,26,28,29,30]	18
2	Lack of experience and personal expertise	CEH2	[2,5,6,7,8,9,10,12,14,16,17,19,21,26,28,29,30]	17
3	Financial issues, cost pressure	CEG1	[2,3,7,8,9,11,12,13,15,18,24,26,33]	13
4	Changes or modification in the construction process or after completed work	CEP1	[1,3,4,7,8,9,11,13,18,22,24,34]	12
5	Lack of client involvement	CEG2	[2,5,6,7,8,9,11,17,25,26,28,29]	12
6	Lack of constructability	CEG3	[3,5,6,15,17,20,24,26,28,29,31]	11
7	Inadequate construction planning and poor planning of workload	CET1	[3,7,8,9,10,11,12,14,17,18,24]	11
8	Ineffective management practice	CET2	[8,11,13,14,18,22,24,31]	8
9	Conflicting and incomplete information	CET3	[1,8,11,14,15,18,22,24]	8
10	Defective materials	CEM1	[1,8,10,13,14,20,32]	7
11	Ineffective use of quality management practices and deviation or failure due to poor monitoring,	CET4	[7,8,9,11,14,18,24]	7
12	Poor technology application and lack of IT use	CET5	[7,8,9,12,17,26]	6
13	Changes in government regulations, laws, and policies	CEG4	[15,20,24,31]	4
14	Unpredictable factors from different sources	CEG5	[8,15]	2

The findings of rework root causes in the construction stage of a project revealed that, as with the design stage, all categories of causes are in existence in both sides of the contract. The highest number of rework causes in this stage has fallen in the technical category following by the general/external related factors. The other most frequent cause of rework in this stage is human resources in the contractor side; however, the number of causes in this category from the client-side is deficient. In contrast to the pre-mentioned stages, the total number of rework root causes from the contractor side of the contract is higher than the client-side. This evidence implies that previous studies have mostly focused on the contractor side as they have been more involved in this project stage. Table 7.7 comprises 27 root causes of rework from the contractor side of the contract concerning their code number, references and numbers of citations.

Table 7.7: Rework causes classification in construction stage - liable to the contractor-side of the contract

	Rework root causes	Code	Covered by references	Sum
1	Ineffective use of quality management practices and deviation or failure due to poor monitoring	CST1	[2,3,4,5,6,7,8,9,10,11,12,14,15,18,19,20,22,24,25,27,28,29,31,32,33]	25
2	Inadequate construction planning and poor planning of workload	CST2	[1,2,3,4,5,6,7,8,9,10,12,14,17,20,22,24,25,26,28,29,30,33]	22
3	Insufficient skills in both labour and supervisory levels, lack of supervision,	CSH1	[2,3,4,5,6,8,10,12,16,17,19,20,22,24,25,27,28,29,30,32,34]	21
4	Damage, defect or deviation of products due to carelessness and poor safety consideration	CSG1	[2,4,5,6,7,8,9,11,12,15,16,17,18,19,22,26,28,29,31,34]	20
5	Use of poor-quality material and substandard products	CSM1	[1,2,4,5,6,8,9,11,12,15,16,17,18,19,20,25,26,31,32,33]	20
6	Construction error	CSP1	[2,4,5,6,7,8,9,11,12,15,16,18,19,22,25,28,29,31,34]	19
7	Ineffective management practice and poor site management	CST3	[3,8,11,14,15,16,17,18,19,22,24,25,26,27,28,29,33,34]	18
8	Changes or modification in the construction process or after completed work	CSP2	[2,4,5,6,7,8,9,11,15,16,18,22,28,29,30,31,33,34]	18
9	Poor site condition, environmental conditions	CSG2	[5,6,8,15,17,19,20,22,24,26,27,28,29,31,32,33,34]	17
10	Poor workmanship approach and inappropriate personal attitude	CSH2	[1,5,6,8,10,16,17,18,19,20,24,26,28,29,30,31,34]	17
11	Lack of knowledge, unqualified technical staff and lack of training	CSH3	[7,8,9,10,14,17,20,22,24,26,28,29,30,31,32]	15
12	Poor communication system	CST4	[7,8,9,10,14,15,17,19,22,24,25,31,32,33,34]	15
13	Labour reallocation, alteration and staff turnover	CSH4	[2,4,5,6,7,8,9,12,17,19,22,26,28,29,34]	15
14	Schedule acceleration, time pressures	CSG3	[3,7,8,9,14,15,17,20,22,24,25,26,28,29]	14
15	The omission of some tasks during construction	CSP3	[2,4,5,6,7,8,9,11,17,22,26,30,31,34]	14
16	Poor technology application and lack of information technology use	CST5	[2,4,5,6,7,8,9,12,15,17,24,26,27]	13
17	Defective or damaged materials	CSM2	[1,3,8,10,11,15,18,20,24,25,27,31]	12
18	Inexperienced personnel	CSH5	[7,8,9,14,17,22,25,26,28,29,32]	11
19	Replacement or misplacement of material and equipment	CSM3	[1,10,14,15,20,24,28,29,30,31]	10
20	Use of inefficient equipment or altered material	CSM4	[1,10,15,19,20,24,25,27,33,34]	10
21	Financial weakness such as inadequate funding, cost pressure	CSG4	[3,8,15,20,22,24,25,26,32,33]	10
22	Conflicting and incomplete information	CST6	[3,8,14,20,22,25,26,28,29,33]	10
23	Lack of motivation and care, Carelessness	CSH6	[8,10,19,20,22,24,32,34]	8
24	Untimely deliveries of material and equipment	CSM5	[1,3,8,10,20,24,25]	7
25	Lack of manpower to complete the tasks	CSH7	[7,8,9,17,26,31]	6
26	Poor project documents	CST7	[8,20,22,24]	4
27	Unpredictable factors from different sources	CSG5	[8,15]	2

7.7 Discussion

An extensive literature analysis with the life cycle perspective has been presented for both sides of the contract. Table 7.2 to Table 7.7 show the ranking of rework causes based on the citations from previous studies and Figure 7.4 has summarized the number of causes in each group at three project stages. Most previously generated classification methods are comparable as they almost follow the same pattern. Thus, achieving a comprehensive categorization scheme for classifying rework causes is implicitly possible. Researchers have used different phrases to present the same rework causes in the literature. This study carefully surveyed each identified item from different sources to bring together the most interrelated concepts. For example, excessive overtime (Robinson et al., 2004), fixed time for a task (Palaneeswarane, 2006; Miri and Khaksefidi, 2015), time boxing (Love et., 2010), schedule pressure (Enshassi et al., 2017), accelerating or shortening the schedule (Ye et al., 2015), and insufficient time for activities (Wilson and Odesola, 2017) were recorded as one identified cause under the time pressure title. The summarized result in Table 7.8 is the main contribution of this study and it illustrates a diversity of rework root causes in a wider perspective. This comprehensive list of rework causes can be used and modified by project parties at initiation steps of the construction projects. A structured classification model of rework removes uncertainties about root causes of rework and assists practitioners to manage impacts of rework in later steps.

Following the proposed classification model, all identified causes of rework were clustered throughout the project life cycle. An overview of all identified rework causes in each project stage has been displayed in Table 7.8. This table comprises a list of 37 collected rework causes which are categorized into five primary constructs: process, human resources, material/equipment, technical, and general/external factors. The process related factor is involved with the projects' main activities. The human resources related factor deals with the human attributes. The material/equipment related factor supplies the project requirement. The technical related factor contributes to the supporting project activities, and the general/external related factor covers outsource items or causes that cannot be categorized under the four previously mentioned constructs. Referring to the nature of each construct, six causes were classified under process, 10 under human resources, five under material/equipment, seven under technical, and nine under the general/external category. Each category's underlying causes in the three project stages were placed under liable contract parties with the same reference code from Table 7.2 to Table 7.7. Therefore, coding numbers in each cause does not show an in-order pattern. For example, in the process category, changes are ranked first under the cluster of design-client with reference code of DEP1, while under the cluster of construction- contractor, errors are ranked first with reference code of CSP1. The reinking of rework causes in each category is based on the citation frequencies and simultaneously it is assumed as the importance index of the identified causes. Obviously, higher rank does not indicate higher occurrence probability, but depicts higher research interests.

As it can be seen in Figure 7.4, interest for studying causes of rework under the construction stage of a project was slightly higher than at the design stage while both construction and design were constantly studied more than the procurement stage. In the design stage, the number of identified causes of rework in the client side of the contract is higher than contractor side and it is not surprising because for rework management at this stage, the client involvement has been known to be the primary contributor (Mahamid, 2016a; Yap et al., 2017; Forcada et al., 2016; Love et al., 2010b; Eze et al., 2018b). The distribution of rework causes in both sides of the contract under this stage in Table 7.8 shows a total number of 28 out of 37 identified causes. Nearly all five categories under the cluster of client-design were cited as highly relevant, while the material/equipment related factor under the cluster of contractor-design seemed to be absent in the studies. The most cited cause in both contract sides is a poor communication system with a frequency of more than 20 times from 35 publications. This particular cause was reported as one of the most severe causes of rework (Mahamid, 2016a) in residential buildings that frequently trigger the need for rework management (Eze et al., 2018a). The logic is because communication provides channels for exchanging information between involved parties (Ye et al., 2015).

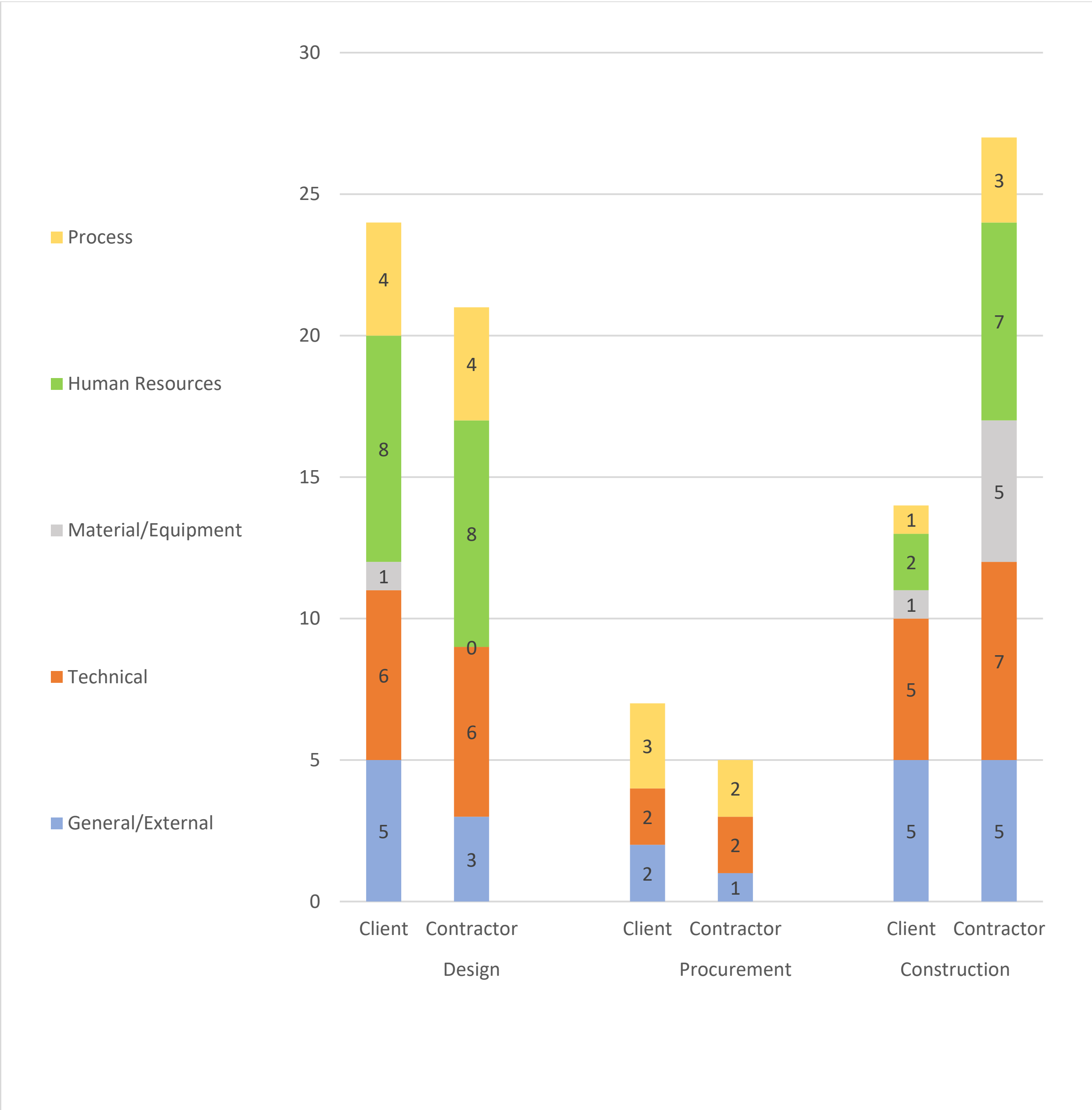


***Figure 7.4**: Distribution of rework factors in three stages of project*

Procurement is the other important project stage that affects project performance thereby contributing to rework occurrence (Forcada et al., 2017). In the procurement stage two categories of human resources and material/equipment were undeniably missed in the studies. The reasons for lack of research in this area needs to be investigated, whether due to the selected procurement strategy by the projects or redundancy. Research interests for assessing rework causes under the procurement stage in Table 7.8 have identified eight items out of 37 causes. Most of them deal with contract management in different ways. Who accepts the responsibility of rework is defined fundamentally in the contract (Love et al., 2006). Poor contract documentation and omission of items in the contract are the highly-cited causes of rework under the client-procurement cluster with the frequency of 20 times over publications. Under the cluster of contractor-procurement, two other causes, namely "ambiguity in contract due to conflicting and incomplete information" and "improper subcontractor selection", were prevalent as the most studied items over 10 publications. Ambiguous scope in the contract documents results in poor contract management and leads to rework (Ye et al., 2015). Employing qualified contractors has been pointed out as the key contributing factor of the industry's success (Chan et al., 2020). The lower number of studies on rework causes in this stage is probably linked to the defined delivery system of projects that mostly merges two stages of design and procurement together. This was aggravated by improper implementation of procurement strategies that have not been adopted widely at the design stage (Salihu and Babarinde, 2020). Even though the procurement stage is the least ranked stage of the project in terms of citation frequencies, the underlying causes in both clusters three and four are very critical in rework management (Al-janabi et al., 2020).

Construction as the last stage of a project presents different results. However, it encompasses 30 identified causes over 37 listed items; distribution of the causes in both contract sides is not equally balanced. While the contractor side of the contract has more contribution to the causes of rework, the other side takes half of the causes in terms of quantity. It is because the contractor plays the main role at this stage. However, the three categories of process, human resources, and material/equipment, present a small number of causes under the client's side of the contract, they become more predominant at the other side. Under the cluster of client-construction, lack of knowledge was the most identified cause by 18 publications from the selected papers. Lack of client knowledge has been introduced as the root causes of many problems in construction projects (Trach et al., 2019). The used of skilled and experienced professionals by both contract parties throughout different project stages also had been recommended to achieve free rework construction (Eze et al., 2018b). Ineffective use of quality management with 25 citations is ranked first under the cluster of construction-contractor as well as the highest frequency among all identified rework causes throughout the project life cycle. This is aligning with the previous research directions that rework is due to the lack of quality focus (Love et al., 1999), but this rank does not correspond to previous studies' outcomes as none of them have highlighted this item in the list of top rework causes.

Table 7.8: Comprehensive list of rework causes in project life cycle with liable contract parties

Project stages			Design		Procurement		Construction	
Contract parties			Client	Contractor	Client	Contractor	Client	Contractor
Group factor causes	**Rework root**	**Code**	**DE**	**DS**	**PE**	**PS**	**CE**	**CS**
Process	Changes, modification and revisions in design / construction changes		P1	P1	-	-	P1	P2
	Error in design, drawings and specifications / construction error		P4	P2	P3	-	-	P1
	Incomplete design, any omission in the design or construction process		P2	P3	P1	-	-	P3
	Inadequate procurement methods / poor contract execution		-	-	-	P2	-	-
	Improper contractor and subcontractor selection		-	-	P2	P1	-	-
	Lack of document control		P3	P4	-	-	-	-
Human Resources	Lack of experience and personal expertise in design and construction		H1	H1	-	-	H2	H5
	Inadequate supervision staff		H4	-	-	-	-	-
	Inadequate manpower to complete the task		-	H4	-	-	-	H7
	Insufficient skilled level manpower		H3	H2	-	-	-	H1
	Poor knowledge of team member, lack of education and training		H2	H3	-	-	H1	H3
	Lack of employee motivation and rewards, Carelessness		H7	H6	-	-	-	H6
	Poor workmanship approach and inappropriate personal attitude		H6	H8	-	-	-	H2
	The absence of job security and other safety rules		H8	H7	-	-	-	-
	Labor reallocation, alteration and staff turnover		-	H5	-	-	-	H4
	Conflict of interests		H5	-	-	-	-	-
Material / Equipment	Defective materials, Non-adherence to material specifications		M1	-	-	-	M1	M2
	Poor-quality material or substandard products / Prefabrication errors		-	-	-	-	-	M1
	Replacement or misplacement of material and equipment		-	-	-	-	-	M3
	Inefficient equipment use or altered material		-	-	-	-	-	M4
	Untimely deliveries of material and equipment		-	-	-	-	-	M5
Technical	Ineffective use of quality management practices / deviation due to poor monitoring		T5	T4	-	-	T4	T1
	Poor technology application and lack of information technology use		T6	T3	-	-	T5	T5
	Poor communication system for coordinating between members		T1	T1	-	-	-	T4
	Inefficient management process, poor site management practice		T3	T5	-	-	T2	T3
	Poor project documents, unclear instructions, poor contract documents		-	T6	T1	T2	-	T7
	Conflicting and incomplete information		T2	-	T2	T1	T3	T6
	Inadequate planning and poor scheduling of workload		T4	T2	-	-	T1	T2
General / External	Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure		G1	G2	G2	G1	G1	G4
	Lack of client involvement		G2	-	-	-	G2	-
	Unclear line of authority		G4		-	-	-	-
	Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation		G3	G1	G1	-	-	G3
	Lack of constructability		-	G3	-	-	G3	-
	Damage / defects / Deviations in the product due to poor handling and safety considerations		-	-	-	-	-	G1
	Governmental regulations / changes and policies		-	-	-	-	G4	-
	Environmental conditions, poor site condition		-	-	-	-	-	G2
	Unpredictable factors from different sources		G5	-	-	-	G5	G5

7.8 Conclusion

The study aim was to identify and classify rework root causes in a project's life cycle to facilitate a better understanding of rework liable to contract parties of the construction project. To achieve the study's aim, a comprehensive review of the literature on the sources of rework was conducted. Reduction of the rework impacts have received extensive attention over the years, but rework nonetheless continuous to exist probably because the effects of rework have not been measured in the project life cycle context (Xue et al., 2010). Although interest in reviewing the topic of rework has increased in recent years, a systematic review on rework root causes from the project life cycle perspective remained undiscovered. Based on the structured method used in this study, a total of 35 papers were identified directly relevant to the sources of rework. The aggregated publications then were systematically reviewed. The main factors affecting rework were identified through a detailed analysis of selected publications from academic journals and conference papers in the construction industry. This paper presents a comprehensive list of 37 rework root causes that have been integrated into a classification model. This paper proposes a structured classification model of rework causes applicable to the life cycle of a project and liable contract parties in three levels. The classification model includes five main constructs. The proposed model shows a full picture of rework root causes in six clusters generated from three project stages and two contract sides. Thus, it alleviates the combination of different levels used in previous classified methods. The provided comprehensive list of rework causes contributes to the rework management body of knowledge. It displays the distribution of causes in both sides of the contract and offers opportunities for further practical research. It can be used as a useful reference that shows the most common causes of rework. Results also can be used as a guideline for construction projects to regulate and adopt more reliable strategies on rework management. The topmost frequently cited rework causes in the reviewed papers include, but are not limited to, ineffective use of quality management practices, poor communication systems, inadequate construction planning, insufficient skills in both labour and supervisory levels, damage, defect or deviation of products due to carelessness and poor safety consideration, use of poor-quality material, and poor contract documentations.

Analysis of the papers and the comparison between categories reflected that all stages of a project had not been covered thoroughly with the identified causes. Rework causes under construction was the most frequently identified stage, whereas procurement was discovered as the least cited stage. However, the result of critical analysis has adequate evidence in each project stages, more focus on studying of the procurement stage is recommended. Since the proposed model needs validation in various contexts, the next step of research will investigate this purpose through a questionnaire survey that examines the effects of rework on contractual claims. Contract documents as the main output of the procurement stage define parties' authorities. Incorrect contract information is presumed to lead rework occurrence (Kakitahi et al., 2014). Searching the relationship between contract clauses and rework within the project life cycle would benefit future models of rework management by developing a framework that is capable to evaluate contracts in terms of identified rework causes. Identifying rework from a contract party's perspective will result in higher awareness of client and contractor by recognizing the root causes of rework at the time of contract preparation

In this paper, the review is limited to the identified causes of rework and does not cover the other aspects of measuring rework impacts. Future research on the identified gaps is recommended to provide a platform for more practical experiments and develop rework management trends. The result inspires further investigations specifically on the categories that have received less attention previously, such as the following areas of study:

- The material/equipment related factor of both sides of the contract at the design stage and the client-side of the contract at the construction stage,
- Human resources and material/equipment related factors of both sides of the contract at the procurement stage.

7.9 Epilogue

This chapter has developed a classification model to address all identified rework root causes throughout the life cycle of a project with liability to the contract parties. The chapter outcomes showed that collaboration between stages of the project could result in a comprehensive model that clearly references the source of rework. The results showed that rework causes at the design stage had been studied enough for the client-side of the contract. At the construction stage, it has been studied more towards the contractor. The study of the rework causes on the contractor side at the design stage and client-side at the construction stage also showed adequate evidence. In contrast, the procurement stage only showed a few studies under two groups of human resources and material/equipment. The insight of this chapter strengthened the need for further investigation on the procurement stage by focusing on contract as the main document of this stage. The role and responsibilities of the contract parties at rework circumstances can be well defined when both parties are involved with the contract process to avoid rework and unnecessary costs. Therefore, it is required to understand how the identified causes of rework contribute to the contract and affect it. The classified rework root causes in this chapter are used to find the common causes of rework in construction contracts. The next chapter will cover the assessment of the most commonly used type of contract in New Zealand to identify the most common causes in construction contracts.

Part three

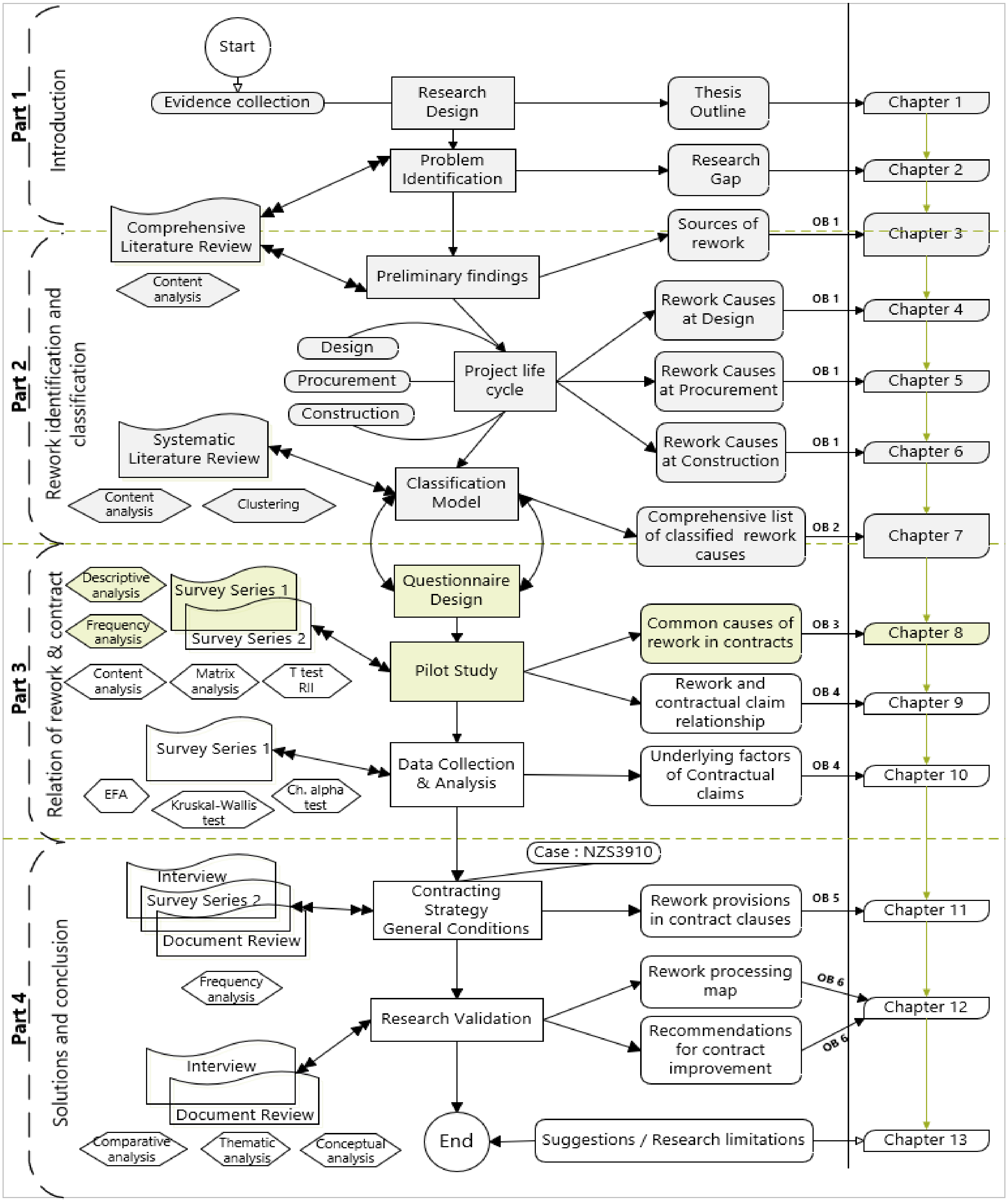
Relational aspects of rework in contracts

Chapter 8. The common causes of rework in construction contracts: A diagnostic approach

Chapter 9. Investigating the relationship between reworks and contractual claims: The salience of contract conditions

Chapter 10. Analyzing underlying factors of contractual claims raised from rework in construction contracts

Thesis-at-a-Glance / Chapter 8



Chapter 8. The common causes of rework in construction contracts: A diagnostic approach

8.1 Prologue

From this chapter onwards, this topic will practically evaluate the case of NZS3910: 2013 as the most commonly used contract in New Zealand construction projects to understand how rework contributes to the contracts. The common causes of rework from the previously developed list are driven in two steps methodology to conduct a pilot study. This chapter first gives various information about rework through the bibliographic reports and then states all previously identified causes of rework in a common list for further examination in construction projects. From the review, a set of 37 items were placed in the final list of rework root causes. In the second step, a questionnaire survey is used to diagnose the relevant causes affecting New Zealand construction contracts from the generated list. Finally, the common causes of rework that imply to the New Zealand construction contracts are proposed for the following research step. This achievement covers the third objective of the research outlined in the introduction chapter.

This chapter is based on the following published Journal paper:

Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (2021). The common causes of rework in construction contracts: A diagnostic approach. *Journal of Engineering, Design and Technology*, 1726-0531, DOI: 10.1108/JEDT-04-2021-0215.

8.2 Abstract

Purpose – The high rate of rework that occurs in construction projects has a negative effect on the performance of the construction projects. Although several mechanisms have been implemented to control reworking, a comprehensive list of rework causes is yet to be provided to present the common causes that contribute to rework in construction contracts. This paper aims to investigate the most common rework causes that need to be addressed in construction contracts.

Design/methodology/approach – A mixed-method utilising both the qualitative and quantitative approach is employed in this paper. First of all, the study adopted a four-step literature review to introduce the rework research trends and provide statistical reports using descriptive analysis. Next, a comprehensive review has been completed using content analysis to identify the common causes of rework in construction projects. Finally, the common causes in construction contracts are further investigated through a quantitative questionnaire survey to validate the initial results.

Findings - The results of the review showed an increasing trend of publications on rework over the last three decades. Most of the studies were conducted in Australia, the UK, Nigeria, and Hong Kong. Based on further investigation in the study area of sources of rework, 37 causes of rework causes were identified and classified in five groups. Then, the most significant causes of rework in construction contracts were compiled in the list of 22 items.

Research limitations/implications - The paper's reported result, contributes to the contract management body of knowledge by proposing a list of common rework causes that can be utilised by practitioners during the contract negotiation to prevent contractual issues. The result of the review can also be used for further investigation of the relationship between rework and contract conditions.

Originality/value –The proposed list of common causes of rework in construction contracts allows project parties to improve the terms of the contract in addressing rework, this could result in fewer contractual claims and disputes. The findings of this study will also guide the investigations into the contract conditions, thus the approach used is constructive.

8.3 Introduction

The construction industry is always under investigation in terms of performance and, generally, there are many criticisms around the poor performance of the construction projects (Isnaini et al., 2015). The primary factors influencing the projects' performance are mainly regarding cost and time (Han et al., 2013). Consequently, numerous researchers have studied the effects of these two leading factors (Hwang and Yang, 2014). The literature has recognised that while there are several reasons for the cost and time overruns, rework has been identified as one of the most significant sources (Hwang et al., 2009; Love et al., 2010b). "An effort for redoing an activity or a process that was implemented incorrectly the first time" is referred to as rework (Love et al., 2002), that is, an activity that is defined as waste in the process and has an adverse effect on the project. Several rework definitions can be found in the literature as described in Table 8.1. Rework in construction projects continues to exist as a chronic problem and since the problem has existed for a long time, it affects the industry's reputation (Love and Curtin, 2019). Thus, announcing the occurrence of rework is not willingly reported by the construction firms, and the impacts of the rework are ignored (Love et al., 2016a; Ahmed and Naik, 2016). Rework also impacts the psychological well-being, project measures, organisational factors (Aiyetan, 2013; Eze and Idiake, 2018b), and the progress of the contractual management (Kim and Skibniewski, 2020).

Despite the various assumptions in the literature, it is confirmed that the rework occurrence is due to the nonconformance in the project specifications or contract obligations (Hwang et al., 2009;

Oyewobi et al., 2011). The nonconformance activities in different settings have been recorded with different terms, such as, changes, faults, errors, defects, deviations, failures, and more (Forcada et al., 2017), while none of them add any value to the process (Bhatl et al., 2016). Using the practitioners' and researchers' interchangeable words has had a negative effect on the success of the rework reduction process (Kakitahi et al., 2014; Taggart et al., 2014a). Furthermore, rework occurs due to the number of causes that originated from various project stages or different contract sides. Thus, previous results are not comparable to generate a unique measure to reduce the impacts of rework (Forcada et al., 2017). The common factors that lead project activities to require rework include yet are not limited to: process performance, such as errors and changes, human resources attributes, such as expertise and skills, lack of quality management, poor IT use and some other technical issues, material replacement, contract documents, and lack of constructability.

In recent years the topic of rework management has become a focus of attention in construction research studies (Ji and AbouRizk, 2018; Safapour and Kermanshachi, 2019; Mahamid, 2020), mostly on the affecting factors, causes and impacts, and rework management models (Zhang et al., 2012). Several approaches have been implemented in construction projects for rework reduction or prevention, such as design scope freezing, information technology use, integration process, change management, quality management, and other methods. However, even though the literature on rework topics shows an adequate number of studies in the last few years, there are very few studies that research the evidence of project performance improvement by rework reduction (Jingmond and Agren, 2015). Understanding the underlying rework causes and their effects on the construction contracts' project performance is critical for the sustainability of the construction industry (Simpeh et al., 2015). Therefore, future work for adopting and implementing more effective strategies on rework management is required.

This paper aims to identify the most common causes of rework in construction contracts. To provide a list of common rework causes in the construction projects, an adequate sample of the relevant literature was reviewed. The final review of the documents suggests that the causes of rework can be classified in five categories: process, human resources, materials and equipment, technical, and general/external. The clustered rework helps construction practitioners understand the underlying causes of rework in contracts and select better strategies to deal with the associated problems.

8.4 Rework conceptualization

Despite the considerable number of research studies that have been undertaken to date, based on a review of the literature there is not a unique definition of rework. In most studies, researchers have described their research scope based on a specific given definition of rework. The rework concept that was presented by the Construction Industry Development Agency in 1995 evolved through the years considering the two main aspects of quality and change (Love and Smith 2018). However, even though there are plenty of available definitions they do not cover snagging and defects in the construction of building projects (Taggart et al., 2014a). The lack of a standard definition resulted in a range of methods to determine rework cost and various measures to quantify the impacts of rework on project performance (Love and Smith, 2018). Thus, generating an acceptable worldwide definition of rework, is still an issue. Table 8.1 shows the trend of the conceptualisation of rework and its definitions based on a review of the literature.

Table 8.1: Definitions of rework identified in the literature

Year	Description	Literature Source
1999	Involves unnecessary effort of correcting construction errors and occurs when a product or service does not meet the requirement of the customer.	Love et al.,
2001	An activity that must be carried out more than once or activities that involves the removal of previously completed work.	(CII) Construction Industry Institute
2002	Unnecessary output caused by mistakes undertaken during the construction process.	Josephson et al.,
2002	The unnecessary effort of redoing a process or activity that was incorrectly implemented the first time.	Love et al.,
2004	Activities in the field that have to be done more than once in the field, or activities that remove work previously installed as part of the project regardless of source, where no change order has been issued and no change of scope has been identified by the owner.	Robinson et al.,
2009	Having to redo work due to non-conformance with requirements.	Hwang et al.,
2011	A waste that involves doing a certain task more than once.	Oyewobi et al.,
2014a	Work discovered to require change (either through errors, omissions, or regulation changes).	Li and Taylor,
2019	Any change that veers from the agreed upon and signed contract.	Safapour et al.,
2019	The waste or redundant part of a project that has become part of the construction process.	Hwang et al.,
2019	The total direct cost of re-doing work in the field regardless of the initiating cause excluding variations and off-site errors.	Love and Curtin,
2020	The tasks of rectifying errors and dealing with changes in scope, quality deviations, and non-conformance, which is wasteful and non-value-adding activity.	Liu et al.,

8.5 Methodology

This paper utilises a systematic literature review followed by a questionnaire survey to meet the qualitative and quantitative parts of the research and to achieve the study's goals. The research methodology stages have been demonstrated in Figure 8.1. These two approaches need to be used together in data collection and analysis as doing so improves the reliability and validity of the results (Kisi et al., 2020).

8.5.1 Stage 1: Systematic literature review

This stage of the research is used to report the research trend of rework publications and to identify rework causes in construction projects. The method of systematic review is widely used in various disciplines including construction management (Ayodele et al., 2020). Systematic review is a suitable method for evaluating previous studies to extract and analyse the data from the literature. The implemented approach in stage one provides a better understanding of the rework trends in the literature for construction projects. This approach extracts data from relevant sources in the literature, analyses the data to generate various categories, and explores new visions for further investigation. Thus, this method was adopted at the initial stage to gain an insight into the rework research trends and to enable identification of the common causes of rework. Following the various definitions that were found for rework, a search of the literature was conducted following the same steps that previous studies used (Schon et al., 2017; Xia et al., 2018; Kasperiuniene and Zydziunaite, 2019; Dallasega et al., 2021). The steps are very clear and easy to follow as described in four steps shown below.

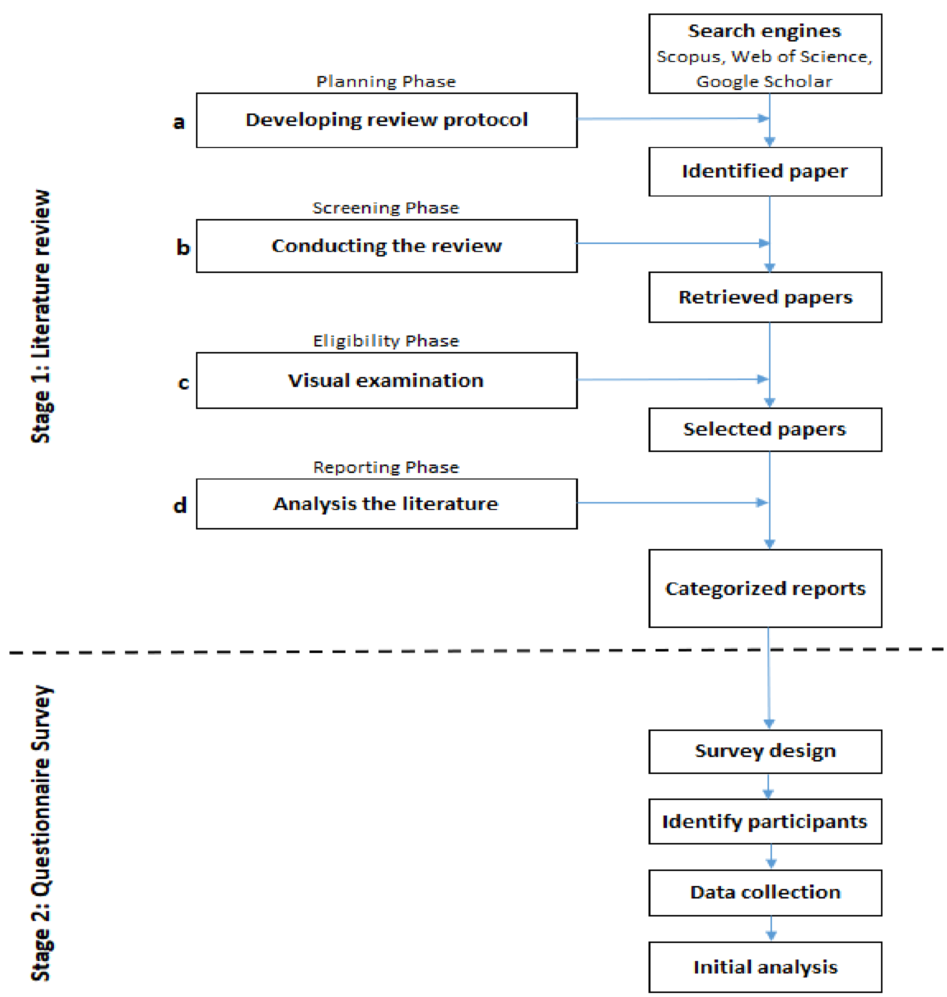


Figure 8.1: *Flowchart of adopted methodology "Research framework", Search date: 27.06.2021*

8.5.1.1 Step a: Developing a review protocol,

The first step, known as the planning phase, involved selecting the required criteria to conduct the search. The review process comprised keyword searches in three databases, defining inclusions and exclusions, removing duplicated documents, selecting final papers, categorising, and data analysis. The search planned to use three databases, namely, Scopus, Web of Science (WoS), and Google Scholar. The selected databases contain the highest quantity of peer-reviewed literature (Wang et al., 2020). A lack of coverage in some search engines is the primary reason for planning to search within three academic databases (Malek and Desai, 2020). The search was carried out then, using the keywords, as described in the following process. Keywords are the critical part of the review, and the selected keywords in this paper to meet the research objectives were "rework" and "construction." The language was then restricted only to English within the time from 1990 to 2020. The inclusion condition was defined to cover the peer-reviewed papers only in journals and leading conferences at the final approved level in the field of construction management. The other types of documents were excluded to maintain the quality of the research. Further refinement was also employed by focusing only on the construction projects and removing irrelevant papers from other sectors.

8.5.1.2 Step b: Conducting the review

The second step, also called the screening phase, aims to identify the relevant research papers. The study started reviewing published papers from 1990 to 2020 in April 2020 and then was updated in June 2021. This period included a sufficient number of articles and conference papers. After the initial search of the keywords without restriction and papers retrieval, 5482 were collected, in which 1023 were from Scopus, 2115 from WoS and 2344 from Google Scholar. Refinement was then required because most of the collected papers were irrelevant to the construction industry. Thus, two criteria were set to screen the collected papers and select the most relevant documents.

1) Published work in the construction industry and,
2) Papers that include only rework in their reports, not the other similar terminologies,

In other words, papers should be directly linked to rework management in construction projects. According to the study's aim, the keywords were limited to two, rework and construction terms that would lead to more precise results. Except for Google Scholar, the other two search engines had more options for advanced search in filtering the publications in line with the defined criteria. The second round of search by applying the inclusion and exclusion criteria, resulted in 139 screened papers in Scopus, 104 in WoS, and 121 in Google Scholar. In total, 364 documents were included for visual examination in the next step.

8.5.1.3 Step c: Visual examination

This step, also called the eligibility phase, is used to assess the quality of the research by reviewing the details of papers in compliance with the study's objective. In this step, an in-depth visual examination was performed to select the right papers for further analysis. The final retrieved papers' information was controlled through a validated review of the sequences in title, abstract, and the main text. The abstract of retrieved papers was initially checked to find if the paper's content was according to the criteria or not. Accordingly, unsatisfactory papers and publications beyond the research scope were excluded. The duplicated papers among the three databases were also identified; documents with the exact same titles were removed to avoid duplication. Eliminating the duplicated papers resulted in 157 published works out of 364 retrieved documents.

8.5.1.4 Step d: Analysis and categorizations

A total of 157 publications were included in this review to establish rework research trends. The comprehensive method of literature review is used for providing reports on the existing evidence in a specific area of knowledge. The results of such a review generally identify gaps in the knowledge and can be used as a starting point for further research on a specific topic. The conceptual boundary of the current review is to involve rework concepts that apply to the construction industry. The papers that were selected from the previous steps were then analysed to provide reports in different categories. In this step, the basic information of each paper was initially transferred to a Microsoft Excel file. The codebook list was then prepared based on each paper's extracted relevant data from the Excel file, as presented in Table 8.2. The list of items in the codebook table is for interpreting the papers, providing statistical reports, and assessing how many categories can be adjusted.

Table 8.2: Codebook list for data extraction and descriptive analysis

Code		Description
A	Basic information	
	A.1. Date	Year of publication
	A.2. Authors	List of the authors' name
	A.3. Title	Title of the article or conference paper
B	Publication information	
	B.1. Journal details	Journal title that published the article including detail address of paper such as Vol., Issue, and pages
	B.2. Conference details	Conference name and proceedings details such as date, location, and paper pages
C	Geographical region	Affiliations including universities and research centers name or industry conducting research
D	Citations	Number of papers that cited the study
E	Research details	Research aim, main results and contributions, perspective, the methodology used and project types

The codebook items were then investigated further to make a list of categories for further analysis. The reports around each category were based on the bibliography features of the papers using a descriptive analysis. The generated categories for further descriptive analysis are based on the publication year, countries' status, research methodologies, relevant journals, and causes of rework as presented in Table 8.3. Once the extraction of the data was completed, all the rework topics, classified causes, and other patterns around it was reviewed in considerable details. A full review of the selected papers resulted in the revealing of 35 publications on the sources of rework. The reports on the sources of rework are based on the content analysis of the extracted data from the Excel file. Content analysis is an inductive method to unfold, outline, and organise the extracted data into groups (Ayodele et al., 2020). Content analysis of the last 35 papers falls into five groups consisting of 37 rework causes that are reported in the result section. The five groups of rework causes are based on the classification methods used in the previous studies (Josephson et al., 2002; Oyewobi and Ogunsemi, 2010; Zhang et al., 2012; Enshassi et al., 2017).

Table 8.3: List of categories for statistical report

No.	Categories of review	Description
1	Yearly base	Evaluating the development of rework management through a trend line
2	Country status	Assessing the score of each country contributing to published papers
3	University status	Identification of most active universities in rework research
4	Authors status	Exploring the contribution of authors in publishing the rework research papers
5	Journal	Identification of the journals that have published rework research
6	Research methodologies	Dividing into subcategories of case study, survey, interview, literature review and others
7	Focused area	Exploring the common area of studies for further content analysis
8	Rework causes	Exploring the causes of rework in the studies on the sources of rework

8.5.2 Stage 2: Questionnaire survey

This stage of research comprises four steps to conduct the qualitative part of the employed methodology. In step one, a questionnaire was designed based on the result of the systematic literature review on the causes of rework. The questionnaire was then confirmed with industrial and academic professionals. Step two involved identification of the participants and the distribution of the questionnaire to conduct a pilot study via an online system. In step three, the initial data was collected through online software called Qualtrics and step four involved analysing the data to investigate the significance of each cause of rework in relation to construction contracts used in New Zealand. The questionnaire included two sections; section one for collecting participants information such as, years of experience in construction and contracting, their job positions, their organisation and project type. Section two involved collecting the opinion of the participants on the effects of the rework causes on the contractual issues. The Likert scale from 1 to 5 was used to rate the respondent's opinion on each rework cause. The questionnaire was distributed using networks and communication tools such as mailing lists.

The first round of data collection for the pilot survey was performed 15 September 2020 using a networking system. Thus, a request to participate in the pilot survey was sent to three associations, the NZ Certified Builders, Civil and Construction New Zealand, and NZ Architects and Consultants. Once the number of recorded files on the Qualtrics software showed adequate responses to start the initial analysis of the pilot survey, the second round of data collection was performed 22 October 2020 using a mailing system. In the first round, there were 63 responses from the members of the prementioned associations. Further investigation into the collected data showed that part of the recorded files is incomplete. After refining all records, a total number of 42 responses remained in order to rank the causes of rework that affect contracts in New Zealand construction projects.

8.6 Results

8.6.1 Category 1- Rework papers on biannual bases

According to the search engines' result, the total number of rework-related papers biannually shows an increasing trend from seven papers in 1999-2000 to 31 papers in 2019-2020. The rework publication status has been presented in Table 8.4. This category of data shows the frequency distribution of 157 papers. The table indicates zero publications between 1990 and 1997; thus, 1998 is a commencement year for using the terminology of rework in construction studies.

However, based on a review in the literature there are some studies that were conducted before 1998 in which other interchangeable words have been used.

Table 8.4: Rework related papers published between 1990 and 2021

Search Engines	1990	1998	1999 2000	2001 2002	2003 2004	2005 2006	2007 2008	2009 2010	2011 2012	2013 2014	2015 2016	2017 2018	2019 2020	2021	Total
Scopus	0	1	5	3	5	3	4	4	7	15	12	10	18	6	**93**
Web of Science	0	0	0	1	0	0	0	0	0	0	2	6	3	0	**12**
Google Scholar	0	0	2	0	2	4	3	3	5	4	10	9	10	0	**52**
Total	**0**	**1**	**7**	**4**	**7**	**7**	**7**	**7**	**12**	**19**	**24**	**25**	**31**	**6**	**157**

Noticeably, the figures in Table 8.4 indicate that studies on rework topics have been initiated between 1998 and 2010 with a total number of 40 papers and within the next ten years this more than doubled to a total number of 117 publications. Figure 8.2 also shows that rework research interests have been increasing within the last 20 years. Since the search of databases was performed in June 2021, the number of published papers in the last column shows fewer papers than the previous biannual terms.

8.6.2 Category 2- Contributions of countries to rework research

In reference to the previous studies' method of scoring, each country's contribution to the rework literature was analysed. Therefore, this paper shows the country's contribution rank quantitatively. The same formula used by previous researchers to calculate each country's score was used in which the credit of the author is split between all participants (Ke et al., 2009; Hong et al., 2012; Yi and Chan, 2014; Wang et al., 2020; Chan et al., 2020). The scores for each author, using the pre-mentioned technique within a multi-author paper matrix, is described in Table 8.5.

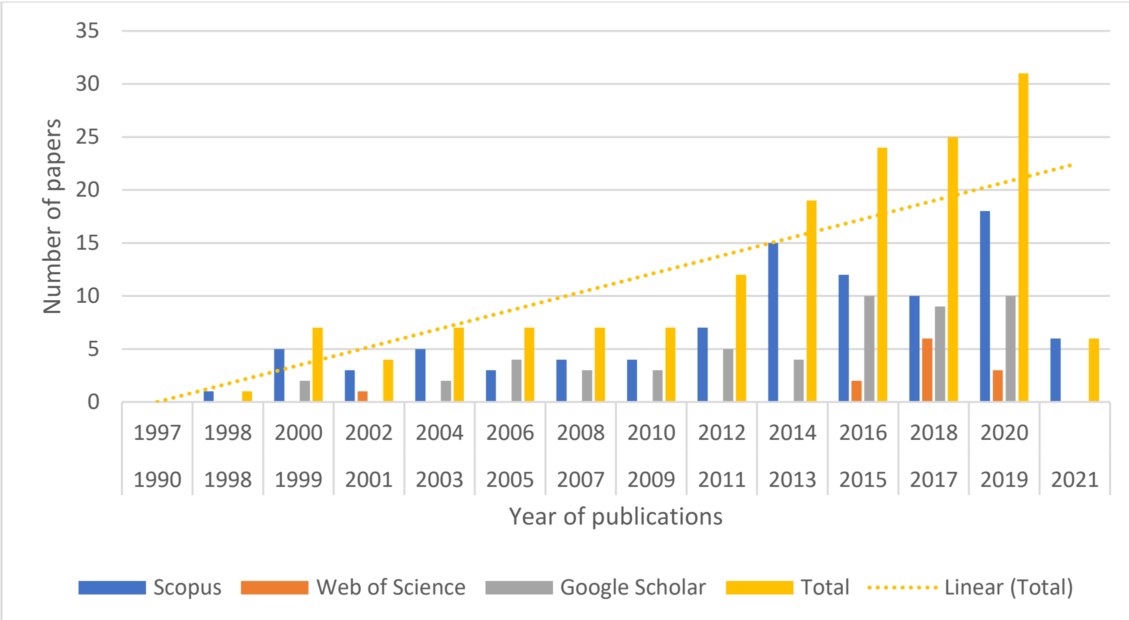


Figure 8.2: *Number of published papers biannually within the selected period*

The papers with six authors or more have been considered the same as the five authors' scores with zero point for the sixth and above authors. The author's score is calculated in each paper, and the total score of each university is calculated by accumulating the score of the relevant authors. The total sum of regional universities' scores is considered the final score of the country that shows the contribution of that region to rework studies. The summary of all calculations on each country's score has been presented in Table 8.6, along with the total number of universities, researchers, and published papers. The top ten countries, Australia, the UK, Nigeria, India, Hong Kong, the United States of America, China, Singapore, Iran, and Canada, have the highest number of published papers with a range of scores from 40.04 to 5.42.

Table 8.5: Multi-authored Papers Matrix for scoring

	Order of specific author				
Number of authors	1	2	3	4	5
1	1.00				
2	0.60	0.40			
3	0.47	0.32	0. 21		
4	0.42	0.28	0.18	0.12	
5	0.38	0.26	0.17	0.11	0.08

The table also shows that the top four countries' contribution to the rework research in construction projects is higher than for the other regions. The first four countries account for more than 50 % of the total publications within the studied period (80.38 scores out of 157). The table also shows that different nations worldwide have participated in rework research - "29 countries". Table 8.6 also presents the number of selected papers according to the 29 countries of origin. Publications from Australia are at the summit in supporting rework research, and it clearly displays a considerable number of publications compared with other countries such as UK, Nigeria, and Hong Kong.

Table 8.6: Research origin of rework related papers published in construction

Country	Institute / University	Researchers Involved	Total Number of papers	Scores
Australia	19	35	62	40.04
UK	17	27	33	16.34
Nigeria	7	25	15	15
India	9	20	9	9
Hong Kong	3	8	18	8.53
United States	11	19	11	8.28
China	10	20	11	7.38
Singapore	6	10	11	6.57
Iran	9	16	6	5.55
Canada	5	14	8	5.42
South Africa	5	7	6	5.4
Saudi Arabia	2	1	4	5.4
Malaysia	2	6	4	3.01
Korea	7	11	4	3
Uganda	1	5	4	2.99
Spain	1	6	4	2.7
Indonesia	4	6	3	2.47
Brazil	2	7	2	2
Sweden	3	4	5	1.68
Germany	2	3	2	1
New Zealand	1	3	1	1
Egypt	1	2	1	1
Poland	1	3	1	1
Portugal	1	3	1	1
Lithuania	1	3	1	1
Sri Lanka	1	2	1	0.79
Palestine	1	2	1	0.68
Bangladesh	1	1	1	0.6
Mozambique	1	1	1	0.12

8.6.3 Category 3- Employed methodologies

A comprehensive review of rework published papers indicated some similarities in the implemented research methodologies. The research methodology tends to follow four steps: a comprehensive “literature review” for identifying the topic, “data collection” via recognized techniques including review papers, case studies, interviews, and questionnaire, then “knowledge processing” via techniques such as statistical, scenario analysis, simulation, and theoretical analysis on the collected data to provide the initial findings of the study, and lastly “validation process” to deliver the conclusions via focus group meetings, pilot studies or further interviews (Ke et al., 2009). The preliminary review on the implemented methodologies in the selected papers showed that while there are some techniques, such as dataset simulation, theoretical and mathematical models have been used in only a few papers; most of the studies have collected their data through one of the conventional methods of case study, literature review, questionnaire survey, and interviews. An overview of the methodologies used for data collection among the selected documents in this paper is shown in Table 8.7.

Table 8.7: Overview of research methodologies on data collection

Research method	Paper	%
Case study	53	33.75
Questionnaire survey	48	30.57
Literature review	20	12.73
Interview	19	12.10
Other methods	17	10.82

The presented information in Table 8.7 illustrates that case studies were used more than other methods solely. Collecting data only through case studies has been used by 53 researchers; however, using it concurrently with other methods can be seen in some of the studies. Various case studies have been used across the publication, including Exploratory, Interpretative, Longitudinal, Single, and Multiple case studies. In summary, 53 papers (33.75%) used case studies, and 48 studies (30.57%) were carried out using a questionnaire survey. Based on the literature review regarding the other type of methodologies, they have been utilised by 20 papers (12.73%). Nineteen studies (12.10%) have been conducted through interviews using unstructured and semi-structured questions, and in the last 17 papers (10.82%), the other methods of retrieving data from the database, simulation, experiment, and running theoretical and mathematical models have been employed. The low number of applied miscellaneous methods will encourage researchers to use other tools rather than the conventional methods to depict the rework predictors in different situations. Since rework is often explored in real projects, it can be concluded that the obtained result in a series of selected papers which mostly relies on the case study, questionnaire survey and interview are very practical, and sometimes it would be difficult for the purpose of generalisation as the majority of studies have been undertaken in various cultural settings (Palaneeswaran et al., 2014; Love and Smith, 2018).

8.6.4 Category 4- List of Journals

This category aims to create awareness about the journals that have published the most rework articles. The list of highlighted publishers may help researchers in their future studies. Concerning the type of publications, 126 of the reviewed studies were published in journals (80%), and only 31 papers appeared in conference proceedings (20%). The search results among the journal papers reviewed indicated that the Journal of Construction Engineering and Management (JCEM) has published the most rework related articles compared with other journals. The Journal of Management in Engineering (JME) was ranked in the second level. In Table 8.8 there is a list of Journals that have published more frequent rework papers. This table shows the name of 14 journals that have published more than three papers. These 14 journals have published 66 out of 126 selected journal articles under the scope of this study.

Table 8.8: Overview of the journals and the number of published rework related papers

Journal title	Number of papers	SJR (Q1-Q4)	H index
Journal of Construction Engineering and Management (JCEM)	17	Q1	105
Journal of Management in Engineering (JME)	5	Q1	62
International Journal of Construction Management (IJCM)	5	Q2	19
Construction Management and Economics (CME)	4	Q1	88
International Journal of Sustainable Construction Engineering & Technology (IJSCET)	4	Q4	2
Engineering, Construction and Architectural Management (ECAM)	4	Q1	54
Journal of Civil Engineering and Management	4	Q2	47
International Journal of Quality & Reliability Management (IJQRM)	4	Q2	82
Sustainability	4	Q1	85
International Journal of Project Management (IJPM)	3	Q1	134
Project Management Journal (PMJ)	3	Q1	37
Civil Engineering and Environmental Systems (CEES)	3	Q2	28
International Journal of Innovative Research in Science, Engineering and Technology	3	-	-
Journal of Engineering, Design and Technology (JEDT)	3	Q2	19
Other Journals*	60	-	-

To bring the main research outputs of rework to light from the well-known academic journals with a prominent position and higher impacts in the research community of construction management, the list of top journals in the construction industry from previous researchers has been used. Accordingly, the total number of 40 papers among the selected 126 journal papers in this study are listed as high impact rework papers as follows: 17 papers from the Journal of Construction Engineering and Management (JCEM), five papers from the Journal of Management in Engineering (JME), four papers from Construction Management and Economics (CME), four papers from Engineering, Construction and Architectural Management (ECAM), three papers from International Journal of Project Management (IJPM), three papers from Project Management Journal (PMJ), two papers from Automation in Construction (AIC), one paper from Building Research & Information (BRI) and one paper from Canadian Journal of Civil and Engineering (CJCE) (Ke et al., 2009; Xue et al., 2010; Hong et al., 2012; Yi and Chan, 2014; Bao et al., 2018). Statistical analysis of the journal papers demonstrates that the rate of published rework papers in a well-known academic journal is about 32 percent.

8.6.5 Category 5- Common causes of rework in construction contracts

This category includes publications with the report on the sources of rework in construction projects. A full review of the selected documents to identify the causes of rework in the construction sector revealed that a total of 35 papers are placed under this study area. The trend of studies on identifying the sources of rework throughout the literature indicated that this area of study has been a focus of attention for several years and remained an exciting topic in current research studies. This group of papers has mainly introduced rework sources and identified a cluster of rework causes from different perspectives. The identified causes contributing to rework have been reviewed utilising a qualitative approach to the 35 relevant publications. Table 8.11 shows the list of studies that were included to identify the causes of rework in this research. The reviewed papers identified 37 causes that contribute to rework based on a qualitative interpretation. The causes of rework derived from the literature were grouped on the basis of the main process of work, human resources attribute, procurement of materials and equipment, supporting technical activities, and general/external items as described in the following sections. Each group in this review consisted of the causes leading to rework in construction projects. The associated causes also provide insight into how they are related to the incidence of rework. The framework used for grouping all of the identified causes was based on the presented results, discussion, and the conclusion of the selected papers. Grouping the causes is critical for developing future effective rework management and strategies. The list of rework causes within each group can be used to measure the impacts of rework in various ways.

8.6.5.1 Causes related to work process

This group of rework causes consists of six items that generally are part of the main process of work. The repeat number of evaluated causes of this group among different articles is presented in Figure 8.3. The number of papers in Figure 8.3 to Figure 8.7 only shows the high frequency of using the same item within 35 of the selected publications from the literature and does not have any significance related to the causes. The list of rework causes under the group of process are as follows:

- (P1) Changes, modification and revisions in design / construction changes
- (P2) Error in design, drawings and specifications / error in construction
- (P3) Incomplete design, any omission in the design or construction process
- (P4) Inadequate procurement methods / poor contract execution
- (P5) Improper contractor and subcontractor selection
- (P6) Lack of document control

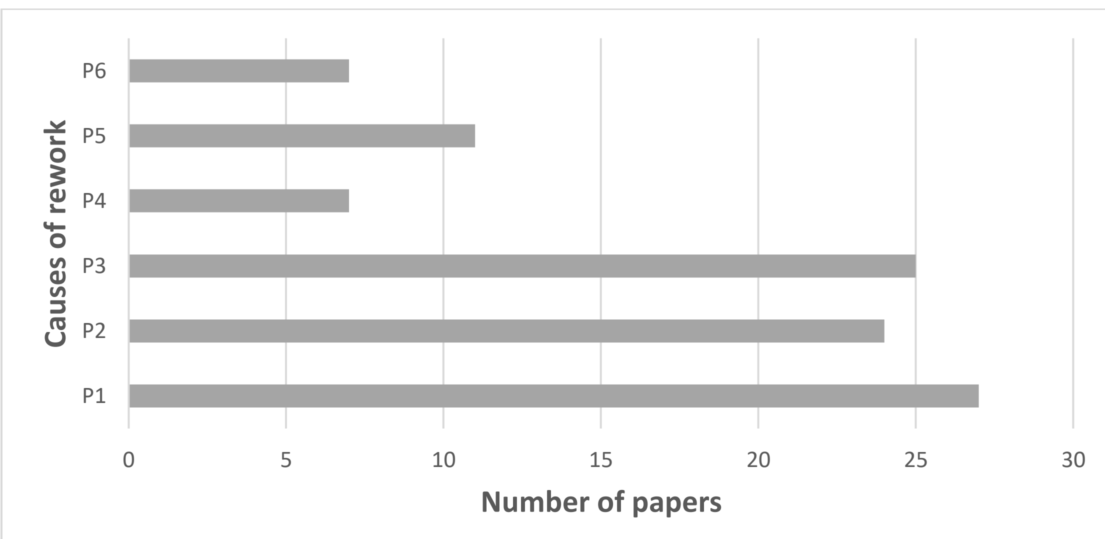


Figure 8.3: *Rework causes related to work process*

8.6.5.2 Causes related human factors

This group of rework causes consists of 10 items that generally are linked to the human attributes. The repeating number of evaluated causes of this group among the different articles is presented in Figure 8.4. The list of rework causes under the group of human related factors are as follows:

- (H1) Lack of experience and personal expertise in design and construction
- (H2) Inadequate supervision staff
- (H3) Inadequate manpower to complete the task
- (H4) Insufficient skilled level manpower
- (H5) Poor knowledge of team member, lack of education and training
- (H6) Lack of employee motivation and rewards, Carelessness
- (H7) Poor workmanship approach and inappropriate personal attitude
- (H8) The absence of job security and other safety rules
- (H9) Labor reallocation, alteration and staff turnover
- (H10) Conflict of interests

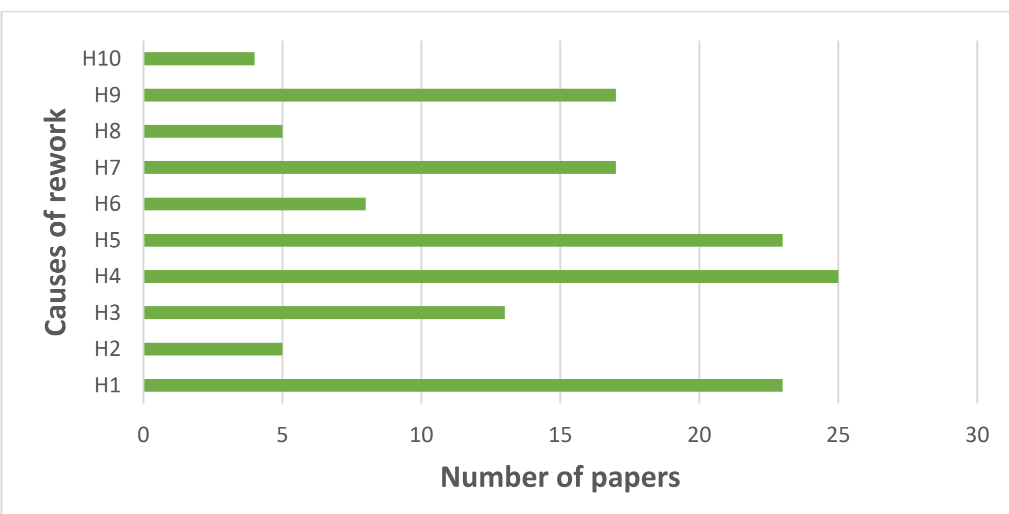


Figure 8.4: *Rework causes related to human factors*

8.6.5.3 Causes related to materials and equipment

This group of rework causes consists of five items that generally are relevant to the procurement of the project's requirements. The repeating number of evaluated causes in this group among the different articles is presented in Figure 8.5. The list of rework causes under the group of materials and equipment related factors are as follows:

- (M1) Defective materials, Non-adherence to material specifications
- (M2) Poor-quality material or substandard products / Prefabrication errors
- (M3) Replacement or misplacement of material and equipment
- (M4) Inefficient equipment use or altered material
- (M5) Untimely deliveries of materials and equipment

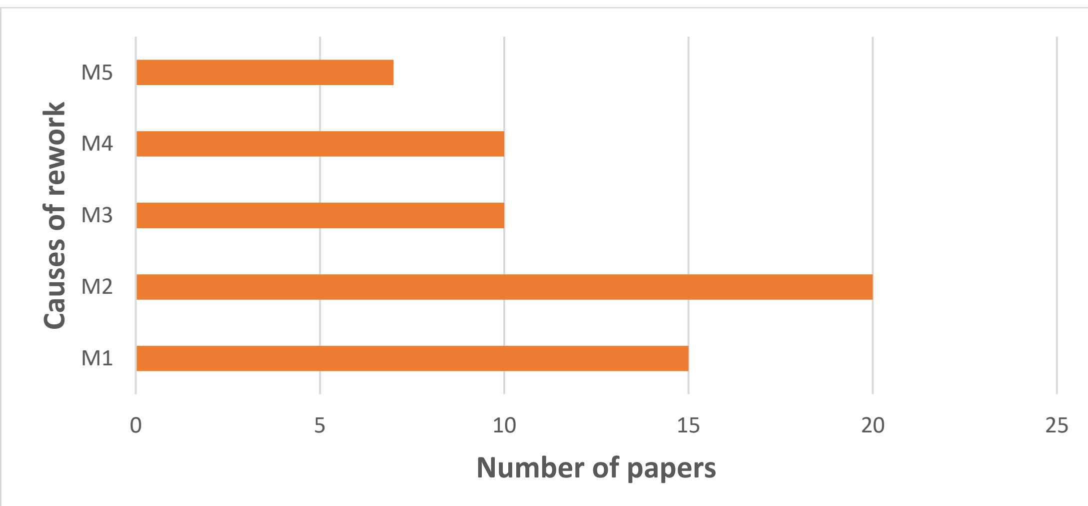


Figure 8.5: *Rework causes related to materials and equipment*

8.6.5.4 Causes related to technical factors

This group of rework causes consists of seven items that generally are used to perform better project management. The repeating number of evaluated causes in this group among the different articles is presented in Figure 8.6. The list of rework causes under the group of technical are as follows:

- (T1) Ineffective use of quality management practices / deviation due to poor monitoring
- (T2) Poor technology application and lack of information technology use
- (T3) Poor communication system for coordinating between members
- (T4) Inefficient management process, poor site management practice
- (T5) Poor project documents, unclear instructions, poor contract documents
- (T6) Conflicting and incomplete information
- (T7) Inadequate planning and poor scheduling of workload

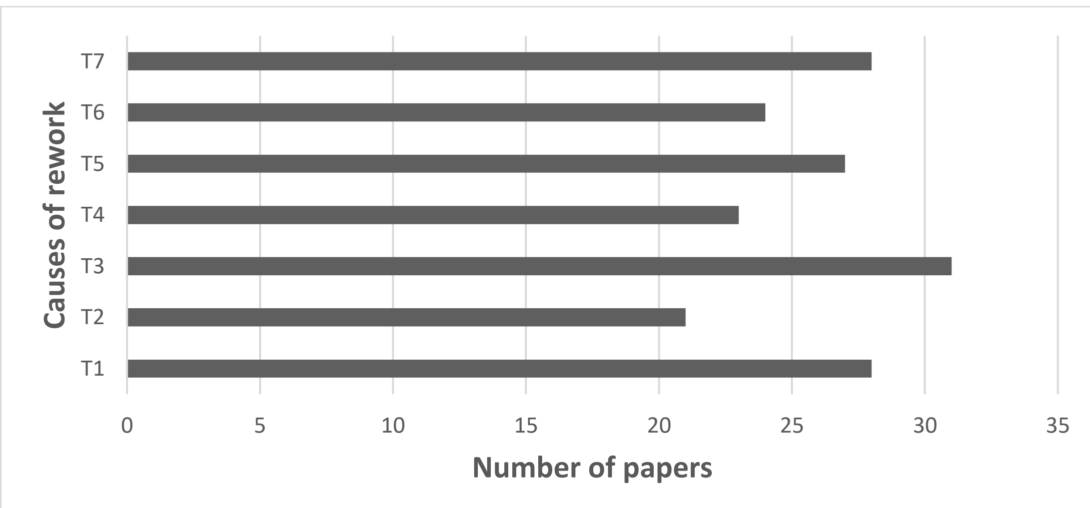


Figure 8.6: *Rework causes related to technical factors*

8.6.5.5 Causes related to general/external factors

This group of rework causes consists of nine items that are listed in no order and generally are imposed from outside of the project. The repeating number of evaluated causes in this group among the different articles is presented in Figure 8.7. The list of rework causes under the group of general/external are as follows:

- (G1) Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure
- (G2) Lack of client involvement
- (G3) Unclear line of authority
- (G4) Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation
- (G5) Lack of constructability
- (G6) Damage / defects / Deviations in the product due to poor handling and safety considerations
- (G7) Governmental regulations / changes and policies
- (G8) Environmental conditions, poor site condition
- (G9) Unpredictable factors from different sources

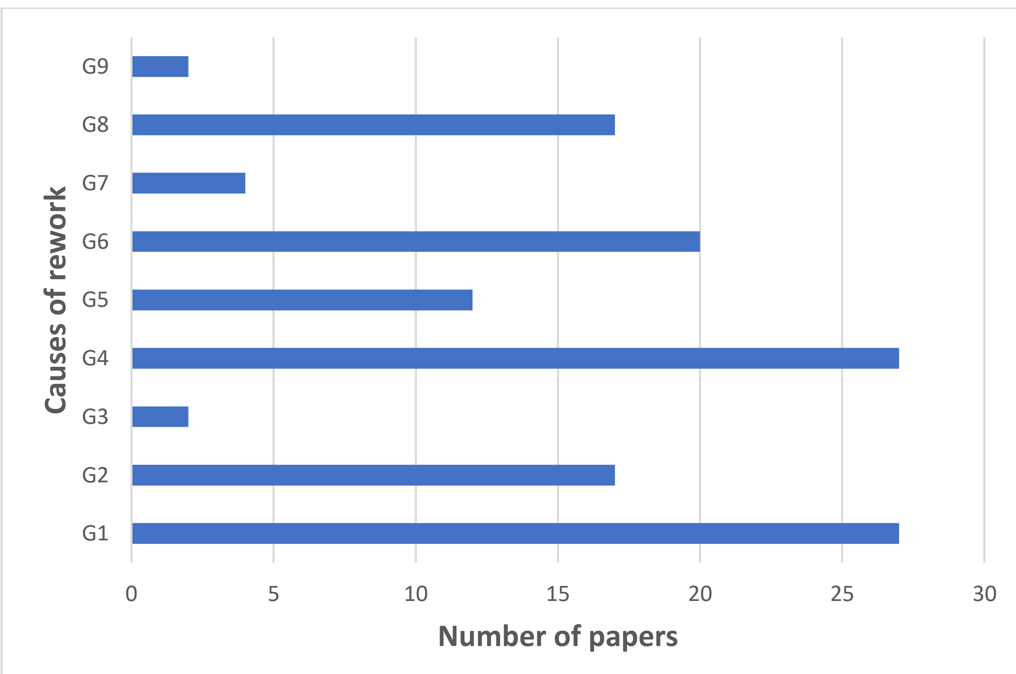


Figure 8.7: *Rework causes related to general/external factors*

8.6.6 Survey respondent's characteristics

The detail of background information about the participants has been provided in Table 8.9. This part describes and analyses the demographic of the respondents in the survey. While the majority of the participants comprise consultants and client organisations (57.1%), the remainder (42.9 %) comprise contractors and subcontractors. Therefore, different views can be captured from different perspectives according to the respondent roles. The minimum average working experiences of the participants is more than 19 years in the construction industry and more than 8 years in contracting activities. This rate of experience justifies the theoretical and practical knowledge of the respondents (Evans et al., 2020). Moreover, almost 60% have managerial positions which sounds appropriate for judgment on the questionnaire (Yap and Tan, 2021).

Table 8.9: Participants profile

Parameter descriptions		Responses	Frequency (%)
Profession/job roles of participants			
	Project Director/Project Manager	21	50%
	Commercial/Contract Manager	5	11.9%
	Quantity Surveyor	7	16.6%
	Others	9	21.5%
Year of experience in construction			
	Less than 10 years	6	14.3%
	Between 10 and 20	9	21.4%
	More than 20	27	64.3%
Contract experience			
	Less than 5 years	6	14.3%
	Between 5 and 10	4	9.5%
	More than 10	32	76.2%
Type of organisation			
	Subcontractor	3	7.1%
	Contractor	15	35.8%
	Consultant	21	50%
	Client	3	7.1%

8.6.7 Rework causes in construction contracts

Cronbach's alpha test was used in this study to check the consistency of the items in the questionnaire. SPSS statistics Version 26 was implemented to analyse this set of data and the computed alpha was 0.910, which is greater than 0.7 as the criteria for reliable data. The Cronbach value toward one indicates the higher degree of internal consistency (Eze and Idiake, 2018a). The significant score of each cause in the questionnaire was evaluated using Mean and Standard Deviation extracted from the frequency report of the analysis. Accordingly, the causes of rework in generating contractual issues were ranked in descending order as shown in Table 8.10. In the cases where the mean score of items is the same, the cause with the smaller standard deviation is considered as more significant (Yap and Tan, 2021).

Table 8.10: Ranking of rework causes that affect construction contracts

Rework causes	Mean	SD	RII %	Rank
Error in design, drawings and specifications / error in construction	4.52	0.594	90.48	1
Incomplete design, any omission in the design or construction process	4.36	0.656	87.14	2
Poor project documents, unclear instructions, poor contract documents	4.24	0.617	84.87	3
Conflicting and incomplete information	4.24	0.617	84.76	4
Changes, modification and revisions in design / construction changes	4.17	0.908	83.33	5
Lack of experience and personal expertise in design and construction	4.00	0.937	79.52	6
Inadequate supervision staff	3.90	1.055	77.14	7
Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	3.86	0.814	77.14	8
Inadequate planning and poor scheduling of workload	3.86	0.872	77.14	9
Lack of document control	3.81	0.994	76.19	10
Ineffective use of quality management practices / deviation due to poor monitoring	3.81	0.917	75.71	11
Inadequate procurement methods / poor contract execution	3.76	0.932	75.24	12
Inefficient management process, poor site management practice	3.76	0.932	74.76	13
Insufficient skilled level manpower	3.76	1.122	74.76	14
Inadequate manpower to complete the task	3.74	0.989	74.76	15
Improper contractor and subcontractor selection	3.71	1.066	73.81	16
Lack of constructability	3.69	0.749	73.81	17
Defective materials, Non-adherence to material specifications	3.55	0.993	70.48	18
Poor knowledge of team member, lack of education and training	3.55	1.041	70.48	19
Poor communication system for coordinating between members	3.52	0.917	70.00	20
Poor-quality material or substandard products / Prefabrication errors	3.48	0.943	69.05	21
Poor workmanship approach and inappropriate personal attitude	3.48	1.065	68.57	22

The Relative Importance Index also has been calculated for each cause to ensure that the ranking of the causes is accurate. If two or more causes show the same mean score and standard deviation, the priority is given to the one with the higher RII. In the questionnaire with the Likert scale 1 to 5, the mean scores higher than 4.20 are regarded as very significant as it shows strongly agree responses from the majority of participants. Furthermore, the mean scores between 3.40 and 4.20 also are significant, as agree and lower than 3.4, are neutral or disagree (Beale and Smallwood, 2019). As such, four rework causes are listed as very significant and 18 items are considered as significant in the rating scale that generate contractual issues. The other causes with the mean score less than 3.4 have been excluded in Table 8.10, to present only the significant causes of rework as the final result of this paper.

8.7 Discussion

Rework research dominates a wide range of processes and activities among the different industries. However, the construction industry has been taken into consideration in this paper. The initial observations from the collected literature revealed that more than 80 percent of the publications belongs to the most recent decade. The increasing trend of publications in recent years, in overall, indicates the importance of rework to the construction industry. Rework studies also are covering different types of projects in a number of regions around the world. Rework studies have been developed mainly by only a few countries, such as Australia and the UK. These two countries alone have contributed about 40% of the research papers. The analysis of the study indicated the other main regions as Nigeria, India, Hong Kong, and the United States. While rework articles have been published by over 60 publishers, the journal of Construction Engineering and Management has the most articles compared to the others. In addition, it can be stated that the research results are very practical as many of the studies have been conducted within real projects through case studies.

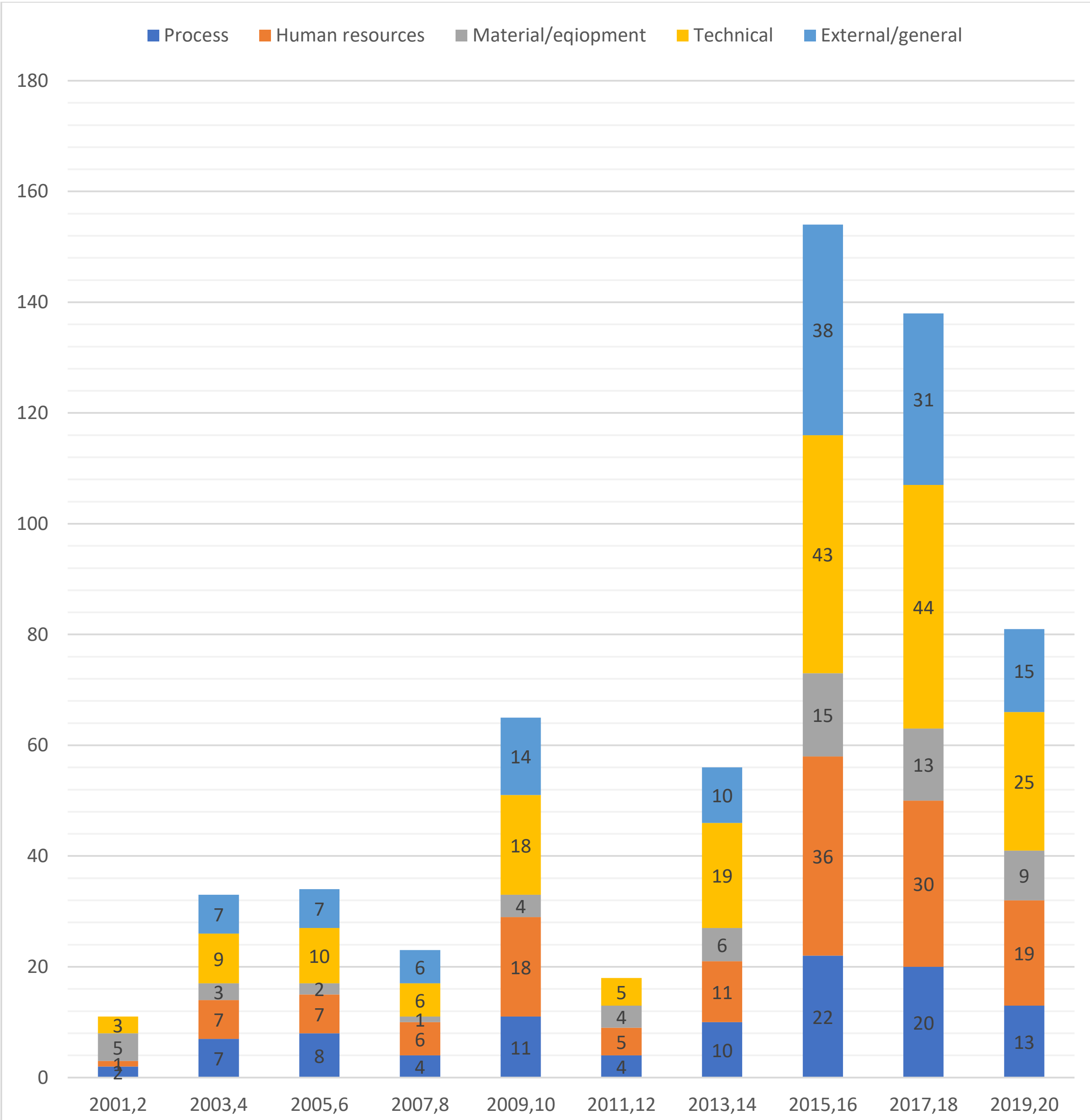


Figure 8.8: *Distribution of five rework groups over time*

While Figure 8.3 to Figure 8.7 show the trend of rework causes under various groups over time, Figure 8.8 compares the categories of rework causes based on biannual periods. This comparison illustrates that research interest in rework causes was the highest between 2015 and 2016, followed by the period between 2017 and 2018. While the causes under the group of materials and equipment seemed to be less considered compared to the other four groups, two groups of human resources and technical were highlighted more often. Exploring the logic behind the ongoing interest to study rework causes in recent years is an area that requires further investigation. In terms of the increased interest to study this area of rework, it requires attention to find out whether it is due to the applicability of rework causes or if it is a result of more research activities in that period. The most frequently reviewed causes of rework based on the literature review under each group will be discussed in the following sections.

Under the group of rework causes related to the process, it seems that changes, modifications, and revisions in the project's design and construction stage have steadily been reviewed more than the other contributing causes. Various research results pointed out that design and construction changes are the most significant causes of rework (Ye et al., 2015; Ajayi and Opeyemi, 2015; Trach et al., 2019). When considering how rework causes under the group of human resources have evolved over the last two decades, inefficient skilled level of manpower, lack of experience and poor knowledge are highlighted more frequently. It is not surprising as low skill level (Forcada et al., 2014) and lack of experience (Ajayi, 2017) have been identified as highly ranked causes of rework in previous studies. Therefore, training is generally recommended to reduce rework through improving labor competencies (Yap et al., 2017). Technology also has influenced human development in recent years. Such trends on rework causes cannot be drawn from the information provided in Figure 8.4, so further research to evaluate the role of technology on the human performance that results in rework reduction is required to be performed. Figure 8.8 also illustrates the high interest rate of studying the causes of rework under the group of technical. There were a number of studies from the beginning that considered six causes of this group with a relatively high index of occurrence. Findings from previous studies confirm that "poor communication system for coordination between members" was ranked first under the clusters of client/owner causes of rework in Australia (Love and Smith, 2003), Ukraine, Nigeria, and Palestine (Aiyetan, 2013; Mahamid, 2016; Trach et al., 2019). Table 8.11 shows that a few studies are concerned with causes relevant to materials and equipment. Among the five causes in this group, only poor-quality material and defective materials due to substandard products or prefabrication errors seemed to be mostly assessed, and the other causes received attention infrequently. The replacement of material by the client is one of the causes of rework with the highest frequency of occurrence (Hwang et al., 2014). Moreover, poor quality of material was ranked second in building projects (Ajayi, 2017), and third in the overall ranking of 43 identified causes in residential buildings (Mahamid, 2016a). The other nine causes of rework under the general/external group also show various views ranging from financial issues, environmental conditions, external events, and other similar terms. Time and cost pressure, such as schedule acceleration to finish the task, lack of funding and/or late payments have attracted the most attention from studies over the years. In the study conducted by (Aiyetan and Das, 2015), time pressure was identified as the third main parameter influencing rework and it was used for conceptual model development.

On the other hand, the results of the survey revealed the most significant causes of rework in the construction contracts in New Zealand. The first leading cause is related to error in design and error during the construction (mean 4.52). Error and its primary role in rework circumstances has been acknowledged in many rework studies, and accordingly solutions for reducing or preventing errors have been proposed. Error in design and construction also contributes to the contract change orders (Hansen et al., 2020) and leads to conflicts and claims in the construction contracts (Jelodar et al., 2016). Love and Smith (2018), have argued the current approaches of errors handling and advised error management to the organisations with a new vision of looking at error as a system behavior. Incomplete design and omission during the process of work is the second leading cause of rework in this study (mean 4.36). Similarly, incomplete design at the time of tender has been ranked under various situations in previous studies; as the most significant cause under design related group in the study of construction projects in Ukraine (Trach et al., 2019), third in the study for the benchmarking of rework mitigation in Australia (Love and Smith, 2003), fifth in the study of building components in Nigeria (Ajayi, 2017), and 11 in the study of residential buildings in Palestine (Mahamid, 2016a). The third leading causes of rework in this study is poor project documents including contracts (mean 4.24). The majority of the respondents in New Zealand agreed that poor project documentation such as deficiencies in the contract documents is a very significant cause of rework in generating contractual issues. Project documents are an important part of the construction contracts. Poor documentation in the contracts leads to individuals' interpretations that finally result in miscommunications and conflicts (Jalali and Moharreri, 2020). Lastly, conflict and incomplete information is the fourth significant cause of rework in this study (mean 4.24). Incomplete information at the design stage was ranked as the second cause of rework in the study of rework impacts on the performance of construction projects (Enshassi et al., 2017). Furthermore, Conflict and inaccuracy of information ranked fifth in rework causes in the study of building construction projects in Nigeria (Aiyetan, 2013). The main reason behind such conflicts is due to the early releasing of preliminary information to speed up the project's progress (Arundachawat *et al.*, 2009). Even though the result of this study is comparable to the most significant causes of rework in other countries, further investigation in the context of New Zealand construction projects is required to understand how rework is addressed in the conditions of the contract.

Table 8.11: Included studies in the review and identified rework causes under each group of rework

References	Country	Process						Human resources										Material & equipment					Technical							General/external factor								
		P	P	P	P	P	P	H	H	H	H	H	H	H	H	H	H	M	M	M	M	M	T	T	T	T	T	T	T	G	G	G	G	G	G	G	G	G
Josephson et al., 2002	Sweden	√	-	√	-	-	-	-	-	-	-	-	-	√	-	-	-	√	√	√	√	√	-	-	√	-	-	√	√	-	-	-	-	-	-	-	-	-
Love and Smith, 2003	Australia	√	√	√	-	-	-	√	√	√	√	√	-	-	-	√	-	-	√	-	-	-	√	√	√	-	√	-	√	√	√	-	√	-	√	-	-	-
Robinson et al., 2004	Canada	√	√	√	-	-	√	-	-	-	√	-	-	-	-	-	-	√	-	-	-	√	√	-	-	√	-	√	√	√	-	-	√	√	-	-	-	-
Palaneeswarane et al.,	Hong Kong	√	√	√	-	√	-	-	-	-	-	-	-	-	-	√	-	-	√	-	-	-	√	√	-	-	√	-	√	-	-	-	-	-	√	-	-	-
Palaneeswarane, 2006	Hong Kong	√	√	√	-	√	-	√	-	√	√	√	-	√	-	√	-	-	√	-	-	-	√	√	√	-	√	√	√	√	√	-	√	√	√	-	√	-
Palaneeswarane et al.,	Hong Kong	√	√	√	-	√	-	√	-	√	√	√	-	√	-	√	-	-	√	-	-	-	√	√	√	-	√	√	√	√	√	-	√	√	√	-	√	-
Love et al., 2009a	Australia	√	√	√	-	-	-	√	-	√	-	√	-	-	-	√	-	-	-	-	-	-	√	√	√	-	√	-	√	√	√	-	√	-	√	-	-	-
Oyewobi and Ogunsemi,	Nigera	√	√	√	√	√	-	√	-	√	√	√	√	√	√	√	-	√	√	-	-	√	√	√	√	√	√	√	√	√	√	-	√	-	√	-	√	√
Love et al., 2010b	Australai	√	√	√	-	-	-	√	√	√	√	√	-	-	-	√	-	-	√	-	-	-	√	√	√	-	√	√	√	√	√	-	√	-	√	-	-	-
Zhang et al., 2012	Canada	√	√	√	-	-	√	√	-	-	√	√	√	√	-	-	-	√	-	√	√	√	√	-	√	√	√	-	√	-	-	-	-	-	-	-	-	-
Aiyetan, 2013	Nigeria	√	√	√	√	√	-	√	-	-	-	-	-	-	-	-	√	√	√	-	-	-	√	√	√	√	√	√	√	√	√	-	√	-	√	-	-	-
Palaneeswarane, 2014	Hong Kong	-	√	√	-	√	-	√	-	√	√	√	-	-	-	√	-	-	√	-	-	-	√	√	√	√	√	-	√	√	√	-	√	-	√	-	-	-
Hwang et al., 2014	Singapore	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	√	-	-	-	-	-	-	-	√	-	-	-	√	-	-	-	-	-	-	-	-
Forcada et al., 2014	Spain	-	-	-	-	-	√	√	√	-	√	√	-	-	-	-	-	√	-	√	-	-	√	-	√	√	-	√	√	-	-	-	√	-	-	-	-	-
Ye et al., 2015	China	√	√	√	√	-	-	-	-	-	-	-	-	-	-	-	-	√	√	√	√	-	√	√	√	√	√	√	-	√	-	-	√	√	√	√	√	√
Miri and Khaksefidi, 2015	Iran	√	√	-	-	-	-	√	-	√	√	√	-	√	-	√	-	-	√	-	-	-	√	√	√	√	√	√	√	√	√	-	√	-	√	-	-	-
Ajayi and Oyedipo, 2015	Nigeria	-	-	√	-	-	-	√	-	√	√	√	-	√	-	√	-	-	√	-	-	-	-	√	√	√	√	√	√	√	√	-	√	√	√	-	√	-
Aiyetan and Das, 2015	Nigeria	√	√	-	-	-	√	√	-	-	-	-	-	√	-	-	-	√	√	-	-	-	√	√	√	√	√	√	√	√	-	-	√	-	√	-	-	-
Mahamid, 2016a	Palestine	√	√	√	-	√	-	√	√	-	√	√	√	√	-	√	-	-	√	-	√	-	√	-	√	√	√	√	√	√	√	-	√	-	√	-	√	-
Shah and Sharma, 2016	India	√	-	-	-	-	-	-	-	-	√	√	√	√	√	-	√	√	√	√	√	√	√	-	-	-	√	√	√	√	-	√	√	√	-	√	√	-
Ahmed and Naik, 2016	India	-	-	-	-	√	-	√	-	-	√	√	-	-	-	-	-	-	-	-	-	-	-	-	√	-	-	-	-	√	√	-	√	-	-	-	-	-
Oyewobi et al., 2016	Nigeria	√	√	√	√	√	√	√	-	-	√	√	√	-	√	√	-	-	-	-	-	-	√	-	√	√	√	√	√	√	-	-	√	-	√	-	√	-
Wilson and Odesola,	Nigeria	√	√	√	√	-	√	√	-	-	√	√	-	-	-	-	-	-	-	-	-	-	√	√	√	-	√	√	√	-	-	-	√	√	-	-	-	-
Enshassi et al., 2017	Palestine	√	√	√	√	-	-	-	-	-	√	√	√	√	√	-	√	√	-	√	√	√	√	√	√	√	√	√	√	√	-	√	√	√	-	√	√	-
Ndwandwa et al., 2017	South Africa	√	√	√	-	√	-	√	-	√	√	-	-	-	-	-	-	√	√	-	√	√	√	-	√	√	√	√	√	√	√	-	√	-	-	-	-	-
Ajayi, 2017	Nigeria	-	-	√	-	-	-	√	-	√	√	√	-	√	-	√	-	-	√	-	-	-	-	√	√	√	√	√	√	√	√	-	√	√	√	-	√	-
Yap et al., 2017	Malaysia	-	-	-	-	-	-	-	√	-	√	-	-	-	-	-	-	√	-	-	√	-	√	√	√	√	√	-	-	-	-	-	√	-	-	-	√	-
Eze et al., 2018a	Nigeria	√	√	√	-	-	-	√	-	-	√	√	-	√	-	√	-	-	-	√	-	-	√	√	√	√	√	√	√	√	√	-	√	√	√	-	√	-
Eze et al., 2018b	Nigeria	√	√	√	-	-	-	√	-	-	√	√	-	√	-	√	-	-	-	√	-	-	√	√	√	√	√	√	√	√	√	-	√	√	√	-	√	-
Trach et al., 2019	Ukrine	√	√	√	-	-	-	√	-	-	√	√	-	√	-	-	-	-	-	√	-	-	-	√	√	-	√	√	√	√	√	-	√	-	-	-	-	-
Hwang et al., 2019	Singapore	√	√	√	√	-	-	-	-	√	-	√	-	√	-	-	√	√	√	√	-	-	√	-	√	√	√	-	-	√	-	-	-	√	√	√	√	-
Safapour et al., 2019	USA	-	-	-	-	-	√	√	-	√	√	√	√	-	√	-	-	√	√	-	-	-	√	-	√	√	-	-	-	√	-	-	-	-	-	-	√	-
Liu et al., 2020	China	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	√	-	√	-	√	-	√	√	√	√	√	√	-	-	-	-	-	-	√	-
Mahamid, 2020	Saudi Arabia	√	√	√	-	√	-	-	-	-	√	-	√	√	-	√	-	-	-	-	√	-	-	-	√	√	-	-	-	-	-	-	-	-	√	-	√	-
Salihu and Babarinde,	Nigeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	√	-	-	-	-	-	-	√	√	√	-	-	√	√	-	-	-	√	-	-	-	-	-

8.8 Implications of the study

In practice, this study highlights the following implications for contract parties. Insights into the rework circumstances in construction projects will allow practitioners to look for solutions to mitigate the effects of rework and provide adequate measures to manage them. The main implication of this research is to enhance the awareness of the practitioners about how rework occurs. By ranking the various causes of rework, this paper has generated a list of significant causes that can be used for addressing rework at the contractual level. The findings of this study have provided evidence on the significant causes of rework in New Zealand construction contracts. Studies to explore the clauses of the contract that need to be addressed in terms of rework will provide a framework that reduces contractual claims and disputes. Thus, it requires the contract parties to be more conscious in the contract negotiation period. Contract professionals may need to pay attention to the causes of rework while contract documents are prepared. Implementing such an approach improves the effectiveness of contracting management, affecting the quality of work and performance of the project. Nonetheless, addressing rework causes in the contract conditions will bring more clarity that may help to interpret claims originating from rework. The higher the accuracy of the contract conditions will help to avoid further contractual claims and disputes during the construction stage (Chen et al., 2018). One way of exploration could be the development of a relationship between rework and contractual claims. Moreover, designers need to understand rework causes to improve their design process to prevent rework in the other stages of a project. Overall, an integrated system between the various disciplines of the client and contractor is required at the early stages of the project to manage the rework efficiently.

8.9 Conclusion

This paper's key objective was to identify the common causes of rework in a classified system used for further investigations in construction contracts. Thus, the paper has summarised the evolution of rework research trends by reviewing the literature from the published papers between 1990 and 2021. Over the past 30 years, there have been many research studies on rework issues in construction projects. Adequate sample cases using different strategies have been reported for reducing or preventing the impacts of rework globally. The literature review depicted the quantum of reported work in rework management, including opportunities for future research. In total, 157 academic papers were identified and selected for descriptive analysis to report publication numbers, research regions, journals, employed methodologies, and common causes of rework. The result showed that studies addressing sources of rework are mainly focused on the causes of rework. Hence, 35 deducted papers from the literature on this study area were extensively reviewed to provide a comprehensive list of common rework causes. Accordingly, a list of 37 rework causes has been clustered into five categories of process, human resources, materials and equipment, technical, and general/external.

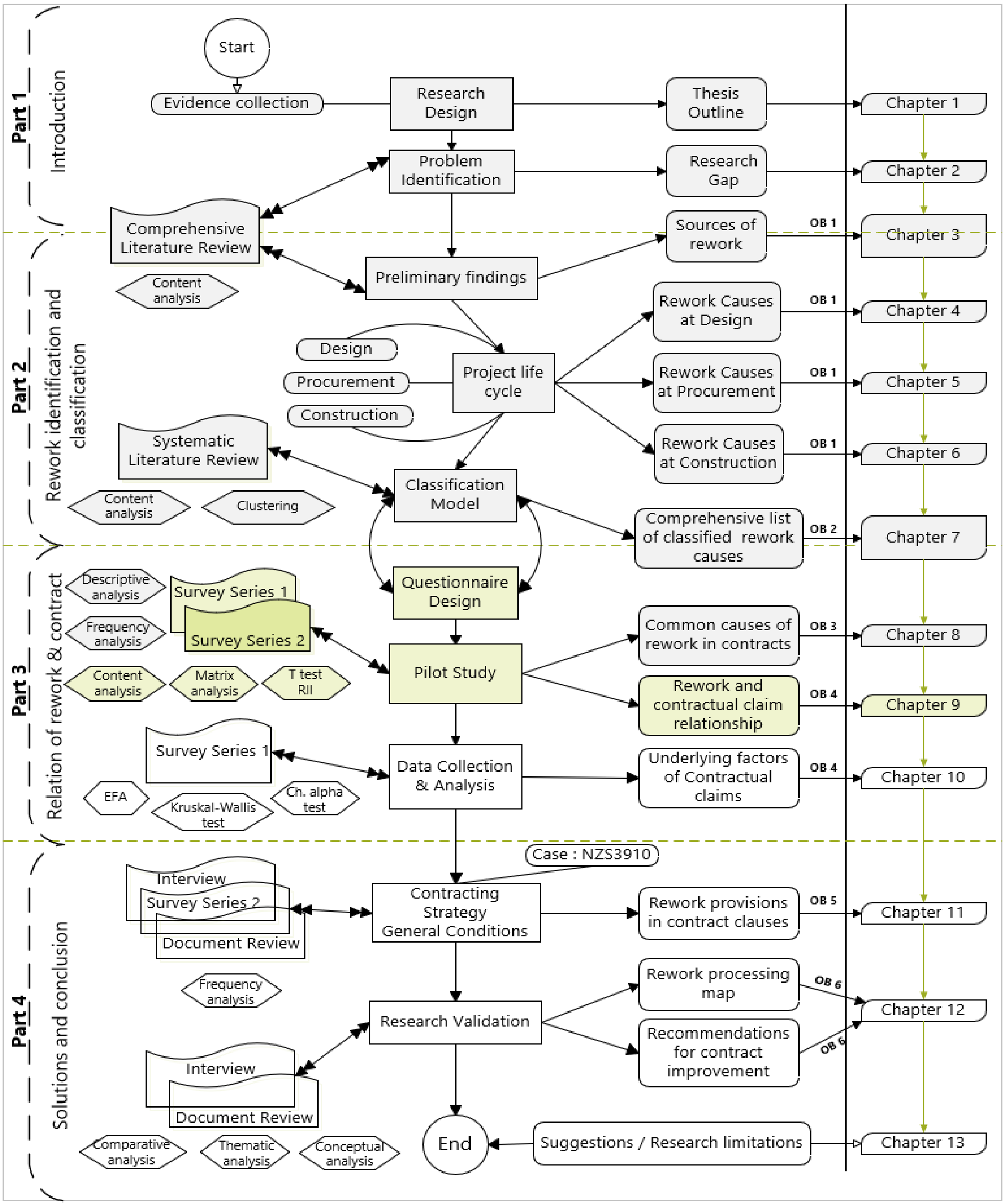
The construction practitioner’s opinions related to the effects of identified rework causes associated with the contracts were then attained through a questionnaire survey. Initially, a pilot survey was conducted to achieve the preliminary results from the New Zealand construction industry. The significant causes of rework in construction contracts were identified through an analysis of the collected data. They were listed as the top four most significant rework causes. The final list of significant causes of rework for further investigation into the contract conditions were then completed by adding 18 more causes. The potential of generating contractual claims and disputes from rework would be better understood if the causes of rework were addressed in the contract documents. The possibility and capability of projects to overcome contractual issues under rework circumstances is an area worth addressing for further investigation. Thus, future research into the contract clauses to suggest an improved decision support system is recommended. The list of 22 common causes of rework provided in this paper will serve as a basis for improving construction contracts. Factor analysis on the list of 22 identified causes, after collecting an adequate number of responses from the survey, will reduce the number of causes to achieve more authentic results. The findings of this study could help contract professionals to obtain insights about the probability of rework before the commencement of the contract. The recognition of causes to address rework in the contract conditions during the negotiation of the parties is a proactive approach that may help to prevent rework occurrences.

While the paper contributes to the contract management body of knowledge through identifying the significant causes of rework, it also has some limitations. Firstly, this paper is limited only to identifying the causes of rework, and the other study areas of rework such as, the proposed models and solutions for rework reduction, the impacts of rework, and the implanted theories and underpinned rework methods, necessitate further exploration. Therefore, identification of the knowledge gaps in the other study areas of rework will require a further review with the focus on construction contracts. Secondly, it has to be noted that five more papers on the sources of rework have been published after conducting this survey in September 2020. Even though the recently identified papers have been included in the rework research trend results, the survey result does not reflect their contributions. Lastly, even though the result of the paper is limited to the initial analysis of the pilot survey, and it cannot be used for generalization purposes; nevertheless, it supports the next stage of the research, to start the interviews and to conduct the qualitative part of the study.

8.10 Epilogue

This chapter focused on the common causes of rework in New Zealand construction contracts. This part of the research explores which causes of rework incorporate the most commonly used form of contract in New Zealand. For this purpose, the contractual issues related to rework causes were investigated using a questionnaire survey. The claim is one of the main contractual issues affected by rework events. Since it is crucial to understand how the common causes of rework affect contracts, the investigation was targeted to provide the common rework causes that facilitate the claim handling process in the next step of research. As such, the relationship between rework and contractual claims requires to be understood. In the next chapter, the relationship between rework and claims with consideration to the contract conditions will be studied in more detail to prioritize the causes linked to the existing provisions of NZS3910:2013.

Thesis-at-a-Glance / Chapter 9



Chapter 9. Investigating the relationship between reworks and contractual claims: The salience of contract conditions

9.1 Prologue

This chapter focuses on the third research objective and partially addresses the second and third research questions. The investigation of the direct relationships between rework and claims in construction contracts for improving contract conditions is presented in this chapter. This relationship depicts the common sources between the contractual claims and rework and identifies the rework-related provisions in the contract conditions. This chapter first identifies the causes of rework that generate contractual claims and then investigates whether rework is addressed adequately in the general condition of the commonly used contract in New Zealand (NZS3910:2013). The chapter follows the exploratory study by conducting four steps methodology to complete the pilot study. Ranking of the causes and matrix analysis then is used for prioritizing the causes. The information and data in this chapter are collected from the designed questionnaire used for the New Zealand construction industry's survey.

This chapter is based on the following published Journal paper:

Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (2022). Investigating the relationship between reworks and contractual claims: The salience of contract conditions. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction.* 14(1), 04521046, DOI: 10.1061/(ASCE)LA.1943-4170.0000519 (ASCE).

9.2 Abstract

Statistics show a high rate of contractual claims in construction projects, impacting the construction industry's progress negatively. Rework is one of the main underlying factors that generate contractual claims. Rework and contractual claims follow a mutual routine. Despite a large number of studies on the causes and impacts of rework on project performance, there has been limited research examining the relationship between claims and rework on the basis of contract documents. The paper first attempts to expose the sources of rework through a systematic literature review and then assess rework causes that fail to be addressed in construction contract documents. The review results identified 37 root causes as the most common rework contributors to the construction projects classified into five groups. The list of rework causes served as a starting point for searching the contractual issues through a questionnaire survey. Accordingly, a relative importance index was used for analysis of the primary data collected from the survey. The result first prioritized the importance level of rework causes in generating contractual claims, preceding rework causes that are not addressed adequately through standard form of contract conditions in construction projects. Findings of the investigations revealed that the general conditions of contract do not address the causes of rework adequately. Therefore, contract documents need improvement to cover contractual claims incidences due to rework. Lack of addressing rework causes in the general conditions of the contract triggers recommendations for revising the contract clauses that ultimately lead to improved claim handling and dispute avoidances.

9.3 Introduction

In the construction industry, a broad range of stakeholders with various requirements are connected through a contract. The contractual approach of the project parties determines the successful level of project delivery (Gunduz and Elsherbeny, 2020). Ineffective management of contracts between client and contractor often leads to conflict and claims. The client-side of the contract asks for the highest quality of the project, and the contractor-side attempts to cover the scope of work using its optimal resources and meeting its financial targets. Adding to that, clients usually change their expectations which increases project uncertainties (Wang et al., 2019). Increasing the numbers of uncertainties in the construction project may result in contractual claims. Contractual claims are generally issued for covering loss and expenses, liquidated damages, or extensions of time (Hwang and Yang, 2014; Hansen et al., 2020; Kim and Skibniewski, 2020). When a claim arises, both sides of the contract follow their interests on a contractual basis. However, the contractor's goal would be to cover the expenses by searching the contract clauses in respect of unforeseen circumstances (El-adaway et al., 2018).

The unavoidable occurrence of contractual claims has been discussed sufficiently in the complicated nature of construction projects. According to (Moza and Paul, 2018) the quality of contract documents is one of the sources of claims and conflicts. Since the adverse effects of a claim are predictable by the contractual parties, the occurrence of dispute cases is preventable. Thus, the method of dealing with the claim and reimbursing its impacts needs to be defined. If the contractual parties successfully reach an agreement, the claim would be managed; otherwise, it results in disputes. Overall, the claim progression procedure has been placed in the contract conditions to legitimize claim assessment and avoid the occurrence of disputes (Abdul-Malak et al. 2020). Furthermore, the mechanism of claim assessments and their solutions are almost always addressed in the standard forms of contract conditions in the construction industry. However, understanding the contractual terms among these contracts is not easy for all construction practitioners as the conditions are articulated by legal entities (Raj et al., 2009).

A comprehensive review of the literature revealed insufficient research identifying the relationship of rework and claim. How contractual claims are affected and may result in dispute has not been studied yet under rework circumstances. Therefore, there is a need to investigate the causes of rework in association with contractual construction claims. Since contractual claims are referred to in the contract conditions (Jelodar et al., 2016), rework causes generating such claims can also be referenced to the same conditions. For example, a claim could cover the client's changes when appropriately incorporated into the contract's relevant clause. Concurrently, the imposed changes may result in rework occurrence. Due to the similarity of the causes between claim and rework in this example, the relevant contract conditions for addressing change can be utilized for addressing rework. This paper attempts to provide the basis for further research on contract conditions and their potential to address rework by identifying relationships between claims and rework causes. As a result, it is necessary to characterize this relationship first through examining their common root causes. The reported study in this paper uses a review approach to identify common causes of rework and then explores the relationship between rework and claims. The objectives of this study include the following:

1) To identify rework causes that generate contractual claims and establish the relationship between rework and claim
2) To investigate if rework is addressed adequately in the general conditions of the contract in construction project

The study examines the standard form of contract for building and civil engineering construction "NZS3910:2013" as the most commonly used contract document in New Zealand construction projects for achieving Objective two of the paper. NZS3910 has been designed to be flexible for industry uses and includes the required provisions to cover a variety of engineering and building projects with different administration methods.

9.4 Need to explore contract conditions in rework circumstances

To some extent, contract conditions have been shaped in a standard format in the construction projects of many countries. Based on the literature review, claims and associated disputes can be related to contract conditions, so their underlying causes, such as rework, can systematically be linked to the contract conditions. From the literature it can be implied that rework triggers a claim, and poor contract conditions make the scenario even more complicated (Besaiso et al., 2018). This paper intends to make contribution to rework, by improving contract management on construction projects. Rework causes are very complex and interrelated. Many researchers have studied rework in the design and construction stages of projects but studying rework in the procurement stage is very limited. The contract document is the main output of the procurement stage of a project, and poor contract documentation has been identified as a major contributing factor to the occurrence of rework (Love et al., 2006; Mendis et al., 2013; Mendis et al., 2015). In addition, contract provisions play a critical role in claim handling and can prevent disputes. Therefore, the focus of the research reported in this paper is to understand the relationship between rework and contractual claims and explore the adequacy of the conditions of the contract in addressing their common causes. Understanding this relationship is vital as it ultimately serves as a framework for improving the general conditions of the contract. Proposing further recommendations for revising the current format of contract conditions to address rework would result in better management of claims and disputes. It could enhance the contract provisions as part of the solution for claim handling that is incorporated into dispute prevention.

9.5 Common sources of claim and rework in construction projects

There is an interdependent relationship between rework and contractual claims of construction projects (Palaneeswaran et al., 2014; Ajayi and Oyeyipo, 2015). Correlation coefficient analysis through neural network modeming showed that contractual claims and rework were significantly related (Palaneeswaran et al., 2006). Therefore, rework consistently pushes contractors looking for claims to compensate cost and delayed time, specifically when rework influences the budget and critical path of the project. Despite a strong correlation between rework and claims, the investigation of their relationship is limited in the literature; however, extensive research has been dedicated to each subject separately. Due to such a scarcity of empirical research, this paper aims to examine claims under rework manifestations. Rework has been introduced as one of the causes of claims in various studies (Love and Curtin, 2019; Eze and Idiake, 2018a; Wang et al., 2019; Banwo et al., 2015). Rework, and claims, cause overruns and delays that ultimately lead to poor project performance. The effects of rework on a construction project have been studied in Nigeria and the result showed that contractual claims are reduced when rework triggers are eliminated (Eze et al., 2018a). Causes of rework can be examined under various claim situations. Take an example of a material shortage in the market that generally ends with using alternative material, but the contractor needs to obtain the client's pre-approval for the material replacement. In this way, contractors save their position to be eligible for a claim in the future, while using alternative material is one of the root causes of rework in many projects.

The sources of claim and rework are common in many circumstances. For example, when changes occur, they cannot be isolated due to the existing interrelated chain of cause and effect. If the contractors are not sure about compensation for rework costs, they are most unlikely to perform requested changes with priority, and therefore claims appear. Jelodar et al., (2016) categorized causes of claims into three main groups: project uncertainties, contract and process, people, and behaviour. The causes of claims in UAE construction projects were investigated and the results identified seven types of claim to be: contract ambiguity, delay, acceleration, changes, extra work, errors and omissions, and site conditions. The investigation then concluded that the main root causes were related to variation orders, delays by the owner, material changes, and variations in quantities (Zaneldin, 2020). Further, investigation into the FIDIC contract conditions to determine the priority of the claim and dispute factors in an overseas construction project in Korea revealed 30 claim risk factors, of which failure to examine contract conditions at the time of tender was ranked highest (Choi and Kim, 2016). Other causes that were identified in common as contributors to rework were: acceleration, unrealistic contract, site management, improper planning, inadequate contractor experience, mistakes during construction, improper construction methods, quality assurance and control, material quality and shortage, change orders, mistakes and discrepancies in the contract document, lack of communication, weather conditions, site conditions, and coordination problems (Kim and Skibniewski, 2020).

Rework root causes are variables that facilitate the occurrence of claims. These variables may appear as an event, a chain of factors, or triggers resulting in rework in the project. The emergence of rework root causes at all project stages is a possibility that cannot be ignored. Previous researchers have identified various root causes of rework. The study carried out by Liu et al. (2020) revealed that most rework costs are generated by three factors: contractor field management, design management, and client management. It also categorized 37 contributing sub-causes of rework under 11 significant factors in China. Ranking of the sub-causes of rework in this study showed that lack of communication between client and project parties has the highest impact on rework cost followed by design mistakes, contradictory instructions, ineligible techniques, and poor site conditions. Factors identified by (Hwang et al., 2019) included client changes, design errors and omissions, design changes, contractor error and omissions, contractor changes, vendor errors and omissions, vendor changes, and transportation errors. These factors as the sources of rework were examined to measure the impacts of BIM implementation in construction projects in Singapore. The omission and planning, change issues, funding and communication issues, poor workers, and resource control are the principal rework risk triggers in Nigerian construction projects that cause rework (Eze et al., 2018a).

Mahamid (2016a) in the survey conducted among residential building in Palestine found that poor communication of client with contractors and consultant, poor-quality material use, and poor site management are the most severe rework causes that need attention. Other studies also have confirmed that the client significantly contributes to most rework projects (Hwang et al., 2014). The study of the client rework-related factors in Singapore revealed that the client usually replaces material, changes project plans and scope, is involved in low-level decision-making processes. Using substandard services, defects under the grouping of related technical factors, lack of support for site management, lack of commitment in the quality management related group, disturbance of personal planning, carelessness, lack of skill and inexperienced staff under the human resources related factors are known as the highest contributors to rework occurrence in the study done by (Oyewobi and Ogunsemi, 2010). According to (Enshassi et al., 2017), attempts to defraud, competitive pressure, ineffective management, and schedule pressure are the main causes of rework in the Gaza Strip that influence the productivity of construction projects. The most commonly used rework factors and their root causes can be found in the studies done by (Palaneeswaran et al., 2008; Love et al., 2009a) categorized under four headings: client, contractor, site management, and subcontractor groups. They include changes, errors, omissions, lack of allocating funds, low contract fee, ineffective use of quality management, poor technology use, and incomplete design at tender time, leading to poor contract documentation. Some other factors and causes of rework related to external sources or environmental aspects have also been identified, including political issues, economic situations, and weather conditions (Mahamid, 2016b; Enshassi et al., 2017).

The characteristics of the project are altered by activation of rework root causes. Thus, the project results do not meet the contract or the client's requirements. According to (Al-Janabi et al., 2020), poor contract management could result in ambiguity in the contract documentation. Initially, such ambiguity is due to the poorly defined scope of the project by the client. Mistakes in the contract documentation create errors during the construction process that will ultimately end with change orders, claims, and rework. Thus, the procurement stage of the project needs more investigation to minimize such problems. Further studying of the effects of procurement on rework in construction projects has also been recommended (Anjum and Azam, 2019). This research aims to identify the root causes of rework through a comprehensive review of the literature and examine their influence on contractual claims by conducting a questionnaire survey. The identified root causes provide a basis to understand the potential problems in rework occurrence that lead to claims and other contractual issues. Thus, it would help project organizations to control rework's adverse effects such as disputes by addressing identified causes in the contract documents.

9.6 Methodology

For this study, a mixed-method of literature and survey was used to cluster, and rank rework causes that generate claims using relative importance index analysis. The study followed comprehensive literature to identify the causes of rework, and then a questionnaire approach to collect data was carried out. The initial strategy was based on the analysis of implemented theories for meeting the sources of rework through the literature. The survey then comprised the structured questions, including 37 identified rework causes collected from previous studies for further investigation. The employed strategy was completed by gathering the professionals' opinions to evaluate the contractual claims during rework circumstances. The second phase was designed to assess contract documents in the presence of rework causes among practitioners in New Zealand construction companies. Before sending questions out to collect data, a pilot study was conducted to verify that questions are reliable, answerable, and designed appropriately to align with the research objectives.

The adopted framework of four-level methodology to gain insight into the relationship between rework causes and contractual claims in New Zealand construction contracts is presented in Figure 9.1. After pre-analysis of identified rework causes and categorizing them into five groups of factors, the questionnaire survey using a 5 Likert-point scale was distributed to the targeted participants. Lastly, descriptive statistics were adopted for participants' demographic information, and a relative importance index was performed for ranking the causes of rework. The methodology's outline simply follows the sequences as described hereafter:

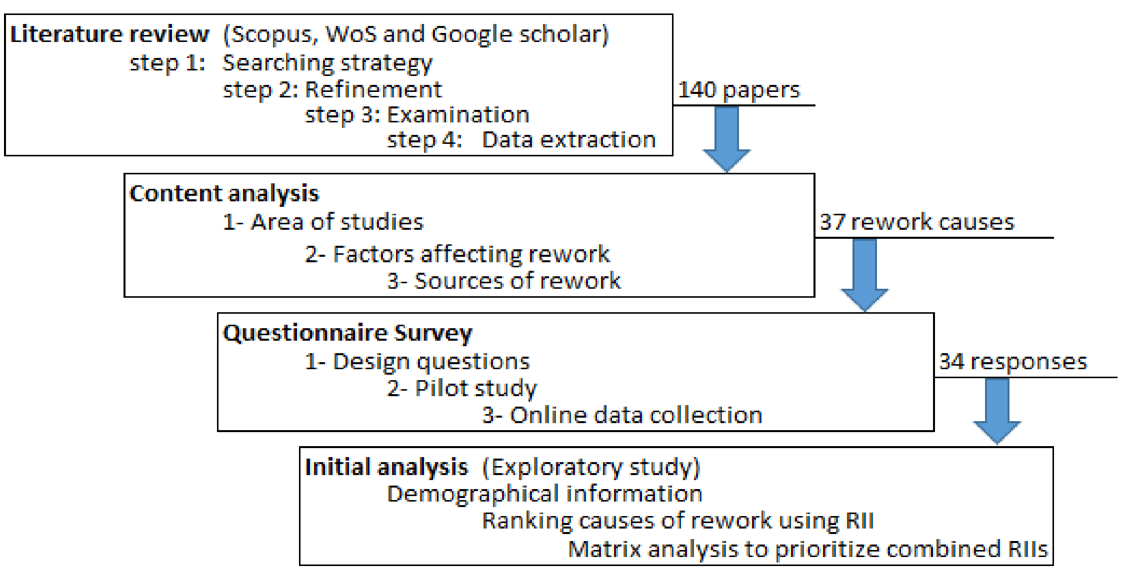


Figure 9.1: *The diagram of applied methodology*

9.6.1 Literature Review and content analysis of the literature

A four-step systematic literature review was carried out. In this stage, rework-related articles were identified to determine the possible causes and their classification models. The comprehensive literature review followed four main steps: (a) defining a strategy search by choosing the keyword of rework in the title of papers in the field of construction between 1990 and 2020, (b) refining the identified papers by applying some exclusion and inclusions to find more precise articles according to the scope of the study, (c) quality assessment of the remaining papers by scanning the titles and reviewing the abstracts, (d) extraction data from the final shortlisted papers using Microsoft Excel file. Similarity checking to prevent duplications in published papers and identified rework causes was also carried out. Three search engines were employed for retrieving relevant journals and conference papers. The shortlist of relevant articles was prepared after screening the full text of the selected papers. This stage finally concluded with a list of rework root causes disseminated throughout the project's life cycle.

9.6.2 Questionnaire design and Pilot study

In reference to Table 9.7, a total of 37 retrieved root causes of rework from the literature were selected to be used in the preliminary questionnaire. Following the literature's concept, the similar causes of rework were grouped to construct rework factors under five broad headings: process, human resources, material and equipment, technical, and general/external related factors. Since one purpose of this paper is to explore the significant causes to be included in the next research step, it was decided to use an exploratory survey research design. A well-structured questionnaire to collect the data from the causes leading to contractual claims was designed. The questionnaire was based on the five-point Likert scale "from strongly disagree (1) to strongly agree (5)" to measure the influence of each cause on claims. The survey involving the use of these structured questions covers the quantitative part of the research. A pilot study verified the questionnaire and ensured that the questions are appropriate for research purposes. The questionnaire was tested with four experts, two from the academic field and two from the industry. The academic experts reviewed the fluency and clarity of the questions in line with the study's objectives and confirmed the simplicity and precise language (Gunduz and Elsherbeny, 2020). Also, questions were controlled as they need to be easy to answer (Eze et al. 2018a). Two industry experts were interviewed, and a draft copy with a covering letter was emailed to get their comments about the content validity. They gave their comments to modify questions based on the industry's expectations. The selection criteria of pilot study participants were mainly based on their expertise and years of experience related to the research subject. Each interviewee had more than 30 years of experience in contracting and construction management. According to their advice, the questionnaire was slightly modified to improve the quality by merging the same items from different project stages, as the general conditions of the contract covers the entire life cycle of a project. The pilot study ensured that all questions are sufficiently defined without the possibility of misunderstanding arising (Ye et al., 2015). The survey included two lead questions as follows with 37 causes of rework listed under each question. Question one was desired to determine which causes create claims and question two desired to establish which causes have not been addressed in the general conditions of the standard from of contract in New Zealand.

Question 1. To what extent do you agree that the following rework root causes lead to claims and other contractual issues?

Question 2. To what extent do you agree that the conditions of contract NZS3910:2013, adequately addresses the following rework root causes?

9.6.3 Conducting survey

The finalized questionnaire was developed as an instrument for data collection in two separate parts. The survey was started with general questions to collect demographic information of participants such as experience, project value, type of organizations, and position. Before moving to the next part of the survey, participants needed to advise whether they are from the "client or contractor" side of the contract. Then they were given the developed list from the literature that contains 37 rework root causes. This part asks to what extent participants agree that rework causes lead to claims and other contractual issues. It explores the relationship between claims and rework causes. Respondents were then asked to answer to what extent they agree that the contract conditions adequately addressed each of the causes listed in the questionnaire. A five-Likert scale was used to measure and quantify each cause's importance. The questionnaire was agreed to be used online, and the survey questions were placed on Qualtrics software and distributed electronically to draw the professionals' views on the construction industry. The target population for the main research was a combination of clients and contractors working on civil and infrastructure projects, certified builders, architectural consultant firms, and other organizations that generally use the standard form of contract in their projects.

A list of 173 firms was provided for the first round of questionnaire distribution by checking the Infrastructure New Zealand and Association of Consulting and Engineering in New Zealand "ACENZ" authorities. The list comprised 133 architects and consultant firms and 40 civil and construction contractors. The questionnaire link was emailed to the targeted firms with a cover letter explaining the research aims. All invited firms participating in the survey were asked to complete the questionnaire if they had experience of contracting management. The invitation emails introduced the survey and requested participants to answer the survey question only if they have experience using the standard form NZS3910 contract conditions. As a result, all respondents have enough understanding of the claims process under construction contracts. This point brings more validity and reliability to the collected data (Kisi et al., 2020).

Since the research process is completed later by conducting an interview, it was necessary to analyse the primarily collected data for designing the interview questions. The Qualtrics software showed the completed survey with 46 participants throughout one and a half months, a response rate of about 26.58%. The achieved rate was suitable for starting the initial analysis on ranking rework causes to design the interview questions. According to (Yap et al., 2017), the sample size between 30 to 500 is adequate for initial analysis in most of the conducted research. Therefore, the collected data from the completed questionnaire by 46 respondents were extracted to the SPSS for performing the required analysis. A more detailed review of the completed survey revealed that only 34 responses were properly filled in with all the required questions. The remaining 12 responses with incomplete answers were considered invalid and discarded from the list. Figure 9.2 illustrates the respondents' distribution based on the type of organizations and their response rate. All participants' cumulative response rate is about 20% based on 173 distributed and 34 submitted/returned questionnaires. This rate is close to the acceptable normal range for conducting research analysis in construction management (Hwang and Yang, 2014; Hwang et al., 2016). Conducting research analysis on the basis of the same number of responses and less also can be seen in the literature (Banwo et al., 2015; Oyewobi et al., 2016; Lessing et al., 2017). The responses comprised 21 client-side of the contract and 13 contractor-side, showing relatively sufficient coverage of both contract sides for an acceptable result.

9.6.4 Data analysis and results

This paper presents a statistical analysis using a Relative Importance Index (RII) to evaluate collected data and rank the causes of rework for both study's objectives. A Five-Points Likert scale of 1 to 5 was used to measure the frequency of each rework cause and then provide the priority list of causes. According to Zaneldin (2020), collected data from the construction research survey using Likert scales is frequently analyzed through the RII method. Therefore, the RII method is employed in this paper to measure the importance of rework causes. The RII technique facilitates comparative analysis, depicts the most contributing elements of management, and helps planners allocate resources better (Alaghbari et al., 2018). This method determines the importance level of each cause listed in the questionnaire and then ranks all causes. The RII result identifies the most significant rework causes that lead to contractual claims and gives the severity indication for each cause. The list of 37 identified rework root causes are the variables of this research that affect claim and other contractual issues in construction contracts. The ranked causes of rework then were transferred into a matrix through a combination of the relative importance index of each cause in relation to both objectives of the study. The matrix prioritizes rework causes at different levels of importance for further studying.

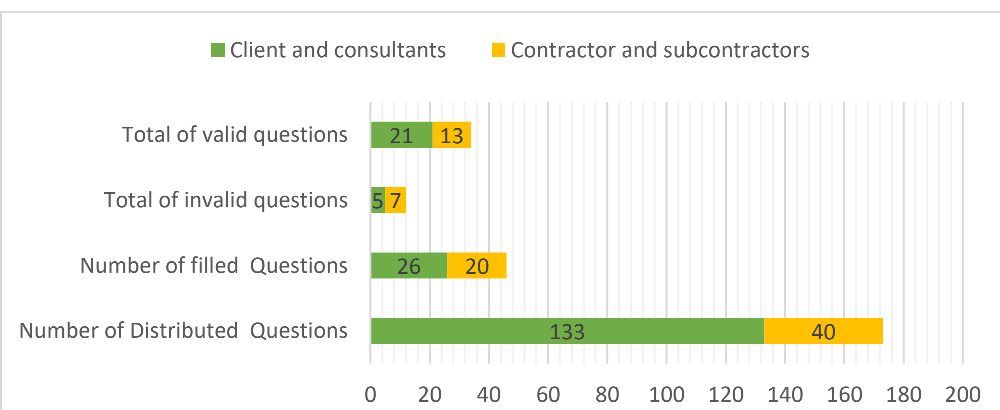


Figure 9.2: *Distribution of respondents and organizations*

9.7 Results of the systematic literature review

To identify the cause of rework, 35 articles out of the initial 140 documents were relevant to the research scope. Content analysis of the relevant papers resulted in the identifying rework causes as listed in Table 9.7, which are classified into five groups as the most common rework causes. Table 9.7 also shows the total number of citations within the reviewed papers in this study's scope. These causes can result from either the nature of construction or the other imposed determinants such as human attributes, procurement approaches, external factors, and supporting activities. In line with the previous research studies on the classification of rework causes, the identified 37 items are clustered into the generic sources for interpretation and further discussion concerning the contract. Some of the causes are process-based and ignoring them stops the progression of work. This group included the causes of rework that mostly occur during the project's main activities (Zhang et al., 2012). Changes, errors, omissions, and incomplete or faulty processes can be categorized under process-related factors. Knowledge, skills, experiences, motivations, and other similar characteristics are human attributes and can be clustered in one group of causes. Some causes are related to the provided material or used equipment directly affecting the construction project's outcomes. The causes linked to supplying the required material and equipment for the project are categorized under material/equipment-related factors (Robinson et al., 2004). Other causes are related to the activities that provide support services to the main process, such as quality control for monitoring, employing technology, communication means, planning, and scheduling for controlling projects. All these causes are clustered under technical-related factors (Oyewbi and Ogunsemi, 2010). The last group of causes consisting of nine items is generally linked to the external sources and listed in no particular order.

9.8 Analysis and survey result

The detailed demographic of respondents is shown in Table 9.1. As summarised in Table 9.1, demographical data analysis revealed that the consultants' companies had contributed the most to the survey with the frequency of 19 out of 34 responses equal to 55.88%. About 61.76% of the participants were from the client-side, and the remaining 38.23% filled their survey questions from the contractor-side. Therefore, the importance index of rework causes comprises enough responses from both sides of the contract. In terms of the role of participants, the highest percentage is Project Directors with 32 %. The respondents' other positions that show 23 % include "two CEOs, three project advisors, one regional manager, one contract engineer, and one building surveyor."

Table 9.1: Demographic characteristic of respondents

Profile	Classification	Frequency	%
Organizational type	Client	2	5.88
	Consultant	19	55.88
	Contractor	11	32.35
	Subcontractor	2	5.88
Role of participants	Project director	11	32.35
	Project Manager	6	17.64
	Contract Manager	1	2.94
	Commercial Manager	3	8.82
	Quantity Surveyor	5	14.70
	Others	8	23.52
Years of experience	Less than 5 years	0	0
	6-10 years	5	14.70
	11-15 years	2	5.88
	16-20 years	3	8.82
	21-25 years	4	11.76
	Over 25 years	20	58.82
Contract side	Client- side	21	61.76
	Contractor-side	13	38.23

Most respondents have more than 25 years of experience in the construction field, with a rate of 58.82%. This rate verifies that the analysis result is authentic based on the given information from an experienced sample. Regarding the years of experience in contracting management, all participants are from the construction sector, and the highest percentage belongs to the group having more than ten years' experience with 76% compared to the other groups. The high percentage of this group with more than ten years of experience in contracting management strengthens the collected data's reliability and results.

9.8.1 Internal reliability of the questionnaire

The T-test technique was used to ensure that the sample size, including two categories of 21 clients and 13 contractors, is adequate to deliver a trustworthy finding. This test is used to find discrepancies between different groups of respondents in answering the questions. The results confirmed that the p-value of only three causes out of 37 regarding Objective one was less than 0.05 as can be seen in Table 9.2. In other words, there are no significant differences between the two groups of client and contractor for the majority of variables, and consequently, the result of the initial analysis is meaningful due to minimal inconsistencies (Lee et al., 2020). The SPSS result also showed a p-value for all 37 causes in Objective two is more than 0.05. Thus, the initial analysis result is satisfactory for conducting the next research step.

Table 9.2: Result of T-test for the causes of rework

Rework cause "Variable"	Group	N	Mean	P- value (Sig.)
Inadequate supervision staff	Client-side	21	3.76	0.003
	Contractor-side	13	4.00	
Insufficient skilled level manpower	Client-side	21	3.62	0.011
	Contractor-side	13	4.31	
Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	Client-side	21	3.90	0.006
	Contractor-side	13	3.54	

The validity of the responses also was verified through a reliability test. Before data analysis, the reliability of the questions needs to be examined. For this purpose, the internal consistency of the variables among two different respondent groups, "Client and contractor," were measured using the Cronbach Alpha test. Since a Likert scale is used to measure the study variables, the questionnaire's reliability can be checked through the Cronbach Alpha test. The result of this test with the figure above 0.7 shows higher internal consistency based on the participants' responses and proves the reliability of the questions (Gamil and Rahman, 2020; Gunduz and Elsherbeny, 2020). The Cronbach Alpha test results among all 37 rework causes were between a range of (0.949 to 0.953) in Objective one and equal to 0.968 in Objective two. This result proves the reliability of the questions. Thus, the data's internal consistency received high appraisal, and the collected data was reliable for performing further analysis. IBM SPSS version 26 software was used for performing all analysis in this paper.

The Relative Importance Index of each rework cause has been presented in Table 9.3 and the result of implementing RII for each group of factors is presented in Table 9.4. It shows that process related factors are mostly generating contractual claims more than the other groups of factors followed by technical related factors and human resources factors. Therefore, these three groups have greater priority for further investigation as they result in higher numbers of claims in projects. In terms of being addressed by contract conditions, the group factors of material and equipment stand higher than the other groups meaning that the conditions of contract have adequately addressed the causes of rework under this category and more investigation may not be required. Whereas the group of human resources related factors with lower RII has more priority for further investigation as they seemed to be less addressed in the conditions of the contract. Table 9.3 shows the relative importance index for each of the causes of rework to meet the study's objectives. The result showed that the rework leads to contractual claims under various situations. The causes of rework illustrate the causal relationship between rework and claims. The other side of the result showed that contract conditions do not adequately address the causes of rework, making the assessment of claims even more difficult. When the contract conditions do not provide enough legal evidence for processing claims, they are more likely to lead to conflict and disputes. Based on this result, further investigation on contract conditions is required.

Table 9.3: Relative Importance index of rework causes for objectives of the study on NZS3910

Group	Rework root cause	Objective 1 RII	Objective 1 A	Objective 1 B	Objective 2 RII	Objective 2 A	Objective 2 B
Process related factors							
P1	Changes, modification and revisions in design / construction changes	0.841	3	4	0.747	1	1
P2	Error in design, drawings and specifications / error in construction	0.923	1	1	0.652	3	5
P3	Incomplete design, any omission in the design or construction process	0.894	2	2	0.658	2	4
P4	Inadequate procurement methods / poor contract execution	0.7	6	15	0.552	5	17
P5	Improper contractor and subcontractor selection	0.705	5	14	0.529	6	20
P6	Lack of document control	0.717	4	12	0.582	4	13
Human resources related factors							
H1	Lack of experience and personal expertise in design and construction	0.77	1	6	0.511	6	23
H2	Inadequate supervision staff	0.764	2	7	0.517	5	22
H3	Inadequate manpower to complete the task	0.729	4	11	0.541	2	19
H4	Insufficient skilled level manpower	0.77	1	6	0.511	6	23
H5	Poor knowledge of team member, lack of education and training	0.741	3	9	0.517	5	22
H6	Lack of employee motivation and rewards, Carelessness	0.647	6	20	0.523	4	21
H7	Poor workmanship approach and inappropriate personal attitude	0.711	5	13	0.517	5	22
H8	The absence of job security and other safety rules	0.482	9	29	0.511	6	23
H9	Labor reallocation, alteration and staff turnover	0.6	7	25	0.529	3	20
H10	Conflict of interests	0.505	8	28	0.558	1	16
Material & Equipment related factors							
M1	Defective materials, Non-adherence to material specifications	0.735	1	10	0.688	1	2
M2	Poor-quality material or substandard products / Prefabrication errors	0.717	2	12	0.670	2	3
M3	Replacement or misplacement of material and equipment	0.623	3	22	0.611	3	11
M4	Inefficient equipment use or altered material	0.611	4	23	0.582	4	13
M5	Untimely deliveries of material and equipment	0.605	5	24	0.558	5	16
Technical related factors							
T1	Ineffective use of quality management practices / deviation due to poor monitoring	0.752	3	8	0.623	3	9
T2	Poor technology application and lack of information technology use	0.6	6	25	0.523	6	21
T3	Poor communication system for coordinating between members	0.688	5	16	0.517	7	22
T4	Inefficient management process, poor site management practice	0.729	4	11	0.547	5	18
T5	Poor project documents, unclear instructions, poor contract documents	0.817	2	5	0.635	2	7
T6	Conflicting and incomplete information	0.847	1	3	0.670	1	3
T7	Inadequate planning and poor scheduling of workload	0.752	3	8	0.564	4	15
General/external factors							
G1	Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure	0.670	3	18	0.576	6	14
G2	Lack of client involvement	0.635	5	21	0.558	7	16
G3	Unclear line of authority	0.594	6	26	0.670	1	3
G4	Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	0.752	1	8	0.594	5	12
G5	Lack of constructability	0.752	1	8	0.541	8	19
G6	Damage / defects / Deviations in the product due to poor handling and safety considerations	0.682	2	17	0.594	5	12
G7	Governmental regulations / changes and policies	0.535	7	27	0.641	2	6
G8	Environmental conditions, poor site condition	0.652	4	19	0.629	3	8
G9	Unpredictable factors from different sources	0.652	4	19	0.617	4	10

A combination of these two-importance indexes would facilitate further discussion on the causes of rework in relation to the contractual claims and contract conditions. The listed causes of rework in Table 9.3 can take two indicators from each objective of the study and make a matrix with two dimensions. Figure 9.3 shows the matrix that has been made by RII of the study's objectives. Each objective's RII has been divided into five equal parts from top to bottom to show the importance level of causes according to the industry's feedback (Kassem et al., 2020). The level of importance has been indicated by very important, important, moderate, less important, much less important. The assessment is based on the matrix scale of the RII value, where the lowest and highest are 0.482 to 0.923 for Objective one, and 0.747 to 0.511 for Objective two (Husin et al., 2019). The matrix then shows seven different areas that have been coloured for identifying the priority of combinations between importance indexes (Luo et al., 2018). Area (VII) that encompasses very high RII in both objectives has the highest priority for further investigation, followed by the areas (VI) and (V). The other areas including (IV), (III), (II), and (I) consist of rework causes that have moderate or lower RII on both sides of the matrix and therefore have less priority for further investigations. A two demotions matrix was then used for covering the result and placing each rework cause distributed in the defined zones (Kassem et al., 2019). The result of this combination has been presented in Figure 9.3.

Table 9.4: Relative Importance index of rework group factors

Rework Factors	Objective 1		Objective 2	
	RII	Rank	RII	Rank
Process related factors	0.797	1	0.620	2
Human resources related factors	0.672	3	0.524	4
Material & Equipment related factors	0.658	4	0.622	1
Technical related factors	0.741	2	0.583	3
General/external factors	0.658	4	0.620	2

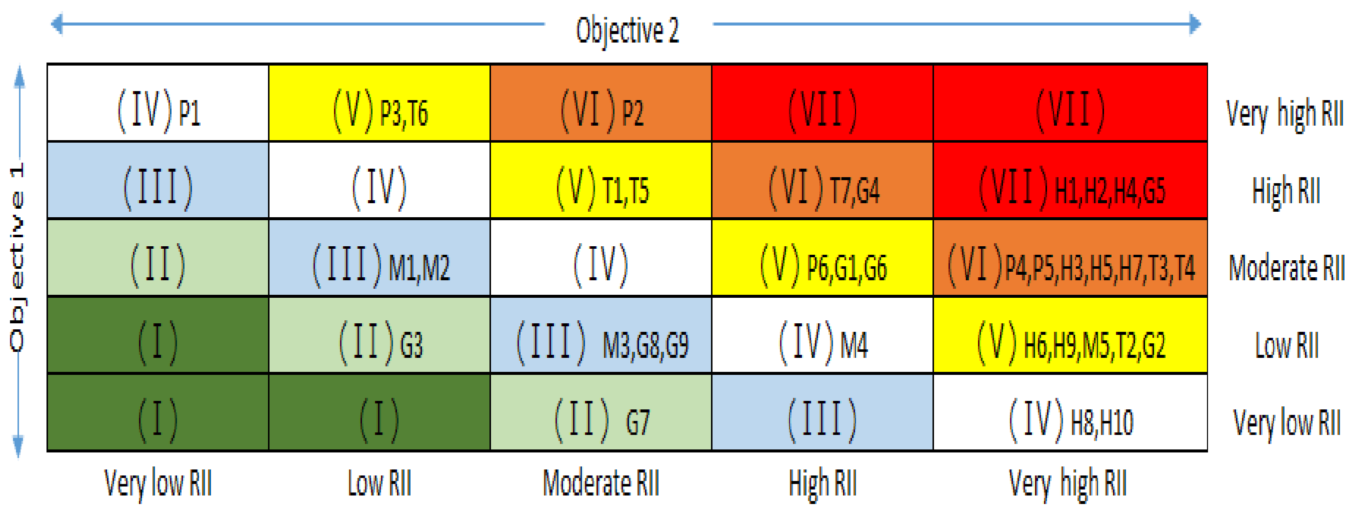


Figure 9.3: *Matrix of relative importance index of rework causes*

Table 9.5 shows the criteria and boundaries for dividing the range of RII in the both objectives of the study. Data analysis on the Objective two showed a range of 0.511 to 0.747 as the relative importance index of each evaluated cause. A higher score shows that respondents are more likely to agree that the condition of the contract adequately addresses the root causes of rework, and a lower score means the causes of rework have not been addressed adequately in the contract conditions. Therefore, the lowest RII in Objective two has the highest probability of leading to conflict or dispute as no reference has been placed in the contract conditions. Since the provided list of causes in the survey was not against or aligned with contract parties' interests, it is worth mentioning that the RII result is most likely unbiased; however, the number of participants from the client-side was higher than from the contractor-side.

Table 9.5: Ranking criterion for dividing Relative Importance Index into five levels

Scale	Level of importance	Objective 1 Range of RII	Objective 2 Range of RII	Level
0 ≤ x ≤ 20%	Very high	0.923-0.835	0.511-0.558	1
20% < x ≤ 40%	High	0.834-0.747	0.559-0.605	2
40% < x ≤ 60%	Moderate	0.746-0.658	0.606-0.652	3
60% < x ≤ 80%	Low	0.657-0.570	0.653-0.700	4
80% < x ≤ 100%	Very low	0.569-0.482	0.701-0.747	5

9.9 Discussion

9.9.1 The main source of claim under rework circumstances

Rework shares a variety of common causes with claim and can be used as a trigger for claim management. Lack of claim management triggers dispute situations that usually lead to a deterioration in the quality of the party's relationship. Contract parties use the identified sources of the claim as evidence for reasoning based on the contract provisions. Nonetheless, identification of the sources of claim needs to be performed in advance to the proposing of a solution. Different singular or multiple causes may originate claims and it is critical to understand which combination of causes has made a claim (Jelodar et al., 2016). The relevant importance index of each cause listed under Objective one ranks them in terms of their influence in generating contractual claims. Therefore, a higher RII shows more probability of generating a claim from that particular source. The following section first discusses the most influential causes of rework under five categories and then provides a priority list of top causes for future investigations.

Among the six causes under the group of process-related factors, error in design and construction stands as the first rank of causes that highly trigger the generating of claims. Reviewing of the completed design to identify design errors by an expert team has been suggested to be included in the standard contract agreements (Mendis et al., 2015). Design error has been also ranked at the top of claim, dispute and conflict causes in previous studies (Kisi et al., 2020; Saseendran et al., 2020), while (Zaneldin, 2020) has ranked this cause at level 9 among 45 reviewed items in UAE. A large proportion of construction errors are raised due to mistakes in contract documentation (Dosumu, 2018) and it is interesting to note that this cause has been ranked second in the study of dispute causes in Sri Lanka (Illankoon et al., 2019). The RII of the ten rework causes under the human resources group showed that lack of experienced staff and insufficient skilled level manpower are highly generating claims. A study in Egypt also ranked interpersonal skills and construction law experience together in the second level of factors causing construction claims (Mohamed et al., 2014). With a relative importance index of 0.735, defective materials are ranked as the highest cause compared with the other four causes under the group of material/equipment-related factors. Failure to disclose the used material specification by a contractor was among 13 severe factors influencing construction contract disputes in Nigeria (Aiyewalehinmi and Nkumah, 2019).

The technical-related factor that comprises seven different causes revealed that conflicting and incomplete information can be the most influential causes in generating a contractual claim. According to (Ekhator, 2016) a lack of information and conflicting data leads to misunderstanding, and (Enshassi et al. 2009) stated that design errors arise from conflicting information; both end with claims. It has also been ascertained that rework is managed well when information is adequate with no conflictions (Oyewobi and Ogunsemi, 2010). In the last group of causes that have been clustered under the name of general/external related factors, two underlying causes - lack of constructability and time pressures - stand at the top of the list between nine causes. In the list of conflict causes presented by (Gajaman et al., 2019), a reluctance to check for constructability is categorized under consultant related factors. On the other side, time pressure is a common practice for the construction industry; however, it is almost always underestimated by construction practitioners (Palaneeswaran et al., 2007). In the study done at Nigeria (Aiyetan, 2013) time pressure ranked sixth under design related factor related to the causes of rework. In addition, time pressure is one of the variables of organizational culture that influence rework occurrence (Oyewobi et al., 2016).

9.9.2 Contract conditions in a claim incident from rework

The relevant importance index of each cause listed under Objective two ranks them in terms of being addressed adequately within NZS3910 contract conditions. The higher RII of each cause shows more contract conditions coverage that makes for a lower priority for further investigation. Therefore, items with lower relative importance indexes would have more priority for further investigation. The lower rate of RII means that specific rework causes has not been addressed adequately within the contract conditions, and it requires more study to find a solution or provide recommendations for improving relevant clauses of the contract. The initial results of this paper will be used for discussion on the clauses that can be linked to rework. Therefore, the next step of the study provides insight into contract conditions by conducting interviews with legal professionals and construction practitioners to understand how rework can be addressed in the contract to avoid conflicts.

Under the group of process-related factors, changes in design and construction "RII 0.747" are ranked highest in terms of being addressed in the contract conditions. Change also ranked the highest among all investigating causes. Therefore, it is known as one of the causes that have been covered enough under the examined contract conditions. In the study of claim causes and types in India, eight types of claim have been introduced, in which changes claim was ranked at the third level after extra work and delay claims (Al-Qershi and Kishore, 2017). Changes claims also have been identified as the most common type of claim in construction projects (Atanda and Fabi, 2015; Hansen, 2016; Zaneldin, 2020). In contrast, improper contractor and subcontractor selection with an RII of 0.529 ranked as the lowest cause. In other words, the condition of contract has, relatively speaking, addressed this cause less than other causes categorized under this group. Although selection of contractor and subcontractor has been studied adequately under rework circumstances, it seems to have received very limited studies under claim situations. A research study for reducing construction disputes through effective claim management ranked improper contractor selection at level 8 among 31 identified factors causing construction claims (Mohamed et al., 2014).

Table 9.6: Priority list of rework causes for further investigation in the general conditions of the contract NZS3910

Priority	Root causes of rework	Code	Group factor
(1)- Cluster of causes in "VII area of Fig.3"			
1	Lack of experience and personal expertise in design and construction	H1	Human resources
1	Inadequate supervision staff	H2	Human resources
1	Insufficient skilled level manpower	H4	Human resources
1	Lack of constructability	G5	General/external
(2)- Cluster of causes "VI area of Fig.3"			
2	Error in design, drawings and specifications / error in construction	P2	Process
2	Inadequate procurement methods / poor contract execution	P4	Process
2	Improper contractor and subcontractor selection	P5	Process
2	Inadequate manpower to complete the task	H3	Human resources
2	Poor knowledge of team member, lack of education and training	H5	Human resources
2	Poor workmanship approach and inappropriate personal attitude	H7	Human resources
2	Incomplete design, any omission in the design or construction process	T3	Technical
2	Inefficient management process, poor site management practice	T4	Technical
2	Inadequate planning and poor scheduling of workload	T7	Technical
2	Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	G4	General/external
(3)- Cluster of causes in "V area of Fig.3"			
3	Incomplete design, any omission in the design or construction process	P3	Process
3	Lack of document control	P6	Process
3	Lack of employee motivation and rewards, Carelessness	H6	Human resources
3	Labor reallocation, alteration and staff turnover	H9	Human resources
3	Untimely deliveries of material and equipment	M5	Material/equipment
3	Ineffective use of quality management practices / deviation due to poor monitoring	T1	Technical
3	Poor technology application and lack of information technology use	T2	Technical
3	Poor project documents, unclear instructions, poor contract documents	T5	Technical
3	Conflicting and incomplete information	T6	Technical
3	Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure	G1	General/external
3	Lack of client involvement	G2	General/external
3	Damage / defects / Deviations in the product due to poor handling and safety considerations	G6	General/external

Under human resources-related factors, conflicts of interest with a relative importance index of 0.558 are ranked the highest for referencing in contract conditions. Conflicts of interest as a root cause of rework may not be required to be assessed under claim events as most of the contract conditions cover it in their clauses (Raj et al., 2009). In contrast, lack of experience, insufficient skilled manpower, plus the absence of job security, ranked the lowest among all causes, which means that the contract conditions have not covered these root causes of rework adequately compared to the others. Most probably, incorporating these items in the contract provisions is very difficult (Jelodar et al., 2016). Two causes - experienced staff and skilled manpower - are seen in the list of most significant dispute causes in construction projects (Illankonn et al., 2019) but the absence of job security has not been evaluated under claim causes yet. Defective material, one of the main triggers of the claims under the material/equipment group, has been addressed adequately in the contract conditions with the high RII of 0.688. Previous studies also claimed that defective material accounted for 20% of non-conformance cost of projects (Josephon et al., 2002; Oyewobi and Ogunsemi, 2010). Conversely, untimely deliveries of material and equipment with an RII of 0.558 ranked as the lowest; therefore, it has priority for more investigation through the contract conditions. Late supply of material by client makes the contractor eligible for an extension of time claim (El-adaway et al., 2020). Late material delivery is very dependent on the terms and conditions of the contract when categorized under construction change order (Hansen et al., 2020).

Under the technical-related factor group of causes, the highest and lowest identified causes are "Conflicting and incomplete information" and "Poor communication system for coordinating between members" with RII of 0.670 and 0.517, in which the lowest one needs more investigation within the contract conditions. Poor information generates project uncertainties (Eze et al., 2018a) and uncertainty has been identified as one of the third main causes of claim (Jelodar et al., 2016). Previous studies also stressed that poor communication among project parties may lead to claims and conflict (Mahamid, 2016a). Poor communication has also been identified as a critical item in rework occurrences by numbers of studies (Eze et al., 2018a; Ye et al., 2015). The cause with RII of 0.670, namely, the "Unclear line of authority," is ranked the first item, and "Lack of constructability" with the relevant importance index of 0.541 is ranked the last cause under the group of general/external causes that has more priority for exploring the contract conditions. The line of authority generally lies with the role of the Engineer in the most standard form of contract worldwide in which clauses of the contract clearly make reference to them (El-adaway et al., 2016). Lack of constructability has not been listed under causes of claim in the study done by (Zaneldin, 2020) but implementing constructability during various stages of a project is one of his suggested solutions for preventing claims.

The priority list of rework causes for further investigation as the main contribution of this paper has been presented in Table 9.6. This list narrows down only to the causes that need to be focused on for the next research steps through interview. The priority list has been extracted based on the importance areas of the matrix and clustered causes with the same level of importance in three clusters.

9.10 Conclusion

The paper aims to provide basic information for further studying the relationship between rework and claims by investigating rework causes in construction contracts. Various practical works and theories have been employed to reduce or manage claims through the years, but a general agreement has yet to be reached on the relationship between the causes of rework and contractual claims. The paper explores whether the general conditions of the contract address the identified causes of rework from the literature or not. A foundation for this study was established by conducting a comprehensive literature review to identify the causes of rework in the first instance. Over the past 30 years, considerable literature has been directed to research rework issues in construction projects. Adequate sample cases using various strategies have been reported for reducing or preventing the impacts of rework globally. Content analysis of the papers revealed that a large proportion of rework studies have focused on rework root causes, explaining that a great effort has been made to understand the nature of rework. The comprehensive literature review identified 37 root causes of rework, classified into five distinct groups for further investigation. Based on the classified causes of rework, a survey questionnaire was designed and distributed to the industry to examine the relationship between identified rework causes and contractual claims, and to explore the adequacy of the general conditions of the contract in addressing rework. The identification of rework causes that affect contractual claims can assist in reducing construction disputes.

The ultimate goal of the survey was to find the most important causes of rework that have not been addressed in the contract conditions. For this purpose, after collecting an adequate number of responses on the survey, the initial analysis using the method of RII was performed to prioritise the most significant causes of rework. The performed analysis ranked rework causes in terms of not being addressed by the contract conditions of the most commonly used standard form in New Zealand “NZS3910”. This initial result showed that the general conditions of NZS3910 do not address the causes of rework adequately. As such, this exploratory study needs more empirical investigations with construction professionals to improve contract conditions. Further investigation into the clauses of the contract could be developed on the basis of feedbacks from the industry for addressing rework in contract conditions. A developed framework could enable contractual parties to manage their aspects during the handling of claims as a result of rework. Thus, the concluded result from the initial analysis of this paper will be used for the interview questions to find the solutions for improving contract conditions during rework circumstances.

The result of this paper is limited to the contract conditions contained in the NZS3910 and cannot be extended to other standard forms of contract. Also, the study may be limited by the higher number of responses from the client side compared to the contractor side. This may have the effect of skewing the results towards client perspectives. Future investigations could ensure a balanced proportion of study participants, if indeed this had any effect on study findings. Finally, the small sample size in the current study confines the generalization of the findings, but the study's contribution provided evidence that some causes of rework can quickly trigger the occurrence of a claim. Therefore, empirical testing with a larger sample accompanied with validation interviews could address these limitations.

Data availability: All data, models, and code generated or used during the study appear in the submitted article.

Table 9.7: Root causes of rework identified from the literature

Group		Rework root causes	Covered by references	∑
1	Process	Changes, modification and revisions in design / construction changes	[1,2,3,4,5,6,7,8,9,10,11,13,15,16,18,19,20,22,23,24,25,28,29,30,31,33,34]	27
2		Incomplete design, any omission in the design or construction process	[1,2,3,4,5,6,7,8,9,10,11,12,15,17,19,22,23,24,25,26,28,29,30,31,34]	25
3		Error in design, drawings and specifications / error in construction	[2,3,4,5,6,7,8,9,10,11,12,15,16,18,19,22,23,24,25,28,29,30,31,34]	24
4		Improper contractor and subcontractor selection	[4,5,6,11,12,19,21,22,25,34]	11
5		Inadequate procurement methods / poor contract execution	[8,11,15,22,23,24,31]	7
6		Lack of document control	[3,10,14,18,22,23,32]	7
7	Human Resources	Insufficient skilled level manpower	[2,3,5,6,8,9,10,12,14,16,17,19,20,21,22,23,24,25,26,27,28,29,30,32,34]	25
8		Lack of experience and personal expertise in design and construction	[2,5,6,7,8,9,1,0,11,12,14,16,17,18,19,21,22,23,25,26,28,29,30,32]	23
9		Poor knowledge of team member, lack of education and training	[2,5,6,7,8,9,10,12,14,16,17,19,20,21,22,23,24,26,28,29,30,31,32]	23
10		Poor workmanship approach and inappropriate personal attitude	[1,5,6,8,10,16,17,18,19,20,24,26,28,29,30,31,34]	17
11		Labor reallocation, alteration and staff turnover	[2,4,5,6,7,8,9,12,16,17,19,22,26,28,29,34,35]	17
12		Inadequate manpower to complete the task	[2,5,6,7,8,9,12,16,17,25,26,31,32]	13
13		Lack of employee motivation and rewards, Carelessness	[8,10,19,20,22,24,32,34]	8
14		The absence of job security and other safety rules	[8,20,22,24,32]	5
15		Inadequate supervision staff	[3,9,14,19,27]	5
16		Conflict of interest	[11,20,24,31]	4

[1] Josephson et al., 2002;
[2] Love and Smith, 2003;
[3] Robinson et al., 2004;
[4] Palaneeswarane et al., 2005;
[5] Palaneeswarane, 2006;
[6] Palaneeswarane et al., 2008;
[7] Love et., 2009a;
[8] Oyewobi and Ogunsemi, 2010;
[9] Love et., 2010b;
[10] Zhang et al., 2012;
[11] Aiyetan, 2013;
[12] Palaneeswarane et al., 2014;
[13] Hwang et al., 2014;
[14] Forcada et al., 2014;
[15] Ye et al., 2015;
[16] Miri and Khaksefidi, 2015;
[17] Ajayi and Oyeyipo, 2015;
[18] Aiyetan and Das, 2015;
[19] Mahamid, 2016a;
[20] Shah and Sharma, 2016;
[21] Ahmed and Naik, 2016;
[22] Oyewobi et al., 2016;
[23] Wilson and Odesola, 2017;
[24] Enshassi et al., 2017;
[25] Ndwandwa et al., 2017;
[26] Ajayi, 2017;
[27] Yap et al., 2017;
[28] Eze et al., 2018a;
[29] Eze et al., 2018b;
[30] Trach et al., 2019;
[31] Hwang et al., 2019;
[32] Safapour et al., 2019;
[33] Liu et al., 2020;
[34] Mahamid, 2020;
[35] Salihu and Babarinde, 2020.

Table 9.7: Root causes of rework identified from the literature

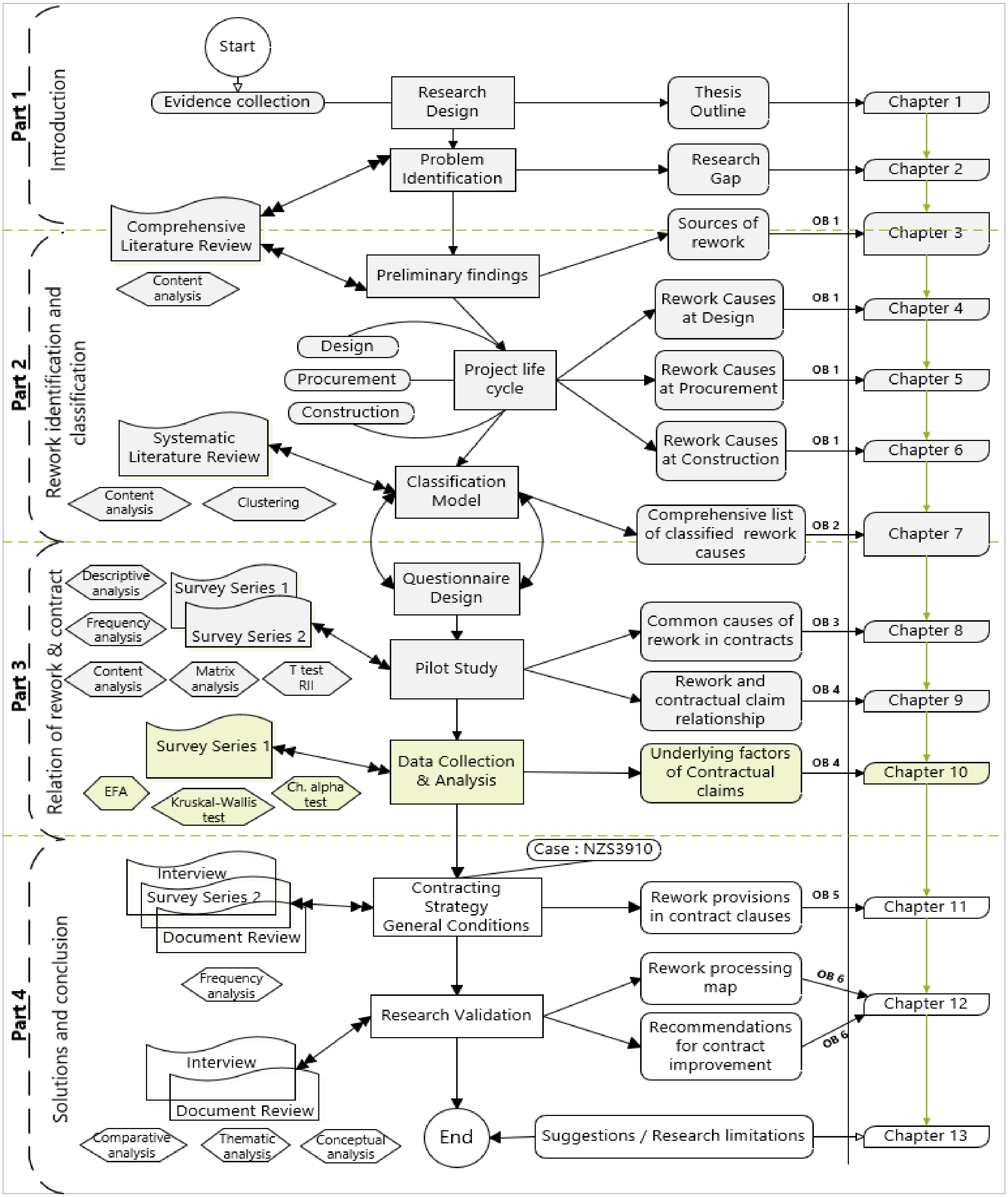
Table 9.7: Continue

Group		Rework root causes	Covered by references	∑
17	Material & Equipment	Poor-quality material or substandard products / Prefabrication errors	[1,2,4,5,6,8,9,11,12,15,16,17,18,19,20,25,26,31,32,33]	20
18		Defective materials, Non-adherence to material specifications	[1,3,8,10,11,13,14,15,18,20,24,25,27,31,32]	15
19		Inefficient equipment uses or altered material	[1,10,15,19,20,24,25,27,33,34]	10
20		Replacement or misplacement of material and equipment	[1,10,14,15,20,24,28,29,30,31]	10
21		Untimely deliveries of material and equipment	[1,3,8,10,20,24,25]	7
22	Technical	Poor communication system for coordinating between members	[1,2,5,6,7,8,9,10,11,12,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,	31
23		Ineffective use of quality management practices / deviation due to poor monitoring	[2,3,4,5,6,7,8,9,10,11,12,14,15,16,18,19,20,22,23,24,25,27,28,29,31,32,33,35]	28
24		Inadequate planning and poor scheduling of workload	[1,2,3,4,5,6,7,8,9,10,11,12,14,16,17,18,19,20,22,23,24,25,26,28,29,30,33,35]	28
25		Poor project documents, unclear instructions, poor contract documents	[2,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,22,23,24,25,26,27,28,29,30,31,33]	27
26		Conflicting and incomplete information	[1,3,5,6,8,9,11,14,15,16,17,18,19,20,22,23,24,25,26,28,29,30,33,35]	24
27		Inefficient management process, poor site management practice	[3,8,10,11,12,13,14,15,16,17,18,19,22,24,25,26,27,28,29,31,32,33,34]	23
28		Poor technology application and lack of information technology use	[2,4,5,6,7,8,9,11,12,15,16,17,18,23,24,26,27,28,29,30,35]	21
29	General/External	Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure	[2,3,5,6,7,8,9,11,12,13,15,16,17,18,19,20,21,22,24,25,26,28,29,30,31,32,33]	27
30		Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	[2,3,5,6,7,8,9,11,12,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,35]	27
31		Damage / defects / Deviations in the product due to poor handling and safety considerations	[2,4,5,6,7,8,9,11,12,15,16,17,18,19,22,26,28,29,31,34]	20
32		Environmental conditions, poor site condition	[5,6,8,15,17,19,20,22,24,26,27,28,29,31,32,33,34]	17
33		Lack of client involvement	[2,5,6,7,8,9,11,12,16,17,19,21,25,26,28,29,30]	17
34		Lack of constructability	[3,5,6,15,17,20,23,24,26,28,29,31]	12
35		Governmental regulations / changes and policies	[15,20,24,31]	4
36		Unclear line of authority	[20,24]	2
37		Unpredictable factors from different sources	[8,15]	2

9.11 Epilogue

This chapter examined the relationship between rework and contractual claims using the Relevant Importance Index and matrix analysis. The initial review showed that both rework and claims could be raised from the same sources, so the direct relationship between rework and claims was identified. Thus, investigating the effects of rework on contractual claims leads to identifying rework provisions in the contract conditions. From the findings of this chapter, it can be noted that improving the contract conditions will require more attention only to the causes of rework that affect construction contracts while have not been addressed adequately in the contract clauses. For this purpose, New Zealand construction practitioners were asked to share their opinion through a survey questionnaire if they use NZS3910:2013 as their main contract. The results showed that 26 items out of 37 previously identified rework causes through the literature prioritize further studying as they are placed in the high-ranked area of the matrix. The results also provided three clusters of causes in terms of their importance which can be considered in the next research steps. The results of this chapter and chapter eight as the common causes of rework in construction contracts are used to identify underlying factors of contractual claims. It allows construction practitioners to benefit from both rework and claims management simultaneously, which can significantly improve contract conditions. The connections between rework causes and clauses of the contract are targeted to be achieved in the following steps through conducting interviews. The next chapter presents the underlying factors of contractual claims by performing the factor analysis.

Thesis-at-a-Glance / Chapter 10



Chapter 10. Analyzing underlying factors of contractual claims raised from rework in construction contracts

10.1 Prologue

The fourth objective of this research is to understand how rework affects construction contracts to find the weakness of the contract conditions for improvement. The initial assessment of NZS3910:2013 and the effects of rework on generating contractual claims in the previous chapter revealed a direct relationship between rework causes and contract clauses. Various causes of rework may generate different contractual claims, and each claim may refer to multiple clauses and provisions of the contract. Thus, this chapter analyzes the underlying factors of contractual claims to improve the contract conditions by performing exploratory factor analysis. The chapter starts with a literature review on the causes of rework in construction contracts and then explores construction practitioners' opinions about the causes of rework in generating contractual claims. Factor analysis reduces the number of causes, so assessing the contract's relevant clauses will be more concentrated by referencing contractual claims' underlying factors. The usefulness of this reduction lies with their abilities to enhance our understanding of how contract conditions are affected by contractual claims and rework. More discussion on the result of this analysis is presented at the end of this chapter.

This chapter is based on the following Journal paper:

Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Analyzing underlying factors of contractual claims raised from rework in construction contracts. *Journal of Construction Engineering and Management (*ASCE). ID: COENG-12141.

10.2 Abstract

The enhancement of the contractual claim process in construction projects upgrades the relationship of the parties and reduces conflicts and disputes so, it is critical to the success of contracts. The previous studies related to contractual claims are primarily focused on the general causes of claims, and relatively little attention has been paid to rework causes in claim handling. Given the causal relations of rework and the increasing rate of contractual claims and disputes in construction projects, the necessity to implement rework management has become more critical. Although the effects of rework have led to claims and disputes, a quantitative approach has not been undertaken to analyse the relationship between rework causes and contractual claims. This study seeks to identify the key rework causes requisite for claims and aims to categorise the direct causes of rework in generating contractual claims based on the contract conditions. Therefore, it apprises the correlative rework causes and contractual claims. A quantitative approach involving survey research was used as a means of data collection. Based on a review of the literature, a comprehensive list of rework causes was developed as a questionnaire, and the results were then analysed using the exploratory factor analysis method. The results provide evidence of the construct validity of the rework to measure the four distinct dimensions of contractual claims: Human Resources, Material and Equipment, Management and Planning, and Process. This study bridges the knowledge gap of dimensionality between rework and contractual claims, which can create measures that address the causes of rework in terms of contractual claims. The paper suggests that rework management could reduce contractual claims through attention to rework causes at the early stages of contracting.

10.3 Introduction

The high rate of contractual claims in construction projects requires attention before turning to the dispute. Contractual claims are generally associated with adverse effects to the construction projects and are also cause for delays in the project completion time. It leads to loss of profit and it acts as a substantial expense to the projects. Evidence suggests that the global average value of disputes in 2019 was 30.7 million USD, and the average length of dispute for the construction projects was 15 months (Arcadis, 2020). Three main reported reasons for disputes in the Arcadis statement (2020) included poorly drafted and incomplete claims, failure to extend time and compensation, and failure to understand the contractual obligations. Disputes that arise in any contract type, and the level of active disputes in the construction stage of the project affect the level of project performance (Soewin and Chinda, 2018). Organisations need to deal with the issues raised around conflict either through an internal agreement or other means of dispute resolution. Without the knowledge of the structure of contractual claims, the improvement of contracts is difficult. Considering the complexity of projects in terms of contract administration, the claims handling process should be able to improve the condition of the contract to attain better outcomes such as lower disputes. The improvement of contract conditions can be achieved through a clarity of the clauses which need to be fitted together logically and follow a correct procedure and process (Broome and Hayes, 1997).

Rework is one of the contributing causes of contractual claims. Effective rework management has been recognised as an appropriate strategic method to achieve the required performance of construction projects as it deals with the key underlying elements of cost, time, quality, and safety (Zhang et al., 2012; Ma et al., 2019a; Eze and Idiake, 2018a; Liu et al., 2020). Even though the negative impact of rework on contractual claims has been emphasised in previous research (Ajayi and Oyeyipo, 2015; Palaneeswaran et al., 2008), no evidence has been established to show the relationship between rework causes in the contract conditions. Rework incorporates risk by its nature and disputes can occur if the allocation of risks is unclear (Besaiso et al., 2018). Rework is positively linked with a raised level of contractual claims. In other words, if rework can be reduced, then a lower rate of contractual claims can be achieved. Thus, the common causes of rework in construction contracts for further assessment of the contractual claims need to be identified and categorized. This study researches the root causes of rework in contractual claims as a prerequisite to the improvement of contract conditions. Except for a few studies that confirm the positive relationship between rework and contractual claims (Love and Edwards, 2004a), most of the previous research has studied these two phenomena separately. The combination as the best factor-set between the two is still unknown, and the underlying dimensions of rework-claim situations have not yet been established.

The need to reduce generated contractual claims among different contract conditions has encouraged various research studies. As a result, some solutions have been advised to manage trending to fewer disputes. For example, providing better communication with trust will improve the relationship of the parties as it has effect on the method of dispute resolution (Gad et al., 2016). Despite the importance of procurement strategy in enhancing project performance (Love and Edwards, 2004b) most rework research has concentrated on design and construction. Therefore, the decisions to adopt rework reduction or prevention are usually taken during the design and construction stages. Consequently, the procurement stage is left without practical decisions for rework management. Overall, there is a lack of consideration regarding rework and construction waste minimisation in the contract (Ajayi et al., 2017). The knowledge gap here is the extent to which the causes of rework influence claim outcomes, such as disputes. Developing a framework that combines rework causation in contractual claims to uncover the underlying factors is a requirement. This study fulfills this gap by extracting the underlying intentions involved with the causes of rework-claims via the following objectives:

1) The identification of rework causes that generate contractual claims
2) Exploring the underlying factors of rework management for better claim handling

The structure of standard contracts in construction projects focuses more on the goal of the contractual party than the project (Harper et al., 2016), while the relational contracts more likely follow a project integration approach (Jelodar et al., 2016). The use of contracts to prevent part of the key causes of rework will significantly reduce time and cost overruns (Ajayi et al., 2017) and contractual claims (Jalali and Moharreri, 2020). Thus, the most common causes of rework were identified through a review of the literature and then put in a questionnaire survey for further factor analysis. In the context of construction management studies, the questionnaire survey has been used widely to rank relevant variables (Yap et al., 2020). To explore rework causes in the mitigation of contractual claims, a quantitative method was employed in this study. The study aims to evaluate the causes of rework related to contractual claims in the construction contracts by conducting an exploratory factor analysis. In this study, the technique of factor analysis is used to explore the underlying factors of the 24 rework causes that generate contractual claims. Factor analysis is a technique for data reduction and summarising the results if there are multiple relationships between the variables (Yap et al., 2018).

10.4 Literature review

The essential rule for the effective evaluation of rework management in construction projects is considering the sources of rework and reviewing its causes. Although reviewing rework causes may take time in the contracting process, it will save a significant amount of cost and time during construction. Rework management in construction contracts also improves the design process and it will result in fewer construction contradictions. Rework management is a technique for reviewing the causes of rework to reduce or prevent errors and omissions that improves the performance of projects. In terms of rework management as it relates to the performance of projects, it is necessary to consider rework causes in the early stages of the project. Rework management would be more effective if it begins at the initial planning phase of the project. Many problems and issues in the construction stage can be identified before starting the project by conducting good communication among contractual parties at the procurement stage of the projects.

Procurement strategy plays a crucial role in better managing construction projects, especially as it relates to the control of the relationship between the parties (Windapo and Adediran, 2017). Litigation is a common practice in construction projects due to the adversarial nature of the relationship in the construction industry and the tendency for conflicts and disputes (Soewin and Chinda, 2018). Contractual claims are generated due to the various interpretations of the contract clauses among the parties involved (Moza and Paul, 2018). Contractual claims in construction projects are inevitable particularly if the claims result in delays and cost overruns (Lee et al., 2020). Generally, the claims involve a request for an additional payment on the part of the contract over and above the agreed upon cost based on the contact conditions (Banwo et al., 2015). The claim handling process for resolving disputes among contract parties is crucial in selecting the method of dispute resolutions (Assaad et al., 2020). Although claim management cannot be assessed in isolation, some relationships have been recognised between project performance and contract conditions with the means of rework. A study to investigate knowledge modeling for contract disputes asserted that inadequate contract documentation results in rework and variations that decrease the performance of projects (Wang et al., 2019). According to Jalali and Moharreri (2020), an inappropriate contract is the key cause of contractual claims and disputes that lead to poor project performance in terms of time and cost overruns. This finding verifies earlier findings by Sorde and Sawant (2015) that emphasised the requirements to change some of the clauses in the general contract conditions to improve the cost performance. Studies across the nations show similar indications regarding the importance of contract documentation as it relates to rework (Wang et al., 2019; Mendis et al., 2013; Mohamad and Madon, 2006). Freezing the contract clauses that deal with design is one strategy that reduces waste and reworking in construction projects (Ajayi et al., 2017). Thus, understanding the underlying causes of rework that improves claim management in construction contracts is an important aspect that will help to enhance the performance of projects.

Love and Smith (2003), in the article titled, Rework Mitigation in Projects qualitatively introduced the causes of rework in construction projects. Since then, most other studies have referred to these identified causes or add to it, and very few have proposed a comprehensive list in their studies. In another study in Canada (Robinson et al., 2004), the details of rework causes were examined to develop a standard methodology for measuring and classifying field rework in construction projects. Then the role of the supply chain and its effects on rework was evaluated by (Taggart et al., 2014a). The key to reducing the impacts of rework was then studied recently to present the rework concept, history, and the new methods involved in implementing rework management best practices (Safapour and Kermanshachi, 2019). A lack of attention to reworking management in the contract stage has been identified as a problem during construction (Asadi et al., 2021b). However, while rework has been researched in previous studies; up until now, the comprehensive quantitative approach has not been employed to analyse the causes of rework in generating contractual claims in the contracting process. The pertinent causes of rework that potentially affect the risk of contractual claims were explored by conducting a systematic background review (Asadi et al., 2021a). After reviewing all related studies, the most common causes of rework in construction projects have been summarised in Table 10.1 (Asadi et al., 2022).

Table 10.1: The common causes of rework in construction contracts

No.	Rework cause	References
RC1	Changes, modification and revisions in design / construction changes	Mahamid, 2020; Ye et al., 2015
RC2	Error in design, drawings and specifications / error in construction	Hwang et al., 2019; Oyewobi et al., 2016
RC3	Incomplete design, any omission in the design or construction process	Enshassi et al., 2017; Palaneeswarane et al., 2014
RC4	Inadequate procurement methods / poor contract execution	Hwang et al., 2019; Ye et al., 2015
RC5	Improper contractor and subcontractor selection	Mahamid, 2020; Aiyetan, 2013
RC6	Lack of document control	Safapour et al., 2019; Forcada et al., 2014
RC7	Lack of experience and personal expertise in design and construction	Love et al., 2010b; Mahamid, 2016a
RC8	Inadequate supervision staff	Yap et al., 2017; Mahamid, 2016a
RC9	Inadequate manpower to complete the task	Hwang et al., 2019; Palaneeswarane et al., 2014
RC10	Insufficient skilled level manpower	Yap et al., 2017; Zhang et al., 2012
RC11	Poor knowledge of team member, lack of education and training	Ajayi, 2017; Forcada et al., 2014
RC12	Poor workmanship approach and inappropriate personal attitude	Mahamid, 2020; Josephson et al., 2002
RC13	Defective materials, Non-adherence to material specifications	Yap et al., 2017; Aiyetan, 2013
RC14	Poor-quality material or substandard products / Prefabrication errors	Liu et al., 2020; Love et al., 2010b
RC15 *	Untimely deliveries of material and equipment	Enshassi et al., 2017; Zhang et al., 2012
RC16	Ineffective use of quality management practices / deviation due to poor monitoring	Liu et al., 2020; Mahamid, 2016a
RC17	Poor communication system for coordinating between members	Hwang et al., 2019; Ye et al., 2015
RC18	Inefficient management process, poor site management practice	Yap et al., 2017; Mahamid, 2016a
RC19	Poor project documents, unclear instructions, poor contract documents	Liu et al., 2020; Hwang et al., 2019
RC20	Conflicting and incomplete information	Enshassi et al., 2017; Ye et al., 2015
RC21	Inadequate planning and poor scheduling of workload	Ajayi, 2017; Love et al., 2010b
RC22	Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	Oyewobi et al., 2016; Ye et al., 2015
RC23	Lack of constructability	Hwang et al., 2019; Palaneeswarane et al., 2008
RC24 *	Damage / defects / Deviations in the product due to poor handling and safety considerations	Mahamid, 2020; Oyewobi et al., 2016

10.5 Methodology

At the early stage of the research, the literature review method was carried out to identify the common causes of rework. This approach was selected due to the potential of reducing contractual claims in the studies that are not addressing rework management. Consequently, a comprehensive list of rework causes was used to prepare the questionnaire. The survey question was designed based on the list of rework causes extracted from the literature review. A list of 24 rework causes was combined as the common causes of rework in construction contracts, and a Likert-scale online survey questionnaire was developed due to the exploratory nature of the study. Before sending the questionnaire out to collect the data, a pilot study was conducted with four respondents, this included two from academia and two from the construction industry. The feedback from the pilot study was implemented into the questionnaire. The questionnaire was distributed electronically through a survey link to a range of construction companies, clients, consultants, lawyers' firms, and builders active in the field of construction that use the standard form of contract in their projects. This combination of respondents maximises the quality of information from a wider perspective. The survey instrument used a five-point scale with causes ranging from 1 (strongly disagree) to 5 (strongly agree). The participants in the survey were from diverse areas and included owners, contractors, builders, consultants, and lawyers, all of whom had experience using the standard form of contract. A total of 560 survey links were distributed by email with a reminder follow-up email to the none-respondents after a month. Over a period of six months, 162 (29%) responses were collected using Qualtrics software. The response rate is slightly near 30 percent which is higher than the required free parameter ratio to propose a reliable solution, and statistical analysis based on such a rate would be reliable (Yap et al., 2020).

The six professional bodies in New Zealand were used as the main source to identify the active companies in construction projects including Civil Contractors New Zealand “CCNZ”, Association of Consulting and Engineering “ACENZ”, Infrastructure New Zealand, New Zealand Certified Builders “CBNZ”, New Zealand Institute of Building “NZIOB” and, New Zealand Construction Industry Council “NZCIC”. Out of the collected data from the respondents, 38 participants did not respond to all questions, and they were dropped from the data analysis. Thus, 124 completed questionnaires were used for the data analysis, which exceeded the minimum of 100 respondents for such analysis (Xiong et al., 2014). The respondents were only allowed to take the survey based on two main sampling criteria: (1) considering the questions from the client-side of the contract (2) or, from the contractor-side of the contract. Table 10.2 provides more information about the respondent’s background. The job role and experience of the participants varied widely. Of the respondents, nearly 77 percent have been in construction for more than 20 years and 66 percent have experience in contracting for more than 10 years. These qualifications are considered sufficient to have an acceptable judgment from qualified people in the relevant field for such studies of an exploratory nature.

10.6 Analysis and results

To identify the underlying factors of rework involved in the contractual claim process, factor analysis was carried out on 24 causes of rework in several steps of the test for the suitability of the data, the extraction of factors, and for rotations. The obtained results from the survey were then analysed through the exploratory factor analysis “EFA” method to cluster the correlated rework causes into fewer underlying factors that are easier for interpretations. Exploratory factor analysis is a method of discovering patterns to build multidimensional constructs by reducing the observed variables into fewer factors. EFA is employed in this study because the underlying structure of the relations between the rework causes and the extracted factor on the contractual claims have not been established in previous research. This method detects hidden structures in the data and generates constructs that can be used for developing measurement scales (Jadidoleslami et al., 2018). This study uses IBM SPSS Statistics, version 26 to perform EFA to categorise the causes of rework that generate contractual claims.

Table 10.2: Respondents and background information of their organisation/project

Description		Sample size	% of respondents	Notes
Profession/job roles of participants				The total of 124 participants
	Project Director/Project Manager	41	33.1%	
	Construction/Site Manager	6	4.8%	
	Commercial/Contract Manager	16	12.9%	
	Quantity Surveyor	22	17.7%	
	Others	39	31.5%	
Year of experience in construction				Predominantly over 20 years
	Less than 10 years	30	24.2%	
	Between 10 and 20	36	29%	
	More than 20	58	46.8%	
Contract experience				Predominantly over 10 years
	Less than 5 years	28	22.6%	
	Between 5 and 10	14	11.3%	
	More than 10	82	66.1%	
Type of organisation				
	Design and Architect	21	16.9%	
	Project Management	15	12.1%	
	Construction	49	39.5%	
	Design and Built	9	7.3%	
	Others	30	24.2%	
Value of the involved projects				Mostly less than 50 Million NZD
	Less than 50 Million NZD	91	73.4%	
	Between 50 and 100 Million NZD	11	8.9%	
	More than 100 Million NZD	22	17.7%	
Contract sides				Nearly equal share of contract parties
	Client	57	46%	
	Contractor	67	54%	

10.6.1 Exploratory factor analysis

In advance to run the EFA, the correlation among all the causes was examined to find which items are interrelated. Using two scree plots and principal component analysis methods led to the extraction of the initial number of factors. The value for identifying the significance in the level of factors greater than 0.3 was selected (Harper et al., 2016), and during the test, the Eigenvalue of one was fixed as the usual cut-off criterion for extracting the numbers of factors (Ye et al., 2015). However, there is no cut off rule for such interpretation of the loading factors; for example, the loading factor of 0.4 and 0.45 has been considered in other studies (Olanipekun et al., 2017; Ma et al., 2020). The low magnitude less than 0.30 and the cross-loading causes one at a time were removed (Mazzurco et al., 2020), and then the internal consistency of the appeared factors was evaluated through Cronbach's alpha. The Cronbach's Alpha test was used to validate the consistency of the questions and the sustainability of the data for further analysis. This test is advised if a Likert scale is used in the questionnaire (Ajayi et al., 2017). For the Cronbach's Alpha value greater than 0.7, questions show an acceptable level of reliability. If the α coefficient does not exceed 0.6, the internal consistency reliability is generally considered insufficient (Ma et al., 2020). Using SPSS, the test showed the coefficient of 24 causes before rotation was 0.919, which is higher than the acceptable criteria. Since the questionnaire is based on collected data from two sides of the contract, the client and the contractor, the Kruskal-Wallis test was also performed to evaluate respondents' different categories. If the p-value of this test is less than 0.05, no significant differences are among the groups of participants. The result of the test showed, the p-value for almost all rework causes is more than (sig.) value ranged from 0.063 to 0.890, except for one item as shown in Table 10.3 and therefore there are no differences between the two groups, in answering the questions for the 24 causes of rework in generating contractual claims.

The process of EFA includes examining correlations and variances to determine which cause functions better and how the data is structured. It also depicts which cause measures the same underlying variables, and finally, it discovers the relationship between variables (Mazzurco et al., 2020). Therefore, it is an approach to find the common factors and is used to identify newly developed scales. Furthermore, it determines how well a particular cause aligns with factors, so it allows removing any cause that does not belong to the factor to reduce overlapping variables and improve the quality of the final tool (Ye et al., 2015; Juhari and Arifin, 2020). Before starting analysis by EFA, a test was required to verify that the collected data is adequate for running factor analysis. Therefore, the Kaiser-Meyer-Olkin (KMO) was performed to ensure that sampling is enough. The KMO measures sampling adequacy by estimating the extent to which a factor analysis would provide reliable results (Mazzurco et al., 2020). Using SPSS, the result of KMO test indicated the value of 0.840, exceeding the acceptable criteria of 0.5 (Ye et al., 2015; Jadidoleslami et al., 2018) for satisfactory factor analysis. This rate confirms that the causes in the questionnaire have enough factors in common for running a factor analysis. In addition to that, the Bartlett Sphericity test was conducted to prove the eligibility of the data. The result of this test was significant as the p-value showed (Sig. 0.000), which is less than 0.05 (Juhari and Arifin, 2020). This evidence suggested that the sample size was adequate to conduct EFA for extraction relevant factors (Yap et al., 2020).

Table 10.3: Result of Kruskal-Wallis test for the causes of rework

Rework cause "Variable"	Group	N	Mean Rank	P- value (Sig.)
Ineffective use of quality management practices / deviation due to poor monitoring	Client-side	57	70.54	0.015
	Contractor-side	67	55.66	

Factor analysis allows measuring the ratio of one cause's unique variance to its shared variance, known as its commonality. Table 10.4 also shows the commonality of each cause to report how much variation of the causes will be illustrated by the latent factors, the usual range for this is between 0.4 to 0.7 (Mazzurco et al., 2020). None of the communal loadings are less than 0.4 and more than 0.9; thus, no multilinearity exists (Olanipekun et al., 2017). The factors then were further rotated through the Varimax method for easier interpretation, and the value of 0.3 rotation was set as a minimum load factor analysis (Umar et al., 2019). The first rotation showed seven causes had cross-loaded over three components or over 75% that need to be eliminated as items should not cross too highly between factors (Harper et al., 2016). The cause that had the lowest loading factor was removed, and analysis was re-run. In total, five causes were loaded in more than two components significantly and one over 75% cross-loaded. Thus, six causes were removed from the final list to avoid disruption in the proposed solutions. RC5, RC6, RC16, RC19, RC20, RC23 are the removed causes.

The process of component matrix rotation left 18 causes with factor loading ranged from 0.540 to 0.902 clustered into four components shown in Table 10.4 with a total variance of 63.80 percent - minimum of 60 percent is adequate for the validity of the constructs (Yap et al., 2018). The scree diagram also showed the same result in which the curve is flattened after the fourth component. The title for each component can be selected based on the highest factor loading or a general term that represents the variable concepts (Yap et al., 2018). Each component has been given a label to indicate its contents. With consideration to the E-value and percentage of variances in each component, the following order indicates the importance of underlying group factors. They were Human Resources, Material and Equipment, Management and Planning, and Process factors. Of these causes, six items loaded on component 1, four loaded on component 2, 3 and 4. The conceptualisation of these factors has been discussed further in the discussion section of this paper. The Cronbach Alpha was calculated for each construct to assess the scale's reliability, which needs to be at least 0.7 (Harper et al., 2016). This test for the items within each factor was higher than this criterion. Thus, all components can be taken into consideration as the final list of rework causes in generating contractual claims.

Table 10.4: Component labels, factor loadings, criteria and communality in final rotation of EFA

Factors	Factor loading	Eigen Value	Variance %	Cronbach's alpha	Communality
Component 1: Human Resources factor		**6.31**	**35.08%**	**0.851**	
Insufficient skilled level manpower	0.786				0.684
Inadequate manpower to complete the task / Staff turnover	0.774				0.618
Inadequate supervision staff	0.763				0.630
Poor knowledge of team member or lack of education and training	0.736				0.695
Poor workmanship approach and inappropriate personal attitude	0.624				0.566
Lack of experience and personal expertise in design and construction	0.540				0.450
Component 2: Material and Equipment factor		**2.00**	**11.10%**	**0.849**	
Poor-quality material or substandard products / Prefabrication errors	0.902				0.645
Defective materials, Non-adherence to material specifications	0.866				0.806
Damage / defects / Deviations in the product due to poor handling and safety considerations	0.668				0.625
Untimely deliveries of material and equipment	0.624				0.560
Component 3: Management and planning factor		**1.76**	**9.80%**	**0.797**	
Poor communication system for coordinating between members	0.792				0.679
Inadequate planning and poor scheduling of workload	0.726				0.639
Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	0.698				0.558
Inefficient management process and poor site management practice	0.697				0.682
Component 4: Process factor		**1.41**	**7.82%**	**0.762**	
Incomplete design, any omission in the design or construction process	0.860				0.769
Changes, modification and revisions in design or construction changes	0.756				0.582
Error in design, drawings and specifications / error in construction	0.726				0.640
Inadequate procurement methods / poor contract execution	0.607				0.456
Cumulative % of variance			**63.80%**		

10.7 Discussion

The factor loadings determine that rework management provides a meaningful approach within claim handling, which is affected by four predictor dimensions. It offers a potential improvement in the contract conditions where factors highly positively are influencing contractual claims. The following four factors adequately summarize the larger data set of 24 rework causes and could be classified as the most common components required for improving the condition of contracts for better management of contractual claims. Significant rework causes with higher coefficient values have emphasised the improvement of the human resource process. Due to the undeniable benefits of rework management, categorising these causes provides an opportunity to check unforeseen problems in advance of the construction commencement; thus, solutions can be proposed during the contracting stage. This group of factors provides ground for developing a model for better contractual claims handling and the assessment of its process. The results also have provided future study directions such as improving the contract conditions and performing contractual claims to reduce disputes. The underlying factors of contractual claims generated from rework causes are discussed reference to the relationships shown in Figure 10.1.

10.7.1 Human resources factor

The first component has the highest total variance of 35.08 percent, explaining the most critical rework causes related to human resources attributes. The highest percentage in this group is indicating the degree of importance of their causes in generating contractual claims. This factor is explaining the significance of skilled and experienced professionals in construction contracts. The component is created by inadequate supervision staff, inadequate manpower, insufficient skilled, poor knowledge of team members, and poor workmanship approach, with factor loading ranging from 0.540 to 0.786. This group of causes suggests that contractual claims cannot be minimized without considering the human resources potentials. Human resources management in construction projects is challenging (Yap et al., 2020) as personal attitudes such as the lack of contractual knowledge can significantly affect rework and claims (Wang et al., 2019). This further reinforces the importance of human resources as a key solution for effective claim management (Jalali and Moharreri, 2020; Seo and Kang, 2020). Originally ten causes were in the human resources factors in pre-grouping suggested by the literature of rework studies; however, six are contributed to a component after running factor analysis. The importance of staff and supervisory knowledge has been confirmed in the other field of construction studies. Training is one of the proposed solutions for improving supervisory skills (Juhary and Arifin, 2020). Lack of supervision provides ground for labors falling into activities that may need to be redone (Love et al., 2019b). Improper supervision is ranked second in the study done in Malaysia on the relation between rework and safety (Yap et al., 2020). Other studies also have claimed that supervisory weakness have a direct link to the variations, contractual back charge and claims (Kisi et al., 2020; Banwo et al., 2015; Sorde and Sawant, 2015). The construction industry relies on labor-intensive construction methods. Low-quality workmanship is also one of the issues in recruiting human resources as the available labor in New Zealand is declining in skills and experience (Lessing et al., 2017). Yap et al. (2020), looked at staff turnover as a moral problem and claimed that labor turnover and absenteeism result in productivity loss.

10.7.2 Material and equipment factor

This component accounts for the second-highest variation of 11.10 percent and contains four causes to bring attention to the importance of material and equipment as the critical rework causes. This group comprises four causes with factor loadings from 0.624 to 0.902. It requires selecting a standard material, on-time delivery of material and equipment, removing damage and defects. In addition to selecting the right material, this underlying component requires the substantial use of the material in construction activities. Related items to material and equipment result in rework and contractual claims that generally add more cost to the project. This group of causes have also been discussed in the number of previous reworks, claims and disputes studies (Zhang et al., 2012; Kisi et al., 2020; Moza and Paul, 2018). Material and equipment, including machinery and facilities contributing to 56 percent of incidents at construction projects (Juhari and Arifin, 2020). Depending on the project's situation, clients may ask the contractor to replace a cheaper material, which sometimes causes redesigning work (Yap et al., 2018). Furthermore, late delivery of on-site materials may change work sequences that ultimately cause claims (Aulia et al., 2012; Oyewobi et al., 2016). Effective planning, and on-time delivery are some of the solutions that prevent rework and improve the process of claim handlings (Hwang et al., 2019). An effective material control process begins with a robust QA plan that continues to the end of the project is a good strategy of contracting management (Wang et al., 2019) to overcome issues raised from this component.

10.7.3 Management and planning factor

This component is titled management and planning due to a combination of four causes that contribute to the strategic level of projects with factor loadings from 0.697 to 0.792. This group of causes accounted for 9.80 percent of the total variance, making it the third most important component. The aspects of this factor mainly concern communication, site management, scheduling of workload, and time pressure. It suggests that improved claim management requires planning at different stages of the project to reduce the potential for delay in projects and its subsequent effects (Wright and Fergusson, 2009). Insufficient communication has been ranked the highest in the study of links between rework and safety (Yap et al., 2020). Untimely communication and communication in the wrong ways result in mistaken information exchanges

(Love et al., 2014). An overview of the causes of rework under this component shows that miscommunication and lack of coordination among designers and contractors and site management play a major role in claim handling. The number of variations and contract changes has been increasing through the last few years in New Zealand due to the lack of leadership by the client and poor communication between management and site (Lessing et al., 2017). Good communication among parties requires a collaborative teamwork, it is known as the most critical factor in construction contract administration (Gunduz and Elsherbeny, 2020) and it is an important element of construction relationship quality (Jelodar et al., 2016). A study to provide a model for claims reduction showed that communication is necessary for preventing claims as it plays a mediator role in the relationship between parties (Jalali and Moharreri, 2020). Poor coordination is also ranked in the third level in studying the relationship between rework and site incidents in Malaysia (Yap et al., 2020). This coordination of projects mostly involves activities for delivering information and its relevant issues among all professionals in the project (Yap et al., 2017). The effectiveness of communication is also affected if various subcontractors with different levels of knowledge are involved in the projects (Ye et al., 2015) that result in reworking. Multi-layer subcontracting contributes to one-third of NCRs, which would be challenging in coordination (Yap et al., 2020). Unrealistic scheduling of workload on the other side may result in time pressure. Delays, disruptions and interferences mostly contribute to subcontractors' scheduling during the preparation process (Assaad et al., 2020). Time pressure generates mental stress and physical tiredness which may reduce the performance of projects due to worker mistakes and errors (Love and Smith, 2018).

10.7.4 Process factor

The fourth component of contractual claims is process management that integrates four causes of rework with a total variance of 7.82 percent, emphasising the criticality of the design stage in construction projects. The main concept within this component are changes, errors and omissions, incomplete design and procurement strategy, and the loading factors are between 0.607 and 0.860. The title of this group based on the contents of the underlying causes is “process management”. These reasons directly link to the main process of work that will result in rework and then contractual claims. Thus, this component advocates the need for more control at the process level as an underlying solution for claim handling and dispute avoidance. Adhering to the right process in design management avoids unwanted extra costs from dispute-related claims (Kim and Skibniewski, 2020). Error is another crucial issue in construction contracts (Dosumu, 2018). This is aligned to the recent study by Gunduz and Elsherbeny (2020) that observed a positive relationship between rework and risk of design in contracting management. The unclear scope of work which is not defined at the early stages of the project derives variations to the contract (Lessing et al., 2017). Findings from the other researchers also show that causes under process factors such as changes, and errors are among the significant explanations for the claims and disputes (Jelodar et al., 2016; Zaneldin, 2020). Some of the claims and disputes are linked to the variation clause. Variation is part of the contract conditions that generally deal with change orders initiated from different sources (Besaiso et al., 2018). Rework also has a direct relationship with change orders, so the clearer regulations in such cases prohibit grounds for the future disputes. Removing these issues requires the early involvement of contractors in the design stage. It also requires more awareness from the perspective of the design team regarding the project plan and constructability. Some of the problems related to rework under process factors has to do with the incomplete design drawings. This generally generates delay in the construction process and it can result in grounds for disputes (Jelodar et al., 2016). There are often small delays in design activities where contractors are waiting to get answers or waiting for more detailed designs. These time delays are not accounted for in the contract (Lessing et al., 2017) and can result in disputes about who's responsible for such delays and this can also increase the project cost. Addressing these rework causes at the early stages of a project will reduce contractual disputes (Jadidoleslami et al., 2018). Furthermore, an appropriate procurement strategy results in a good flow of information that ultimately reduces rework and leads to fewer contractual claims.

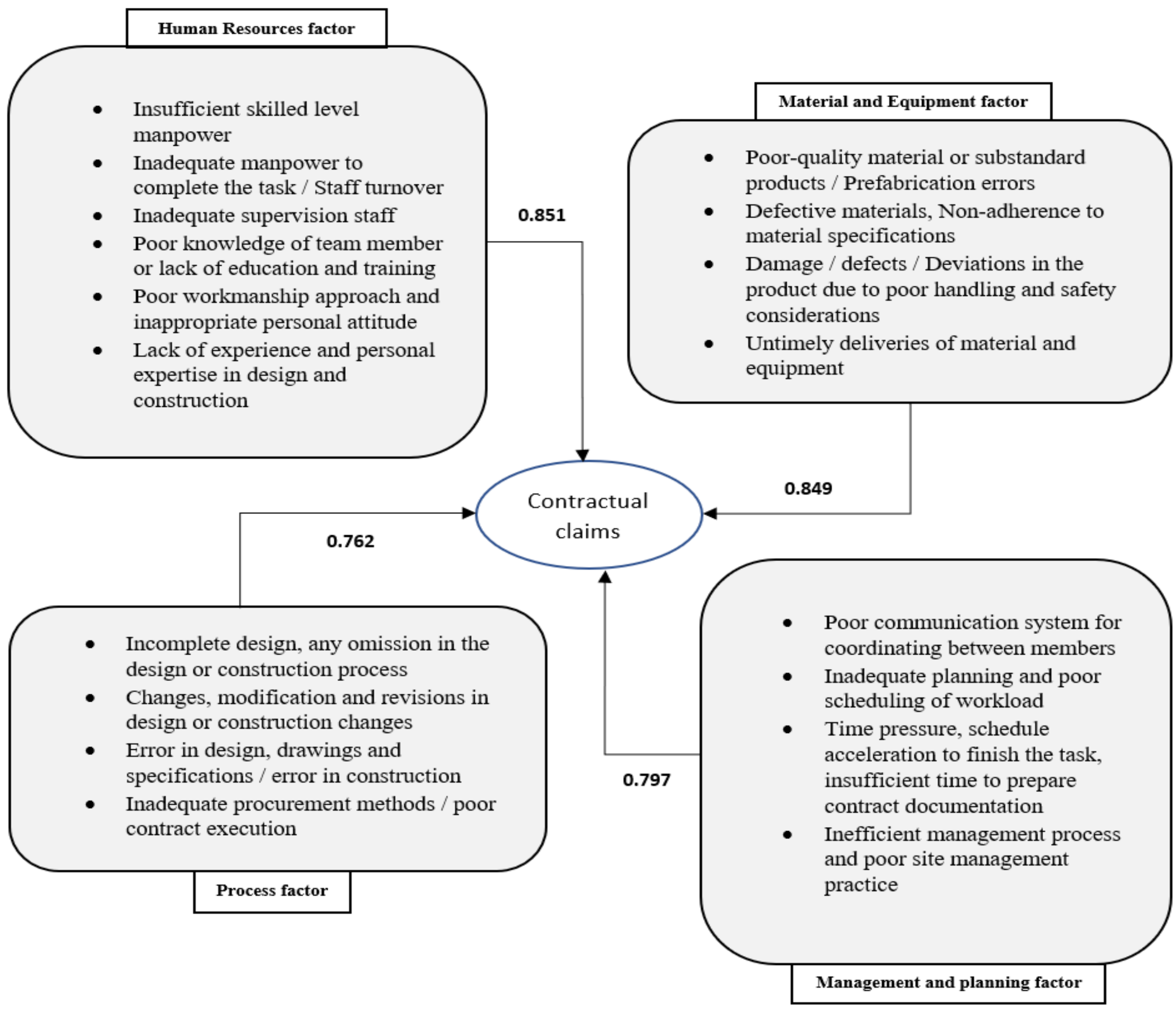


Figure 10.1: *Diagram of the relationships between contractual claims and underlying factors of rework causes*

10.8 Conclusion

Effective claim management is a robust approach for avoiding disputes in construction projects. This study explores the basic causes of rework that have an influence on contractual claims to avoid future disputes. It contributes to the knowledge of rework and contractual claims in construction contracts. A review of the literature showed that little is known about the common causes of rework and contractual claims. This is required as rework occurs persistently in the construction industry. The study assesses how rework causes affect contractual claims in construction projects. This study has been conducted to establish solutions for contractual claim reduction by establishing a relationship between the claims and the rework. Therefore, the key underlying approaches for tackling rework and contractual claims have been discussed. Then an exploratory factor analysis is undertaken to classify the causes of rework in generating claims into four categories as follows: human resources, material and equipment, management and planning, and process. These factors largely explain both rework and contractual claims in construction contracts. The extracted underlying factors in this study can be considered by project managers while preparing contract documents. Thus, projects will reduce the probability of rework and simultaneously prevent contractual claims as an unforeseen circumstance.

The study also implies that human resources management, which encompasses attributes such as skills and experience, and education, needs more attention to bring about a better claim process. In addition to that, effective material management and on-time delivery is also essential for overall claim handling. It can be achieved by implementing a just in time approach and avoid storage and other additional logistics costs. By addressing these sets of identified factors in the condition of the contract, a large part of contractual claims in construction projects can be managed, and fewer disputes will arise. Adequate contractor knowledge in design would prevent variation, which otherwise results in rework and then contractual claims. The study proposes that rework management can reduce contractual claims and disputes by completing the design at early stages, involving contractors at the procurement stage, and avoiding project changes. The analysis could help to develop a multi-dimensional framework for effective measurement of the contracting process. Contractual claims are common in construction projects, and the findings of this study will expand the existing knowledge about the necessary requirements for better management of construction contracts. Therefore, this study contributes to the body of knowledge by providing a quantitative confirmation that not only validate the general statement in the literature that rework has an effect on contractual claims, it also adds to the existing knowledge with new findings.

Some limitations exist in this study which must be considered for future developments. Firstly, the collected data is from a sample of experienced contractors in New Zealand based on the standard form of NZS3910 contract; thus, the applicability of measures in other forms of contracts outside New Zealand might be different. In addition, the sample size of 124 participants meets the requirements related to conducting factor analysis in general. More complementary data is required for the development of more comprehensive models concerning the other causes of claims using confirmatory factor analysis or structural equation modelling. In-depth interviews could overcome the survey limitations of this study by collecting the construction practitioners' opinions and validating the quantitative results. Future research will need to be undertaken to examine other standard forms of construction contracts such as NEC, FIDIC, and so on, as the clauses differ according to various contract conditions.

10.9 Epilogue

This chapter drew the underlying factors of contractual claims that were raised from rework. The contract parties' interests for reducing rework impacts on construction contracts need to be considered. To reduce the impacts of rework in generating contractual claims, the conditions of the contract require improvement in terms of addressing rework causes, and contract parties should review rework provisions when contract documents are prepared. This chapter highlighted more insight into the influential rework causes that generate contractual claims. It helps to prevent conflicts that may occur during construction stage. This chapter concluded four components of causes that most likely are aligned with the classified rework causes in chapter seven. As such, the similarity in the structure of causes validates the common sources of rework and claims and consolidates the existing relationship between the two. The incorporation between these two is used in the next chapter to understand which clauses of the contract may contribute as rework provisions. Therefore, contract parties can review relevant provisions and propose constructive recommendations for better administrating the contract when they enter into the construction contracts.

Part four

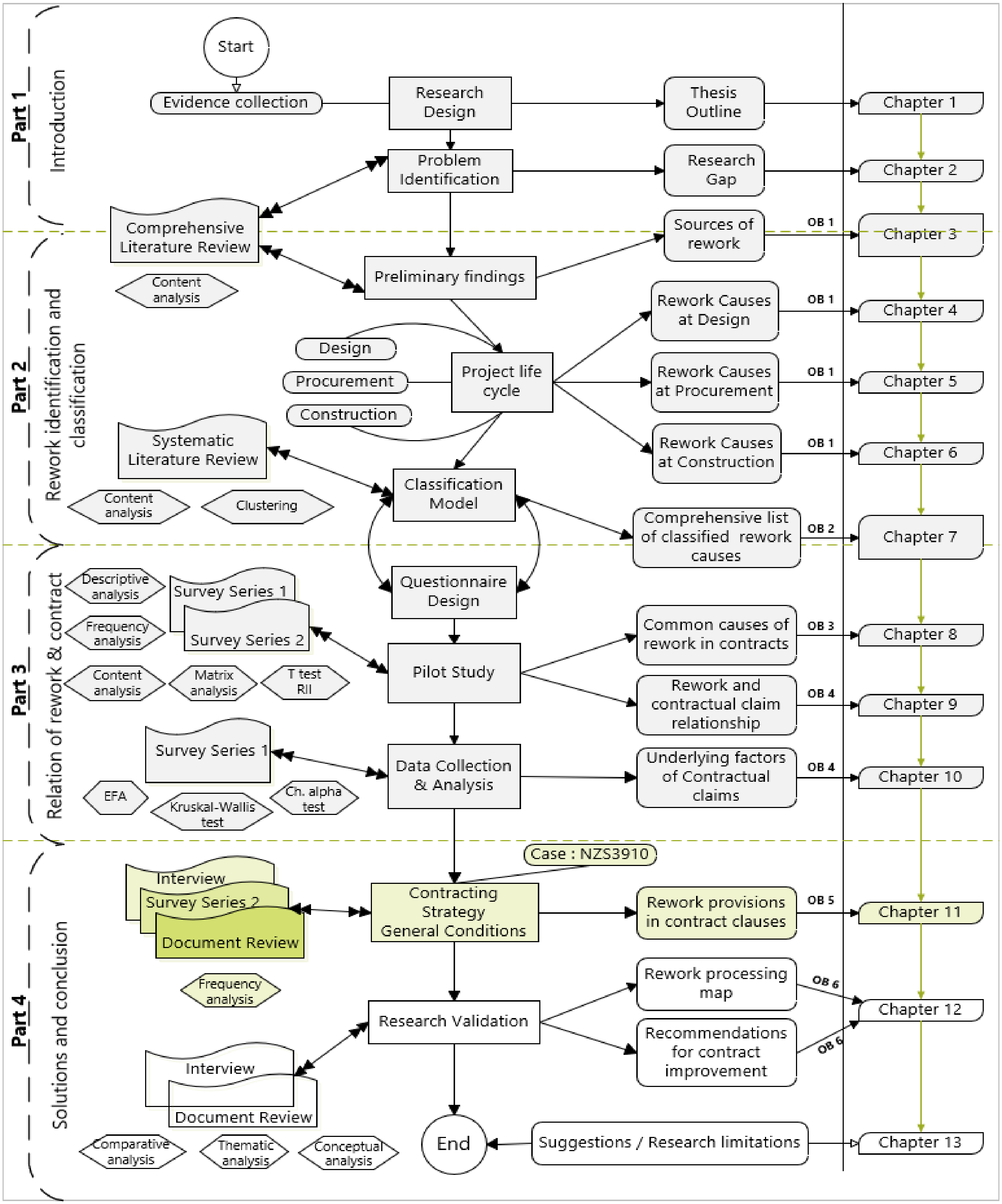
Solutions and Recommendations

Chapter 11. Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach

Chapter 12. Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations

Chapter 13. Conclusion and research recommendations

Thesis-at-a-Glance / Chapter 11



Chapter 11. Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach

11.1 Prologue

The aim of this chapter is to find related provisions of the contract in rework events and the capacity of the clauses of the contract in addressing rework causes. Thus, the conditions of the contract of NZS3910:2013 as the most commonly used contract in New Zealand construction project is examined in this chapter. The chapter has been structured in two parts; it first introduces rework, the common causes of rework in construction contracts and NZS3910, and then uses questionnaire survey and interviews to analyze collected data and compare the clauses of the contract. Following the achieved results from the previous chapters, this chapter concludes with recommendations to search for solutions within the contract conditions for addressing rework causes. A framework will be required to manage rework in a better way that prevents further claims and disputes. The results of this chapter will then be used for revising the contract and proposing a flowchart of activities that could address rework causes more appropriately. More details about this chapter's results are presented at the end of the chapter.

This chapter is based on the following Journal paper:

Asadi, R., Wilkinson, S., and Rotimi, J.O.B. (n.d.). Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction.* ID: S-22-00087.

11.2 Abstract

Rework is an interesting topic in the contract management of construction projects. Contractual provisions related to rework are difficult to trace as they are written indirectly or in a context that is complex. Rework affects the performance of a project in terms of cost, time, claims and disputes. Changes in design, construction and the scope of work that requires rework affects contract sum and date of project completion. Thus, clear responsibility for managing rework is one of the most important issues in construction contracts. If there are well defined responsibilities before the commencement of the project, this will safeguard termination of the contract. In this study, the stipulated provisions related to the causes of rework are reviewed first and then the contractual perspective of the rework is analysed as it relates to the contract terms and conditions. The research follows a mixed method of quantitative and qualitative data collection and analysis. In this paper: (1) a list of rework causes is collected based on the literature review (2) then each rework cause has been assessed in terms that relate to the contract conditions (3) the relevant clauses of the contract related to rework are explored via the interviews. Properly addressing the causes of rework in the contract conditions improves the overall performance of projects and reduces the contractual claims and disputes. The study revealed that there are five major causes of rework that have been addressed in the contract conditions and other causes may require attention at the time of contract preparation. In terms of the remainder of the causes further investigations should enable both parties of the contract to manage their obligations in the case of rework events.

11.3 Introduction

The latest reported disputes amount by Arcadis (2020), show over 30.7 million dollars as the average dollar amount in terms of disputes which prolonged the duration of the project to an additional 15 months. According to (Jelodar et al., 2016), many disputes in construction projects originate from the contract documents. Over 16 percent of claims in construction projects have originated based on the contract documents (Al-Mohsen, 2012). Furthermore, the complex nature of construction projects requires rework as an inevitable part of the projects which sometimes costs up to 25 percent of the contract value (Miri and Khaksefidi, 2015). Such figures confirm the necessity of a contractual guideline for more effective administrating of the contract in rework circumstances. Rework leads to poor performance (Love et al., 2003) and poor performance is the factor that most often contributes to the construction disputes (Aiyewalehinmi and Nkumah, 2019). Rework has been regarded as an influential issue affecting the contractual claims in construction projects. In fact, one of the common causes of contractual claims and disputes is related to rework (Palaneeswaran et al., 2008; Wang et al., 2019). Rework related issues require a clear set of responsibilities between contractual parties to avoid conflicts. In addition, the unfair disclaimer clauses in the contract have the potential to create rework in construction projects (Mendis et al., 2015). As such, practitioners in the construction industry pay for the rework related claims, moreover the parties' responsibilities to follow up on the rework under the clauses of contract conditions are not addressed clearly.

Claim management is an essential part of a successful project (Seo and Kang, 2020), and a successful claim needs to follow the defined steps that are noted in the conditions of the contract (Zaneldin, 2020). Contract provisions are one of the identified critical factors in the successful handling of claims to prevent disputes (Jelodar et al., 2016). If the written provisions in the contract conditions are difficult to interpret (El-adaway et al., 2020), poorly written contract clauses and certain provisions in the contract increase the tendency for misinterpretation (Mendis et al., 2015). Nonetheless, to reduce contractual claims and disputes it is crucial that the clauses in the contract that address rework causes are clearly spelled out in the construction contracts. To reduce contractual claims that originate from rework, it is important to investigate the causes of rework that result based on the contract conditions. As a result, understanding how rework leads to contractual claims and disputes and how the conditions of the contract address such issues have become essential for the contract parties.

The investigation of contractual claims and disputes has always been a critical issue due to the effects on cost and project productivity (Jelodar et al., 2016). The conditions of the contract need to be managed and strengthened due to the increasing rate of construction contracts in the next few years (Assaad et al., 2020). Risks are an inherent part of the rework in construction projects and many contractual issues such as delay, low quality, cost overruns, claims and the subsequent disputes that derive from the improper allocation of risks as set for in the conditions of the contract (Assaad et al., 2020). The contract conditions govern the relationship between the contract parties which at the highest level include the client and the contractor. Both parties of the contract have their own responsibilities for the project that are related to their performance and they are defined in the conditions of the contract. Thus, it is crucial for both parties to be familiar with the contract provisions as they relate to rework events. In addition, claims and disputes need to be assessed to see how the contract conditions address the basic requirements of the parties as they relate to rework events. This statement would be more alarming as part of the cost overruns in construction contracts contribute to rework (Love et al., 2000b). Even though, the contract conditions have been studied in previous research study (Mendis et al., 2015), this paper highlights the importance of undertaking further investigation of the contract conditions in rework situations. Furthermore, most of the previous studies have reviewed the overall conditions of the contract in general terms and very little if any research has been undertaken that has reviewed the conditions under rework circumstances (Asadi et al., 2021b) that involves reducing claims and disputes.

11.4 Goal and Objectives

This paper aims to provide evidence for addressing rework in New Zealand construction contracts by analysing the contract conditions of NZS3910. The contractual parties in construction projects can benefit from this paper's results to facilitate their understanding about the contract provisions related to rework and the associated risks. As such, it would improve the party's ability to manage rework by the early identification of the impacts if rework in the contract which enhances the performance of the projects. The objectives of this paper are to find whether rework causes have been addressed adequately in the contract conditions of NZS3910 and which clause in the contract can be linked to rework and its causes. It offers a better understanding of the rework related provisions and provides guidelines to improve contract drafts taking into account the rework circumstances.

11.5 Background

The previous studies on rework and contractual claims were reviewed to convey the outcomes of the current research to add to and make a new contribution to the body of knowledge. While many research studies have been conducted to understand the impacts of rework on project performance in the construction industry (Love et al., 2004; Mahamid, 2016a), very few have concentrated on the effects of contractual claims that originated from rework. For example, (Simpeh et al., 2015) has developed a rework probability model to determine rework occurrence before the commencement of construction (Taggart et al., 2014a), and examined the role of supply chain in rework management. On the other hand, (Palaneeswaran et al., 2006) conducted a study on the importance of contractual claims and identified the most suitable tools for analysing rework symptoms. Mendis et al. (2015), studied the contractual obligations in rework and waste management and their findings show that quality, workmanship and inspections related clauses are more prone to generate waste and rework in construction projects. If rework occurs due to the client's instruction, any associated cost will be compensated as the contractor can claim it as an approved change order through a variation clause. Therefore, a change order through variation does not result in claims unless there are debates on adjusted time and cost (El-adaway et al., 2016). Different contractual and legal matters such as delay, payments and change orders have been analysed under the various standard forms of the contract (El-adaway et al., 2016; El-adaway et al., 2020), whilst the condition of the contract is silent for rework.

According to (Jelodar et al., 2016), rework, claims and disputes arise from common sources. Even though most of the studies have identified the causes of rework and contractual claims separately, they have not examined or investigated the relationship between the claims, disputes and rework (Asadi et al., 2022). For example, Seo and Kang (2020) investigated performance indicators for claim management based on the issues within the management of various claims. Zaneldin (2020), also evaluated the types, causes and severity of claims in construction projects in UAE projects. In addition, various research studies on the standard form of construction contracts have been performed to improve the provisions of the contract specifically concerning some aspects such as change orders (El-adaway et al., 2016), payments (El-adaway et al., 2017), back-to-back relationship (Assaad et al., 2020), conflict and disputes (Saseendran et al., 2020) and safety issues (Abdul Nabi et al., 2020). There are various perspectives on the assessment of contract conditions; they concern a wide range of factors from change orders, safety issues, contractual effects, claims, disputes, delays, and some of the conceptual frameworks of the contract administrations. Nonetheless, there is little if any research that address the contractual claim aspects of the rework in construction projects. Overall, it can be noted that there is limited research that has studied the clauses of the contract and their interactions and reciprocal actions associated to rework (Mendis at al., 2015).

On the other side, the suggested models and frameworks for contract administration has evolved over the years. For example, (Assaad et al., 2020) investigated the back-to-back relationship under standard subcontract agreements to provide a checklist that enables better project performance. The association between change orders and the clauses in the contract has been studied via research conducted in the United States (Syal and Bora, 2016). In this research the direct and indirect costs associated with change orders have been utilised to examine the relationship of various variables as they relate to the conditions of the contract in four different standard forms of contract. Papajohn et al. (2020), provided a model that enables organisations to compare contract administration functions for various procurement methods. A framework consisting of three dimensions of causes, effects and mitigations was proposed by (Hansen et al., 2020) to better understand contract change orders overall and to improve the performance by minimising the effects of the changes. The findings of this study revealed that contract management practice needs improvement in change orders events. Some other guidelines also have been proposed for different sectors such as public infrastructure projects (El-adaway et al., 2018), and safety related issues under design build standard form of contract (Abdul Nabi et al., 2020). In another study, extension of time under different standard form of contract has been reviewed to present a guideline for administration of provisions related to delay in six different forms of contracts, namely FIDIC, NEC, JCT, EJCDC, AIA and Consensus DOCS (El-adaway et al., 2020). It is advised to shift conflicts raised from different sources such as delays and claims before turning to disputes to the conceptual design the at early stages of the project (Jelodar et al., 2016) which could be possible through the establishment of good communication means to flow the right information. In the study done by Adafin et al. (2021), right information flow was ranked as the 5th most important risk factor influencing budget performance of construction projects in New Zealand. Thus, the contract conditions of construction projects in New Zealand needs to be assessed to provide a guideline for better administration and to reduce contractual claims and disputes.

However, since the process of contractual claims handling, and dispute management is highly influential to the project performance, it needs to be explored on the basis of the contract conditions and most importantly the clauses of the contract. Thus, in this study all identified causes of rework are assessed under the general conditions of the contract. This paper investigates the sources of contractual issues generated from rework that are imbedded in the conditions of the contract. The extent of addressing all identified sources in the clauses of the contract are extensively studied to determine the adequacy of the defined provisions. A study of the court cases of construction projects in New Zealand between 2009 and 2014 showed that over 60 percent of the claim and dispute cases were related to problems between client and contractor. Most previous studies regarding conditions of the contract have generally reviewed the claim processes, not particularly with a focus on the claim derivers. However, even though many researchers have investigated construction claim management, it is necessary to monitor the conditions of the contract under rework occurrences to address rework causes that generate contractual issues. Nevertheless, it was found that no framework has been presented to improve the conditions of the contract in relation to rework that led to contractual claims, conflicts, and further disputes.

11.6 Causes of rework in construction contracts

From a systematic point of view, the two concepts of rework and claim can be regarded as cyclical elements that trigger each other. If rework is not managed properly, it may then change to a conflict. If the condition of the contract does not address such conflicts, it will require further litigation that is very costly (Jelodar et al., 2016). The poor performance of projects raised from rework necessitates the need to design a framework to manage conflicts in a proper manner. Such a framework that shows the common causes of rework and claims is not available in the literature. This study collects the most common causes of rework at the project level that covers all stages of design, procurement, and construction. The comprehensive list of rework causes is prepared based on the literature review indicating 37 root causes in six groups related to construction contracts as shown in Table 11.1. Each group consists of some relevant causes to address the process of reworking in the construction projects (Asadi et al., 2021a).

Based on a review of the literature it shows that rework can occur in both sides of the contract, on both the client and contractor side. In a study performed in Sweden by Josephson et al. (2002), rework was categorised in five groups: client, design, workmanship, materials, machines, and production management. In the work of (Love et al., 2009a), changes, errors, omissions were found as the major associated causes of rework. Generally, rework caused by contractor will be related to technical factors, quality management factors and human resources factors (Oyewobi and Ogunsemi, 2010). In addition, ineffective coordination, poor materials, defective material, and poor safety considerations were also known as the rework causes that were related to the contractors (Ye et al., 2015). In Singapore, the client was found to be more associated to the occurrence of rework. Overall, seven related causes related to the client in rework circumstances were identified as changes in plan, inadequate project objectives, change in specifications, impediment decisions, replacement of material, obstinate nature, and client's financial problems (Hwang et al., 2014). In a study carried out in Malaysia, project coordination, project implementation, technology, machines, design process and site workmanship have been found as the significant factors of rework (Yap et al., 2017). Rework causes associated with the categories of client, consultant and contractor also were examined in the study carried out on the root causes of rework in Nigerian building construction projects (Eze and Idiake, 2018b). Forcada et al. (2014), in their case studies of highway construction projects in Spain, investigated the responsibilities of parties in rework circumstances at three levels of project, organization and people. They found that the risk is involved with the scope changes, and the poor skill level and high complexity that is critical in rework management.

According to the research performed by (Safapour and kermanshachi, 2019) in the USA, the cost of rework is reduced by implementing constructability and quality management strategies. Ndwandwa et al. (2017), considered the cost and time overruns from rework events in South Africa. They found that rework mainly occurs due to factors ranging from design, site, planning and scheduling. In Saudi Arabia the relationship between rework and material waste was examined in the buildings type of project and it added the lack of labor skill and inadequate supervision to the previously identified rework causes (Mahamid, 2020). Then four more causes under contract management category of rework were identified through a study in China that included the fuzziness of the project scope, unfulfilled contract, ambiguity, and low contract payment (Liu et al., 2020). The literature that identified the causes of rework are combined in Table 11.1. Part of the identified causes are heavily dependent on the project type, geographical location, and the economic situation of the construction industry. A shortage of skilled labor, availability of material, and contractors' experience are among those causes. Hence, the list of rework causes is further explored by conducting a survey and professional interviews in New Zealand construction projects using the standard form of contract NZS3910.

Table 11.1: The common causes of rework in construction project

Group	Rework cause	Code
Process	Changes, modification and revisions in design / construction changes	P1
	Error in design, drawings and specifications / construction error	P2
	Incomplete design, any omission in the design or construction process	P3
	Inadequate procurement methods / poor contract execution	P4
	Improper contractor and subcontractor selection	P5
	Lack of document control	P6
Human Resources	Lack of experience and personal expertise in design and construction	H1
	Inadequate supervision staff	H2
	Inadequate manpower to complete the task	H3
	Insufficient skilled level manpower	H4
	Poor knowledge of team member, lack of education and training	H5
	Lack of employee motivation and rewards, Carelessness	H6
	Poor workmanship approach and inappropriate personal attitude	H7
	The absence of job security and other safety rules	H8
	Labor reallocation, alteration and staff turnover	H9
	Conflict of interests	H10
Material / Equipment	Defective materials, Non-adherence to material specifications	M1
	Poor-quality material or substandard products / Prefabrication errors	M2
	Replacement or misplacement of material and equipment	M3
	Inefficient equipment use or altered material	M4
	Untimely deliveries of material and equipment	M5
Technical	Ineffective use of quality management practices / deviation due to poor monitoring	T1
	Poor technology application and lack of information technology use	T2
	Poor communication system for coordinating between members	T3
	Inefficient management process, poor site management practice	T4
	Poor project documents, unclear instructions, poor contract documents	T5
	Conflicting and incomplete information	T6
	Inadequate planning and poor scheduling of workload	T7
General / External	Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure	G1
	Lack of client involvement	G2
	Unclear line of authority	G3
	Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	G4
	Lack of constructability	G5
	Damage / defects / Deviations in the product due to poor handling and safety considerations	G6
	Governmental regulations / changes and policies	G7
	Environmental conditions, poor site condition	G8
	Unpredictable factors from different sources	G9

11.7 NZS3910: 2013

The first standard form of contract in New Zealand was published in 1949. This document that was issued under the name of NZSS 623 was aligned with the standards set forth in Act 1941. In 1964, this form of contract was revised commonly based on the fourth edition of the general conditions of ICE and the available issuance of the FIDIC in 1957 (Robertson, 2018). A few years later, the name of this standard was changed and published under NZS 3910 and in 1987 there was a significant revision. NZS3910 then was revised again in 2003 and in 2013, to bring the status of the document to the current plain version in English. The last edition of this form of contract is currently used as listed as NZS3910:2013 with the title of “Conditions of Contract for Building and Civil Engineering Construction”. The current form of the contract has been designed to be aligned to the Construction Contract Act 2002 and it is intended to be more fit for the purpose. Thus, it was only updated based on the limited scope review of the previous version.

11.8 Method

A mixed methodology of quantitative and qualitative is followed in this paper as shown in Figure 11.1. A multiple step “*literature, survey, contract review and professional interviews*” has been employed in this study by reviewing the causes for rework in the contract conditions of NZS3910 as the most commonly used construction contract in New Zealand. The multiple qualitative approach previously used by (Hansen et al., 2020) to develop a framework for contract change orders mitigations. In the first step, a comprehensive list of rework claim causes was collected from the related literature from various articles to conceptualise the theories. The common causes of rework in New Zealand construction contracts were then studied by conducting a survey to understand which rework causes have been addressed adequately in the contract condition. The highly addressed causes of rework from the survey result were then reviewed based on the contractual provisions stipulated in the standard form of NZS3910: 2013 to validate the result of the previous stages. The collected data from the survey was analysed using Mean and standard deviation to rank the most significant causes that have been addressed in the contract conditions adequately. The main purpose of the survey was to solicit the construction industry’s opinion on the adequacy of addressing rework in the clauses of the contract conditions. The analysed result was then confirmed by the evidence from the interviews with construction practitioners in the contracting field. Thus, the practical work was observed to assess the conditions of the contract in relation to rework by conducting interviews with construction experts and legal professionals to examine all the aspects of the contractual issues. Expert's opinion was compared to the survey result to understand how rework can be addressed better to cover rework and prevent contractual issues, conflicts and claims. This part of the analysis provides basis for further investigation of rework provisions from a practical perspective.

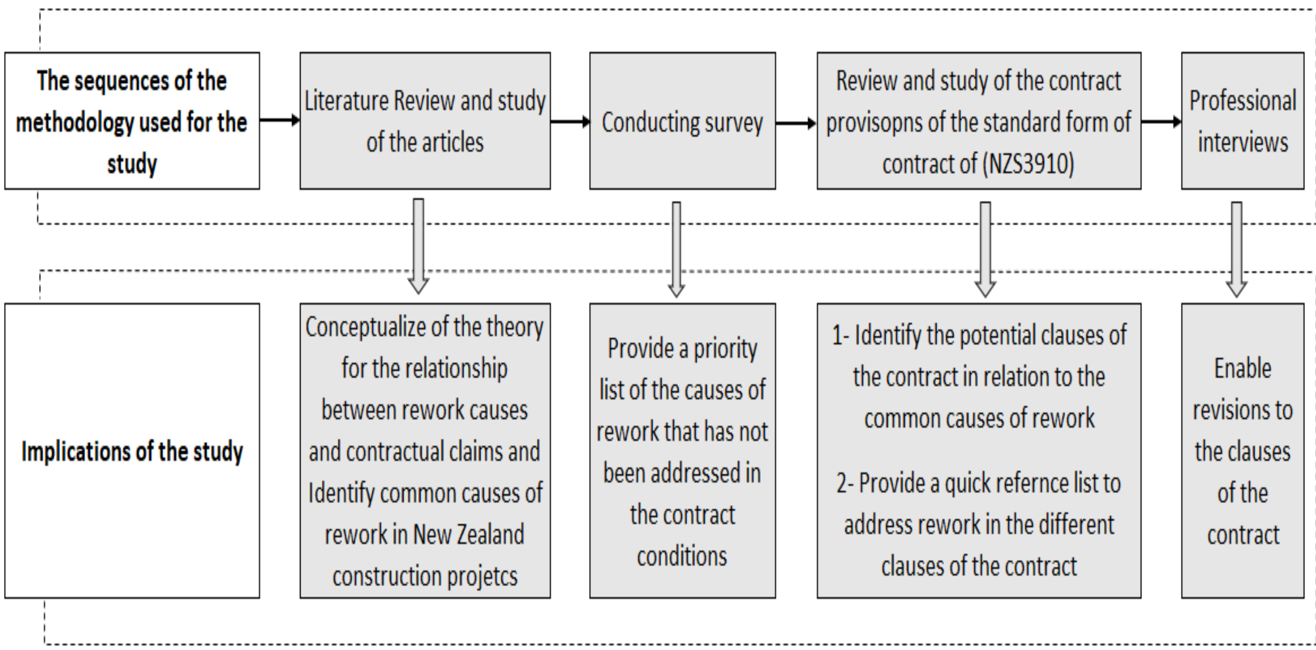


Figure 11.1: *Research methodology*

Contracts in construction project should tentatively be updated and tailored based on the project specification and geographical locations (Mendis et al., 2015). This paper bridges the knowledge gap about addressing rework among the clauses of the contract by reviewing the conditions of the standard form of NZS3910 in New Zealand. The title of this contract "Conditions of contract for building and civil engineering construction" reflects that all provisions and reviewed items apply to the construction projects. The review of rework causes in the conditions of contract provides a contractual perspective of the rework that may result in claims and disputes. Moreover, the interviews regarding how rework is traced in various clauses of the contract provides a practical perspective of rework causes on contractual claims and disputes. This comprehensive method helps contract parties to better understand their responsibilities in rework events. Therefore, both client and contractor can generate their own concerns about rework at the pre-contract stage of the project to define their right and responsibilities under rework circumstances.

11.9 Result and analysis

11.9.1 Step 1: Theoretical conceptualization

According to the given literature in the rework section of the background, the identified causes of rework from previous studies was documented and was then used for the theoretical conceptualisation. The focus was on the causes of rework in construction contracts in various countries around the world. The review of the literature showed that contractual claims have been caused by rework, and on the contrary, proper rework management improves the performance of projects in terms of fewer claims and disputes. A well-designed questionnaire based on a comprehensive review of the literature was prepared and validated before releasing it to the industry. The questions have been reviewed in consultations with four experienced experts from academia and construction industry to improve the quality and ensure the validity of the contents.

11.9.2 Step 2: Conducting Survey

The questionnaire was distributed online through a provided link to the selected target companies including clients, consultants, architects, quantity surveyors, contractors, and active legal firms in New Zealand construction projects. In the survey, the participants were asked to indicate their agreement if the conditions of the contract adequately addressed the identified causes of rework through a five-point Likert scale.

Demographic of the respondents

Table 11.2 shows all the demographical details of the participants with various levels of working experience in construction projects and contract management. Respondents with more than 20 years of experience in construction comprise 43% of the sample size. More than half of the participants "71.3%" had over 10 years of working experience in the contract management field. Thus, the reliability of the survey data is considered high with the adequate knowledge and experience of the respondents. Moreover, participants were from different organization types such as design and architects, project management, construction, design and built companies. Therefore, the survey data covers a range of organisations that use NZS3910 in their construction projects. The size of projects has been represented by the contract values in Table 11.2. It is noted that most participants were involved with projects that were less than 10 million dollars (40 out of 80). Also, the table shows that respondents to the survey questionnaire are nearly equal in terms of numbers from client and contractor sides of the contract.

The result of the survey to explore the extent of addressing rework causes by the contract conditions was analysed under the standard form of contract NZS3910 using Mean and Standard deviation. Surveys with a response scale in construction research generally are analysed through ranking the results using either RII (Zanldin, 2020), or frequency analysis through comparing means (Beale and Smallwood, 2019). The result of the descriptive analysis for each cause has been presented in Table 11.3 showing the viewpoint of client and contractors separately. The overall ranking of rework causes considering both type of organisations is also listed in the table. The differences between the viewpoints of the two contractual parties for ranking rework cause were compared and it was observed that ranking is different between these two group of respondents. The analysis result of the responses received from both parties indicated that P1 “Changes, modification and revisions in design / construction changes” is the most addressed causes of rework in the conditions of the contract with the Mean of 3.83, while M1 “Defective materials, non-adherence to material specifications” ranked second with the Mean of 3.55. P2 “Error in design, drawings and specifications / construction error” came third with the Mean of 3.50, and M2 “Poor-quality material or substandard products / Prefabrication errors” was the fourth cause with a Mean of 3.43 in the ranking list.

Table 11.2: Respondents and background information

Description		Sample size	% of respondents
Profession/job roles of participants			
	Project Director/Project Manager	29	36.2%
	Construction/Site Manager	2	2.5%
	Commercial/Contract Manager	11	13.8%
	Quantity Surveyor	11	13.8%
	Others	27	33.7%
Year of experience in construction			
	Less than 10 years	16	20%
	Between 10 and 20	21	26.2%
	More than 20	43	53.8%
Contract experience			
	Less than 5 years	16	20%
	Between 5 and 10	7	8.7%
	More than 10	57	71.3%
Type of organisation			
	Design and Architect	14	17.5%
	Project Management	13	16.3%
	Construction	24	30%
	Design and Built	9	11.2%
	Others	20	25.%
Value of the involved projects			
	Less than 10 Million NZD	40	50%
	Between 10 and 50 Million NZD	14	17.5%
	Between 50 and 100 Million NZD	8	10%
	More than 100 Million NZD	18	22.5%
Contract sides			
	Client	41	51.2%
	Contractor	39	48.7%

According to (Beale and Smallwood, 2019) mean scores over 3.4 are considered significant items with a Likert scale of 1 to 5. The overall ranking of rework causes addressed by the conditions of the contract only covers four causes as the most significant items. The fifth cause P3 “Incomplete design, any omission in the design or construction process” with a mean of 3.39 is also listed as the significant cause as it is very close to the minimum criteria of 3.4. The ranking of the causes among client and contractor almost follows the same causes with a slightly different order. For example, P1 is ranked as the first cause in both sides. The second ranked causes from the contractor point of view is P2, while the client side ranked P2 and P3 concurrently as the fourth items. P3 is also ranked as the fourth cause under the contractor column. On the other hand, M1 is ranked the second from the client points of view while it is ranked third by the contractor side of the contract. In contrast, M2 is the third ranked cause by the client and it is not in the top five significant causes under the contractor list. Interestingly, the fifth cause under client and contractor organisations are different to the fifth cause ranked in the overall results. The contractor side of the contract ranked M5 “Untimely deliveries of material and equipment” and the client side ranked G3 “Unclear line of authority” as the fifth cause.

The participants share from contractor side is 48.75 % and from client side is 51.25%, thus it can be concluded that the overall ranking in the first column in Table 11.3 is fair for both sides as the final list. It is also worth mentioning that the number of significant causes addressed in contract conditions of NZS3910 is less than 15%, and most of the respondents believe that over 85% of the rework causes have not been addressed by the contract conditions of NZS3910. As such, rework as a continuing problem in construction projects needs more investigation within the construction contracts. In this study, the top five significant causes of rework extracted from the overall ranking (P1, M1, P2, M2, P3) are used for reviewing the contract provisions as follow.

Table 11.3: Ranking of rework causes addressed in NZS3910: 2013

Rework cause	Overall, N=80			Client, N=41			Contractor, N=39		
	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD
P1	1	3.83	1.088	1	3.78	1.194	1	3.87	0.978
P2	3	3.50	1.091	4	3.39	1.159	2	3.62	1.016
P3	5	3.39	1.085	4	3.39	1.159	4	3.38	1.016
P4	21	2.88	1.095	20	2.80	1.308	21	2.95	0.826
P5	23	2.84	1.227	24	2.61	1.302	17	3.08	1.109
P6	18	3.00	1.212	18	2.83	1.263	13	3.18	1.144
H1	29	2.60	1.074	28	2.41	0.974	27	2.79	1.151
H2	30	2.56	1.077	29	2.41	0.999	29	2.72	1.146
H3	31	2.55	1.005	27	2.44	0.923	30	2.67	1.084
H4	33	2.48	1.067	30	2.34	0.965	32	2.62	1.161
H5	32	2.49	1.079	31	2.34	0.990	31	2.64	1.158
H6	34	2.45	1.042	32	2.32	0.960	33	2.59	1.117
H7	36	2.40	1.086	35	2.22	0.962	34	2.59	1.186
H8	37	2.38	0.998	34	2.22	0.881	36	2.54	1.097
H9	35	2.40	0.936	33	2.24	0.860	35	2.56	0.995
H10	20	2.95	0.992	19	2.80	1.005	15	3.10	0.968
M1	2	3.55	0.967	2	3.66	0.965	3	3.44	0.968
M2	4	3.43	1.053	3	3.59	0.948	6	3.26	1.141
M3	7	3.23	1.125	7	3.22	1.013	8	3.23	1.245
M4	12	3.13	1.151	11	3.05	0.973	10	3.21	1.321
M5	11	3.14	1.290	13	3.00	1.183	5	3.28	1.395
T1	13	3.10	1.121	9	3.17	1.160	20	3.03	1.088
T2	28	2.65	0.982	25	2.56	0.950	28	2.74	1.019
T3	27	2.71	1.021	26	2.51	1.003	22	2.92	1.010
T4	24	2.76	1.009	21	2.68	0.960	25	2.85	1.065
T5	14	3.10	1.165	14	3.00	1.245	9	3.21	1.080
T6	6	3.23	1.043	6	3.27	1.096	11	3.18	0.997
T7	19	2.99	1.025	17	2.90	1.020	16	3.08	1.036
G1	22	2.86	1.166	18	2.83	1.263	23	2.90	1.071
G2	26	2.73	0.914	22	2.66	0.911	26	2.79	0.923
G3	8	3.20	0.973	5	3.34	0.911	18	3.05	1.025
G4	17	3.03	1.043	12	3.02	1.129	19	3.03	0.959
G5	25	2.76	1.105	23	2.66	1.063	24	2.87	1.151
G6	10	3.15	1.032	10	3.07	0.932	7	3.23	1.135
G7	16	3.04	1.084	16	2.95	1.117	14	3.13	1.056
G8	9	3.20	1.072	8	3.22	1.107	12	3.18	1.048
G9	15	3.06	1.140	15	2.95	1.139	13	3.18	1.144

11.9.3 Step 3: Review of the contract NZS3910 provisions

The contract conditions of NZS3910 comprise 15 clauses, two appendixes, 16 schedules to the general conditions, 14 guidelines and a general aid to Valuation of Variations. To verify that the identified significant causes in the survey have been addressed in the conditions of the contract, the related provisions were reviewed under the clauses of NZS3910. The keywords of each significant cause were searched in the contract conditions to identify all connections and then all identified links were carefully reviewed to understand the coverage of clauses to address rework. Analysis of the related clauses under the contract NZS3910 was performed using *Nvivo* 12 and coding of provisions based on the selected keywords. In the following section, the contract provisions that address rework causes are discussed by highlighting some of the key points that establishes a reliable link between the causes of rework and the contract clauses.

P1- Changes, modification and revisions in design / construction changes,

Changes in construction projects are very common and generally alter the contracts obligations within the defined scope (El-adaway et al., 2018). The frequency analysis of the keyword of change with stemmed words in NZS3910 showed that change has been used seven times in various clauses of the contract. The conditions of contract address design and construction changes in subclauses **2.3.4**, where it gives general instruction regarding how change in quantities shall be treated as a variation. The subclause **2.7.3** emphasises that the general conditions of contract shall not be varied unless the changes are described or identified in the special conditions or any other references as part of the contract documents. The importance of changes also has been highlighted in subclause **6.3.3**, where it does not allow the Engineer's representative to exercise any changing of the drawings and specifications and only gives such permissions to the Engineer to the contract. Finally, subclauses **9.1.1** and **9.1.2** treat any given direction by the Engineer to carry out the work as a variation and define various possible reasons that may lead to change in the contract. This evidence shows that the first overall ranked cause of rework has been addressed adequately under the following clauses:

- Clause 2, "The contract" and its subclauses as (a) measure and value contract, (b) document prepared by the Engineer or Principal

- Clause 6, “Engineer’s powers and responsibilities” and the subclause of Engineer’s representative
- Clause 9, “Variations” and its subclauses as (a) variation permitted, (b) variation orders

M1- Defective materials, Non-adherence to material specifications,

The frequency analysis of the keywords in NZS3910 showed that the keyword defective with stemmed word has been used 43 times and the keyword material has been used 60 times within the various clauses. Under the definition section, materials have been defined as any raw or manufactured material, good, or things required for use in the contract works. Under the subclause **6.4.1**, the engineer is allowed to inspect or test any materials and work at the place of the manufacturer or site prior to the expiry of the defect notification period. The contract under subclauses of **6.4.2** and **6.5.1** clearly refers to the cost of non-conformance materials and the engineers notice for removing and re-executing or making good of any defective materials before the expiry of the defect notification period. The other parts of the contract have excluded the cost of remedying loss or damage caused by defective material from the coverage of insurance under subclauses of **8.3.5** and **8.7.1**. The contractor shall remedy defects or damages resulting from defective materials under **11.2.1** and therefore, the contractor shall be granted an extension of time for completion of the work when the contractor is fairly entitled to an extension due to the loss or damage to the material under subclause **10.3.1**. This evidence shows that the second overall ranked cause of rework has been addressed adequately under the following clauses:

- Clause 6, “Engineer’s powers and responsibilities” and the subclauses of (a) inspection, recording, measuring and testing, (b) removal and making good
- Clause 8, “Insurance” and its subclauses as (a) contractor arranged construction insurance, (b) principal arranged insurance

- Clause 10, “Time for completion” and the subclause of extension of time
- Clause 11, Defect liabilities and the subclause of remedying of defects

P2- Error in design, drawings and specifications / construction error,

The contract conditions of NZS3910 identify any fault, defect, error and omission in the design of the contract work as one of the expected risks under subclause **5.6.6** that is not in the contractor’s responsibilities. The keywork of error has been used seven times in the contract document NZS3910.Regarding errors in construction stage, the conditions of the contract under subclause **5.8.5** state that if errors appear in the contract works set out by contractor, the contractor unless otherwise directed by the engineer shall rectify that error and the cost of rectifications are to be borne by contractor. This subclause also emphasises that if the error occurrence is due to the client’s incorrect information and the contactor does not know that it is not correct, then the case would be treated as variations. Insurance clause will not cover the cost of rectifying loss or damage caused by errors in design or construction, as it has been excluded under subclauses **8.3.5** and **8.7.1**. This evidence shows that the third overall ranked cause of rework has been addressed adequately under the following clauses:

- Clause 5, “General obligations” and the subclauses of (a) care of the work and site, (b) setting out
- Clause 8, “Insurance” and its subclauses as (a) contractor arranged construction insurance, (b) principal arranged insurance

M2, Poor-quality material or substandard products / Prefabrication errors,

The frequency analysis of the keywork quality in the conditions of the contract NZS3910 showed this word was used 13 times within various clauses. The contractor under subclause **5.1.1** is obligated to provide materials whether temporary or permanent as the same is specified in the contract. Under **5.6.2**, the contractor shall be responsible for the care of materials and under subclause **5.18.2** shall provide a quality plan that describes required procedures for meeting the quality of materials according to the provisions of the contract mentioned in **5.9.2**. Moreover, the engineer to the contract under subclause **9.1.1** may order a variation to the contract within the scope when there is a change in the character or the quality of material and an extension of time shall be granted when the contractor is fairly entitled for loss or damage to the materials under subclause**10.3.1**. This evidence shows that the fourth overall ranked cause of rework has been addressed adequately under the following clauses:

- Clause 5, “General obligations” and the subclauses of (a) general responsibilities, (b) care of the work and site, (c) materials, labour and plant, (d) quality plan
- Clause 9, “Variations” and the subclauses of variation permitted
- Clause 10, “Time for completion” and the subclause of extension of time

P3, Incomplete design, any omission in the design or construction process,

Exploring relevant keywords in the contract conditions of NZS3910 showed that the word “incomplete” has not been used in the document, however “omission” appeared eighteen times. Omission in the design of the contract has been referenced as the expected risks under subclauses **5.6.6**. The insurance in the subclause **8.3.4** needs to be maintained by the contractor for any act or omission arising out of the performance after practical completion until the issuance of the final competition certificate. Any omission in construction stage of project is covered under subclauses **10.4.1** for the practical completion of the works except for minor defects that do not prevent the project being used for its intended purposes. Subclause **11.3.1** says that the final competition certificate will be issued when the contractor remedied all minor omissions and defects that are liable for or all defects notified by the engineer. Making good the omissions and defects in the remaining contract works has also been addressed under subclause **12.3.2** which needs to be the assessed cost to the client. This evidence shows that the fourth overall ranked cause of rework has been addressed adequately under the following clauses:

- Clause 5, “General obligations” and the subclauses care of the work and site
- Clause 8, “insurance” and its subclauses as (a) contractor arranged construction insurance
- Clause 10, “Time for completion” and the subclause of final completion certificate
- Clause 11, “Defect liability” and the subclause of extension of time
- Clause 12, “Time for completion” and the subclause of retention monies

11.9.4 Step 4: Professional interviews

After identification of the rework causes that has not been addressed in the conditions of the contract NZS3910, the next step is to confirm the initial result through the professionals’ interview. The research directed to study the implications of rework causes from contract perspective are very rare. Thus, the qualitative approach is the best way to collect empirical evidence relating to this concept (Jelodar et al., 2016). For the interview section, initially a list of experienced professionals in construction dispute resolution were extracted from the available database on AMINZ and New Zealand Building Dispute Tribunal. The other experts in the construction industry were identified through top tier active construction companies in New Zealand by field investigation and available contacts listed under companies’ websites and LinkedIn and the members of CCNZ. The list of legal professionals and construction experts was then used as the sample to conduct the interviews.

Table 11.4: Interviewees profile

No	Interviewee	Years of experience	Background	Means of meeting
1	I.A	45	Architect and Construction Disputes Consultant	Zoom
2	I.B	21	Building Surveyor, Contract Engineer	In -person
3	I.C	25	Consultant and Contract Engineer	Zoom
4	I.D	25	Construction Lawyer, Adjudication, Panellist of Building Dispute Tribunal	Phone call
5	I.E	17	Commercial Manager in construction Company	Zoom
6	I.F	39	Dispute Board Member, Arbitrator, Adjudicator & Commercial Mediator	In-person
7	I.G	43	Senior Project Director, Contract Engineer	Teams
8	I.H	25	Commercial Manager in construction Company	In-person
9	I.J	25	Quantity Surveyor- Technical Director, consultant company	Zoom
10	I.K	25	Principal Consultant, Contract Engineer	In-person
11	I.L	15	Projects Lawyer, Specialist Construction	Zoom
12	I.M	20	Registered Quantity Surveyor, ADR Practitioner	Zoom
Average of experience		27 years		

Note: Three of the interviewees were members of the committee for preparing NZS3910 editions of 2003 and 2013.

The criteria for selection of interviewees were based on the years of experience in construction and contract management according to this study's scope. Thus, people in the list were contacted by email to ask for their interest in supporting the research study. A total of 15 people out of the 39 identified in the list replied positively to participate in the interview. Finally, 12 interviews were performed and three of the scheduled interviews were canceled due to the workload of the participants. Interviews were performed with the participation of 12 people that led to the theoretical data saturation. Aligned with the purpose of the research, a semi-structured questionnaire was prepared to conduct the interviews, which were then recorded and transcribed. The main questions that have been covered in this paper were:

Q1- How is rework addressed within clauses of NZS3910?

Q2- Which clauses relate to the causes of rework?

Q3- Do you recommend adding a new clause for covering rework in the contract?

The content analysis was then performed using *Nvivo* 12 and the professional's perspective regarding rework in the contract conditions were evaluated to determine their viewpoints about addressing rework in the clauses of the contract. The significant cause of disputes in New Zealand develops from the lack of an independent view of an independent contract administrator or the lack of an independent monitoring of the construction projects. Thus, to deal with rework causes within the contractual provisions, the overall idea is around the role of Engineer. The results showed that there is a similarity in the way professionals understand when rework occurs in construction contracts. It is mostly about the role of the Engineer that facilitates rework processing. As discussed earlier, rework is one of the issues that may result in conflicts, and disputes if is not managed properly. It was also stated by (Seneviratne and Michael, 2020) that the Engineer must take appropriate action if becomes aware of the causes that result in consequent issues such as delay. Generally, if rework occurs due to the significant causes referenced in the contract conditions, a rework claim can suitably be launched by addressing the available contract provisions. Otherwise, rework needs to be handled in a grey area with the possibility of acceptance or rejection by the parties involved. Although some experts believe that more clarification within the contract provisions is required to address rework adequately, some others say that more inter-crossing provisions among various clauses may not be helpful. According to Jelodar et al. (2016), ambiguity in the contract clauses and complexity due to the high number of provisions between contract clauses will result in conflict and dispute emergence.

As rework arises from different sources, any action to tackle the consequences of rework has to be analysed based on the causality nature of the occurred rework. Referring back to the various sources of rework, different strategies were suggested by the interviewees to tackle rework in construction projects. However, most of the of participants agree that quality assurance is the solution with the highest possibility to reduce rework. As such, addressing rework due to the causes listed in Table 11.1, would require a decision on who is liable for that cause. If the liabilities of contract parties are well structured in referencing each rework cause, the subsequent process such as claim handling and disputes resolutions can be managed properly. The interview results are generally suggesting that the current provisions in the contract conditions are not quite enough to cover rework sequences either before or after project completion. Interviewees believe that contractual provisions are essential for referencing rework issues. It was referenced that a clear definition of rework is required to recognise it from defects. While the interviewees believe that rework has not been addressed overall in the contract conditions of NZS3910, adding an extra clause would not be a good solution to cover this deficiency. To generalise comments on rework provisions, it is observed that the majority of participants agree to improve the contract conditions through clarifying rework events and its process within current clauses rather than adding a new clause. Thus, the first suggestion was to add a rework definition to the contract and revise some relevant clauses accordingly.

Table 11.4 shows the basic information about the professionals who attended the interviews for this research. Based on the collected data and observations during the conducted interviews, it was evident that rework is not adequately covered by the current contract conditions NZS3910. All of the professionals were asked directly whether the clauses of the contract address rework or not. The comments from the interviewees are shown in Table 11.5 that covers the question seeking relations between rework and contract clauses. It shows the interviewees opinion about addressing rework in the clauses of contract and the possible clauses that can be linked to rework issues. This table can be used for further investigations regarding any revisions on the relevant rework clauses to improve the contract conditions in order to address rework issues.

Table 11.5: Summary report of interviewees opinions

No	Interviewee	Question 1	Question 2		Question 3
			Clause No. NZS3910	Clause title	
1	I.A	No comments	Clauses 6.4 to 6.8 - 11	Engineer Power - Defects liability	No
2	I.B	Comment 2	Clauses 6.4 - 9 - 10.3	Test and inspection - EOT - Variation	No
3	I.C	No issues	-	Not required	No
4	I.D	Mostly addressed	Clause 6.5	Making Good	No
5	I.E	Comment 5	Clauses 11.2 - 9 - 10.3	Remedying Defect and its provisions - EOT - Variation	No
6	I.F	Comment 6	Clauses 5 - 9 - 10.3	linked to the quality of work - EOT - Variation	No
7	I.G	Comment 7	Clauses 5 - 9 - 11.2	Remedying defects - Variation - General Obligations	No
8	I.H	Mostly addressed	Clauses 5 - 6.5 - 11.2	Remedying defects - Making Good - Normal completion	No
9	I.J	Comment 9	Clauses 6.5 to 6.8 - 9	Making good - Variation	-
10	I.K	Comment 10	Clauses 6 - 9 - 11	Related to the engineer - Defect Liability - Variation	No
11	I.L	Comment 11	Clauses 9 - 11 – 13 - 14	Defects liability - Defaults - Variation - Disputes	-
12	I.M	Comment 12	Clauses 5 - 6 – 10 - 11 - 12	General Obligations - Engineer Power - EOT - Defects liability - Payments	No

Comment 2. Rework is a broad term, which can be a contractor's fault, client fault, supervisors' fault, or architects' fault. The needs for more definition about reworks in the contract are important. It would certainly have to be added to the "interpretation section" of the back of the document.

Comment 5. The current provisions are not covering rework causes, they are particularly descriptive. It's not very descriptive as to who's responsible for what and what's really fair? Where are the tears when a defect occurs? Can be repaired rather than replaced, it's all very reliant on an independent engineer to assess that kind of questions.

Comment 6. Rework has no clear definition in the contract.

Comment 7. In terms of the conditions of contract, although they don't specifically address different types of rework, the contract does address whether the contractor is entitled variation or whether the contractor is required to rework something to the correct standard or to the great quality at no additional cost to the principle. I would say rework is not being addressed properly because of the lack of skills and the lack of supervision within the contract up industry.

Comment 9. There is no word of rework in the contract conditions. Removal and making good is one of those ones, so probably rework has not been addressed enough to be honest. There's been discussion around early warning type notifications, and at the moment I think RFIs always perceive to be a contract's way of letting their design team know that they need more information about rework.

Comment 10. No discussion about rework in the contract, and it's only about defect. There's a clause that the engineer discovers the defective works, and then there's a way deal with rework. This defect is including late defects and defect during notifications period. The defect can be discovered by inspection and if you discover it, that would be rework.

Comment 11. I do think the defects liability section really addresses rework and I think we have the defects notification period in the remedying of defects and that's really where we address the contractor coming back to do rework. To come back and do rework prior to practical completion would need to be in another section of 3910, not in the defect liability section because I think they serve different purposes.

Comment 12. NZS 3910 does use generic terminology, it just talks about remedying defects or nonconforming work, and it is quite important because a lot of the wording is deliberately neutral.

11.10 Discussion and research implications

The earlier discussion presents rework causes in the conditions of the contract NZS3910. The comparison between reviewed clauses of the contract and the survey results presents the most significant addressed causes of rework and then the results of the interviews completes the process of identifying the rework provisions in the contract conditions. The identified rework provisions can be highlighted for the assessment of the contractual claims, conflicts and disputes related to rework events. As rework is a major source of claims and disputes, the professional interviews were performed to identify the various clauses of the standard form of the contract. As shown in Table 11.5, a total of seven items, are identified as the most relevant clauses of the contract related to rework provisions. It shows that: Clauses 6, 9 and 11 have been quoted (58%) by seven out of 12 people to address rework and its causes in the contract. Clauses 5 and 10 have been quoted (30%) by four out of 12 people. Clause 12,13 and 14 have been quoted (8%) by one out of 12 people that address rework and its causes in the contract. Therefore, the most potential area to investigate rework within the contract conditions include: clause 5 “General obligations”, Clause 6 “Engineer power”, Clause 9 “Variation”, Clause 10 “Time for completion”, and Clause 11 “Defect liabilities”. Thus, any further proposing framework or checklist for administrating contracts in rework events will contribute mostly to these identified clauses.

According to the survey results, the causes of rework that have been addressed adequately in contract conditions include changes, defective materials, errors, poor quality materials and incomplete design. It has also been stated by Jelodar et al. (2016), that most of the process related causes are addressed in the contract conditions to cover issues such as changes and errors, and other relevant design issues. Regardless of the pre-mentioned causes of rework, the survey result indicates that most of the rework causes are not addressed by the conditions of the contract. The survey results also confirm that most rework causes are not covered by the current conditions of the contract NZS3910. Both sides of the contract have the same understanding of the contract conditions. In Table 11.3, more than 85% of the causes of rework fall under the mean score of 3.4, which means they have not been addressed by the clauses of the contract. It must be noted that, none of the causes of rework appeared over the mean 4.2 as the highly significant item. All this evidence verifies that contract conditions of NZS3910 need revision to address rework. Thus, further practices to revise the contract conditions through addressing rework provisions will complete this process. The overall comments of the interviewees for the question about addressing rework in the contract, pointed out that rework needs to be defined clearly in the definition section. All interviewees disagree with adding a new clause to cover rework in the contract conditions. Overall, they advised to make some changes in the current conditions instead of adding a new clause. Hence, most of the participants in the interview, nine out of 12 people, confirmed that some clauses of the contract need to be amended or revised to cover rework and its causes. This finding aligns with the survey results discussed earlier.

The causes of rework that have been addressed highlight the need to reorganise rework processing that are identified in the appropriate clauses in the contract. As such, developing a systematic process for rework handling will be the result of further discussion based on the result of this paper. The result of this paper is expected to enhance rework provisions within contract clauses to minimise contractual issues such as claims, and disputes that originated from rework. As shown in Table 11.5, Engineer power, Variations, and Defect liability are the contract clauses that are most related to rework. These three clauses of the contract also are seen in the analysis of the most addressed causes of rework in the survey result. The other two clauses of General obligations and Time for competition are also common between the analysis of contract provisions and interview opinions. As such, the result of this research is valid due to the similarity of the analysis of two the prementioned stages.

The implications of this study based on the presented result and the provided discussion are as follow:

1) Improving the contractual and practical knowledge of parties about rework related clauses that may lead to claims and disputes
2) Addressing the responsibilities of contract parties in rework events
3) Achieving more effectiveness of contract administration by providing a checklist that shows the process of work
4) Providing recommendations that allow contract parties to identify risks attributed to rework at early stages of project

11.11 Conclusion

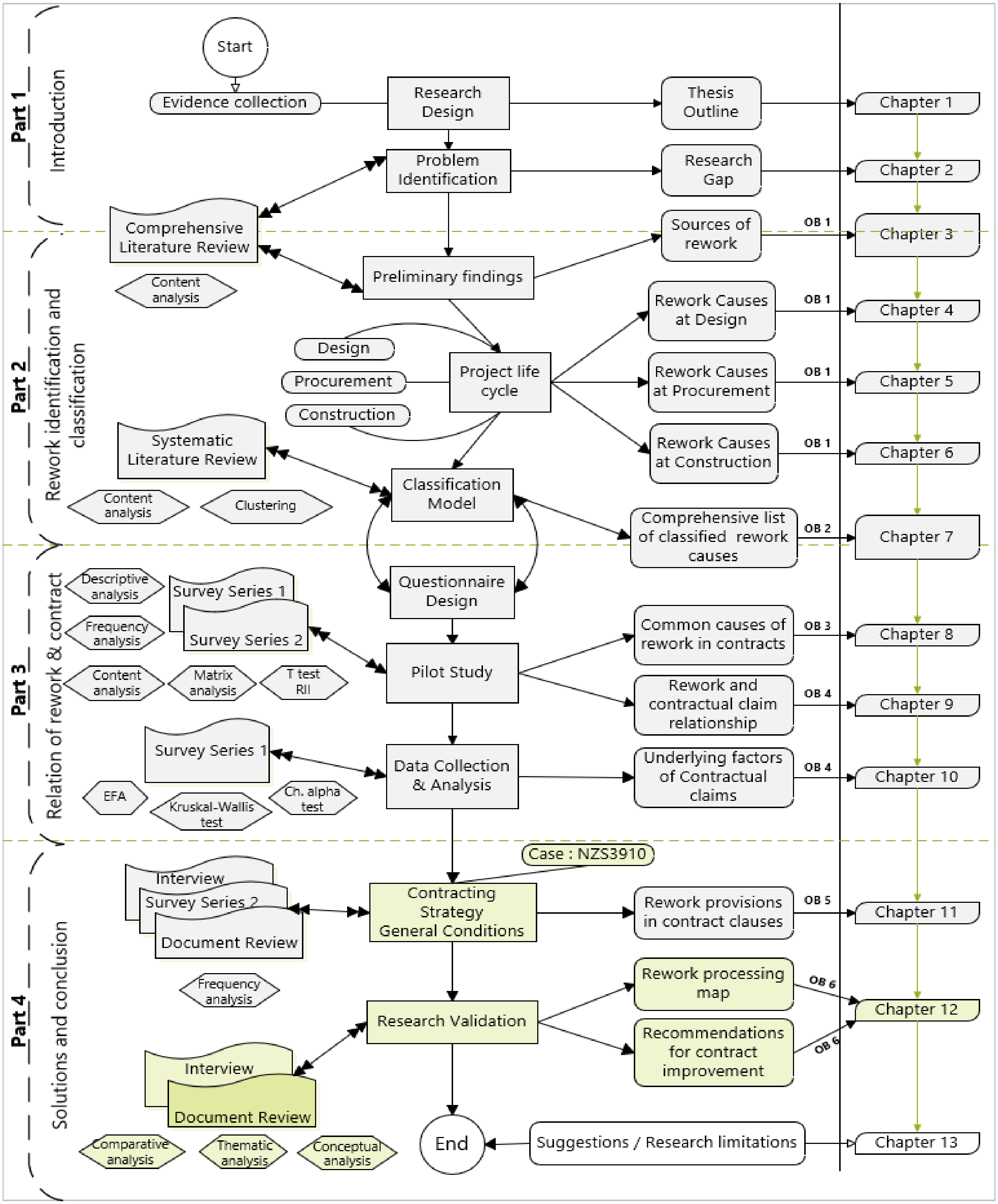
This paper explored rework causes in the contract conditions of construction projects in New Zealand. Moreover, this paper employed survey tools and interviews with professionals in addition to the literature review and theoretical discussions. Thus, the selected method provides a more practical perspective of the causes of rework. Five adequately addressed rework causes were identified as the result of the survey that was conducted. The study findings will contribute to the body of knowledge through the identification of rework provisions within various contract clauses. The results clearly indicated that most of the causes of rework are not addressed adequately in the contract conditions of NZS3910, which requires improvement in contract management practice in rework events. The interview participants responded to the questions by providing evidences from real cases in practical work which points to the necessity of defining rework in contract conditions.

However, most of the participants agreed that adding extra clauses to cover rework is not required. The thematic analysis of the transcribed interviewees revealed the most relevant rework provisions in contract conditions under the standard form of NZS3910. These provisions are: (1) General obligations, (2) Engineer power, (3) Variation, (4) Time for completion, and (5) Defect liabilities. This study will be completed by proposing a framework that shows the process of rework and managing it effectively as noted in the various clauses of the contract. The lack of proposing such a framework is one of the limitations of this study. Further study of the relevant rework clauses of the contract is necessary to validate the initial results of this paper. Therefore, future research can be carried out based on the provided ideas in the implication section of the study. This study also reviewed rework provisions only in one standard form of the contract and the results are limited to NZS3910. The result of this study also requires that the findings are to be compared to the other standard forms of contract to generate a comparison between the relevant clauses. As such, the list of advantages and disadvantages of each of the standard forms will help the process of reworking in contract documents.

11.12 Epilogue

This chapter identified relevant rework provisions of the contract in New Zealand construction projects. The chapter's findings revealed that just a few causes of rework are addressed adequately in the contract clauses, and most of them are not covered by the current contract conditions of NZS3910. The results also identified the most common clauses of the contract that can be referenced as the rework provisions. Thus, further recommendations to improve the contract conditions more likely continue to be added to the earlier identified clauses. Five clauses have been recognized as the most relevant ones under rework events, General obligations, Engineer power, Variation, Time for completion, and Defect liabilities. The next chapter will discuss any other recommended solution for revising contract clauses to address rework and improve the contract's general conditions overall. It also proposes a diagram of activities that can help practitioners when parties preparing contract documents.

Thesis-at-a-Glance / Chapter 12



Chapter 12. Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations

12.1 Prologue

In the previous chapters, relevant clauses of the contract linked to rework were identified by conducting surveys and professional interviews. The analysis was then completed by reviewing relevant contract clauses to evaluate provisions addressing rework causes. However, the previous chapter revealed some connections between rework causes and contract clauses; most of the causes of rework are not addressed adequately. Thus, this chapter continues the interviews by maintaining the discussion to seek solutions and recommendations for improving the process. The discussion's aim is mainly to understand the participants' insight and opinion on how to address rework in the identified provisions and relevant clauses. Then solutions and recommendations were determined from the comparative analysis of the participants' discussion with a documentary review of the contract NZS3910. This chapter proposes a flowchart of rework processing in the contract to improve the contract conditions. This chapter thus addresses the last objective of the research by providing a checklist that can be used before signing the contract to ensure conditions of the contract address rework, resulting in fewer contractual claims and disputes.

This chapter is based on the following Journal paper:

Asadi, R., Rotimi, J.O.B., and Wilkinson, S. (n.d.). Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*. ID: LADR-873.

12.2 Abstract

This paper provides a detail review of rework clauses in the standard form of contract. The terms and conditions of the construction contracts have a significant impact on the project performance. The construction contracts clauses govern the interaction between the parties and may affect the completion date and the final cost of projects. Depending on the complexity of the construction projects, a chain of contract clauses must be written that fit together. In terms of various clauses, the main purpose is to create a fair situation for the parties involved to share their risks. It is more advantageous to the project if the clauses are spelled out, so they are as comprehensive and as precise as possible. The interactions between well-prepared clauses avoid debating over the complicated provisions and may result in fewer conflicts and disputes. The contractual clauses in the standard forms of the contract are referred to as the General Contract Conditions. However, even though many aspects of the contract have been studied previously across the various contract conditions, an assessment of rework in the contract's clauses is of dominant importance. In this paper a three-step methodology is utilised to study rework in contract conditions, (1) conducting a series of professional interviews, (2) reviewing the contract documents and contract's provisions on the leading rework issues and (3) comparing the outcomes to setup the guidelines. As a result, the relevant clauses are identified, and a discussion addressing rework follows. This paper contributes to the body of knowledge of construction contracts by addressing rework in the contract conditions. A flowchart to address gaps and issues in rework provisions across various contract clauses is then developed with a checklist of items that refers to the contract parties. This study provides recommendations to improve the contract conditions, thus reducing contractual claims, disputes and conflicts. It helps construction practitioners revise relevant clauses at the time of contract preparation.

12.3 Introduction

Construction projects have suffered due to the high numbers of disputes and contractual claims. Rework in the contracts is one of the issues that generally causes dispute and appears in the form of contractual claims. Contractual claim is a critical success factor that improves the performance of construction projects (Seo and Kang, 2020). Previous studies revealed that changes in the contract conditions decrease the number of such claims (Moza and Paul, 2018). In the construction projects, the parties' relationship is defined by the contract documents. If the work process and the roles of the parties are defined properly in the contract, rework related risks will be managed satisfactorily, resulting in fewer contractual claims and disputes. Such inconvenient issues in construction projects will be under control if the project parties understand how to manage the contract provisions whenever rework occurs (Asadi et al., 2021b). Understanding the contract conditions related to rework is of extreme importance as the improper allocation of risks associated to rework in the contract often impacts the performance of projects. Therefore, this study investigates the contract conditions to successfully manage the contractual impacts of rework.

Rework in construction contracts often results in increased costs and lengthy processing. Undetected errors before starting construction work led to serious problems such as delay, cost overruns and rework (Pesek et al., 2019). Unbalanced allocated risks associated to rework in the construction contracts, will result in disputes, and can increase the project cost (Apollo et al., 2018; Zaghloul and Hartman, 2003; Lee et al., 2020). Previous research result in New Zealand indicates that about 85% of project disputes between contract parties occur during the construction stage (Jelodar et al., 2016). Thus, addressing rework in the contract conditions improves the parties risk profile and protects them against rework issues. Risk allocation to the project parties is the key concept of construction contracts (Saseendran et al., 2020). The literature shows that even though some clauses have been added to the contract terms as disclaimers to protect the client against contractors' claims, such disclaimers still carry the risk of rework (Mendis et al., 2013). Therefore, the allocated risks must be fair, flexible and balanced as contract parties need to be able to accommodate unforeseen circumstances (Badenfelt, 2011). An appropriate risk allocation model among the contracting parties can thoroughly be achieved by using the standard form of contracts. Contracts in most of the construction industry are prepared based on such standard forms (Wright and Fergusson, 2008). The standard forms of contracts are easy to use for construction practitioners however, they are still counted as the sources of rework and disputes (Besaiso et al., 2018; Broome and Hayes, 1997).

Although considerable studies have been undertaken to reduce the embedded risks in the conditions of the construction contracts, research gaps still exist for the identification of the clauses that encompass rework related risks. Based on a review of the literature, no detailed process is found for addressing rework in the general contract conditions of construction project. The identified gap requires a guideline for mapping the general contract conditions that prevent contractual rework-related impacts such as disputes and claims. This paper seeks to fill this gap by addressing rework in the contract clauses of construction projects. Improving the conditions of the contract to address rework will result in better outcomes in construction contracts and will bridge the existing knowledge gap. This study has been undertaken for two main reasons: (1) it is perceived that construction contracts derive economic growth worldwide (Zheng, 2018), and (2) the current standard form of contract in New Zealand is in need of upgrade (Standard NZ, 2021). Accordingly, the paper follows two objectives: (1) to investigate the clauses of the contract related to rework provisions, and (2) to set out a platform consisting of guidelines for addressing rework in the identified clauses. Achieving these objectives provides evidence of the contribution to the body of construction and engineering management in contracts. The next section reviews the background of the study and the paper is followed by the research methodology section that presents a developed rework management model for the construction contracts.

12.4 Literature Review

Generally, new studies are built on the results of previous research. Since this research focuses on rework in construction contracts, previous studies on rework and contracts were reviewed. The review of the literature on rework in construction engineering and management revealed many work efforts to understand the impacts of rework on performance (Josephson et al., 2002; Hwang et al., 2009; Hegazy et al., 2011; Eze et al., 2018a), identify the causes of rework (Love and Edwards, 2004b; Oyewobi and Ogunsemi, 2010; Hwang et al., 2014; Forcada et al., 2017), and they also propose models to reduce rework impacts. For example, Zhang et al. (2012) generalised a rework reduction program (RRP) model by managing a continuous improvement loop with four functional processes. Forcada et al. (2017), examined the relationships among the factors that contribute to rework to develop a model for rework prediction. Liu et al. (2020), conducted a study on residential buildings in China through multiple case studies on the sources of rework cost and primary liability bearers. Other studies suggested strategies and management practices to handle rework issues such as quality management, change management, error management, and similar practices (Asadi et al., 2021b). Love et al. (2002), investigated the construction project management systems to understand the impacts of changes and rework using a dynamic system model. Safapour et al. (2019), evaluated the best mitigation practices on the impacts of rework by identifying the early indicators of the causes of manageable rework and found they are classified in three categories, namely, organisations, projects and people. The previous evidence of rework studies primarily focused on identifying rework causes or measuring the impacts of rework on construction performance rather than exploring the relationship between rework and contracts or studying the effect that construction contracts have on rework.

On the other side, the literature shows that many research studies have reviewed and analysed various forms of construction contracts worldwide. A considerable number of previous studies have explored various issues associated with the general conditions of contracts (El-adaway et al., 2016; El-adaway et al., 2017; Assaad et al., 2020; Saseendran et al., 2020; Abdul Nabi et al., 2020). In most previous studies, understanding contractual aspects is one of the key contributors to construction contract performance. Among these studies, various aspects of contract conditions have been tested and analysed, such as safety issues, payments, change orders, contractual relationships, contractual claims, disputes, delays, and extension of time. While some previous studies address rework in the contract documents, few evidences are available to indicate the assessment of rework provisions in the conditions of the standard form of contracts. This paper aims to present a guideline for the appropriate utilisation of the rework provisions under the most widely used standard contracts in New Zealand construction projects to address the identified knowledge gap. As such, the relevant rework provisions of the contract are analysed in conjunction with the interview results to generate a checklist that adequately addresses rework. The result of implementing this checklist at the time of contract preparation reduces rework-related conflicts, disputes, and contractual claims.

12.5 Contract management and the need for studying contract conditions

The contract document is the legal component for a project and it facilitates the relations between the design and construction stages (Hassan and Le, 2020). Lack of contract management knowledge as an integral part of the procurement stage will likely increase the construction risks, result in rework and other conflict issues (Coleman et al., 2020). In addition, poorly drafted contract clauses can lead to cost overruns (Sorde and Sawant, 2015), claims (Abdul-Malak et al., 2020), disputes (Jolodar et al., 2016), and rework (Wang et al., 2019). Some significant aspects of the project, such as safety, quality, and work progress, can be measured and controlled using contract management tools. Contract management comprises four phases, starting with (1) contract preparation, (2) contract development as a guideline, (3) contract review to control project, and lastly (4) contract administration (Hayati et al., 2019).

Overall, the client takes the risk if there is ambiguity in the contract documents through the variation clause (Finnie, 2013), so normally the client's interests are protected in the construction contracts. This perception creates a contract that tends more towards the client’s benefit. Consequently, it triggers the project parties to interpret the contract conditions based on their preferences when rework occurs, leading to conflict and disputes (Kisi et al., 2020). Many contractual issues such as conflicts, claims and disputes are avoidable if contract parties cooperate well during the formation of the general contract conditions, which is one of the essential parts of construction contracts (Bubshait and Almohawis, 1994). The contractual issues are mainly raised from the dominant client contracts, lack of contractual knowledge, inadequate attention to the contract documents (Kisi et al., 2020), improper contract documentation and ambiguity (Moza and Paul, 2018), poor contract administration (El-adaway et al., 2018), and failure to understand the client’s requirement as per the contract (Hassan and Le, 2020).

Lack of addressing rework in the contract conditions will also increase the possibility of claims, conflicts, disputes and other contractual issues. Previous studies have identified some of the relevant contract clauses that have the potential to generate rework. Rework also affects the contract's original conditions, and the impacts of rework are the reasons for the construction time and cost alterations (Asadi et al., 2021b). The study conducted by Mendis et al. (2015), provided a valued contribution to the body of knowledge by identifying contract clauses related to rework in Canada. The study revealed that quality concerns are the most significant clauses of the contract regarding rework followed by workmanship and site management, respectively (Mendis et al., 2015). Overall, for New Zealand construction projects, employing proactive strategies to reduce contractual issues has been recommended in the first place instead of using secondary re-active strategies (Jelodar et al., 2021). In other words, improving contract conditions as a proactive strategy is suggested before the commencement of the construction projects. Therefore, there is a need to propose a guideline to manage contractual issues when rework originates disputes and contractual claims.

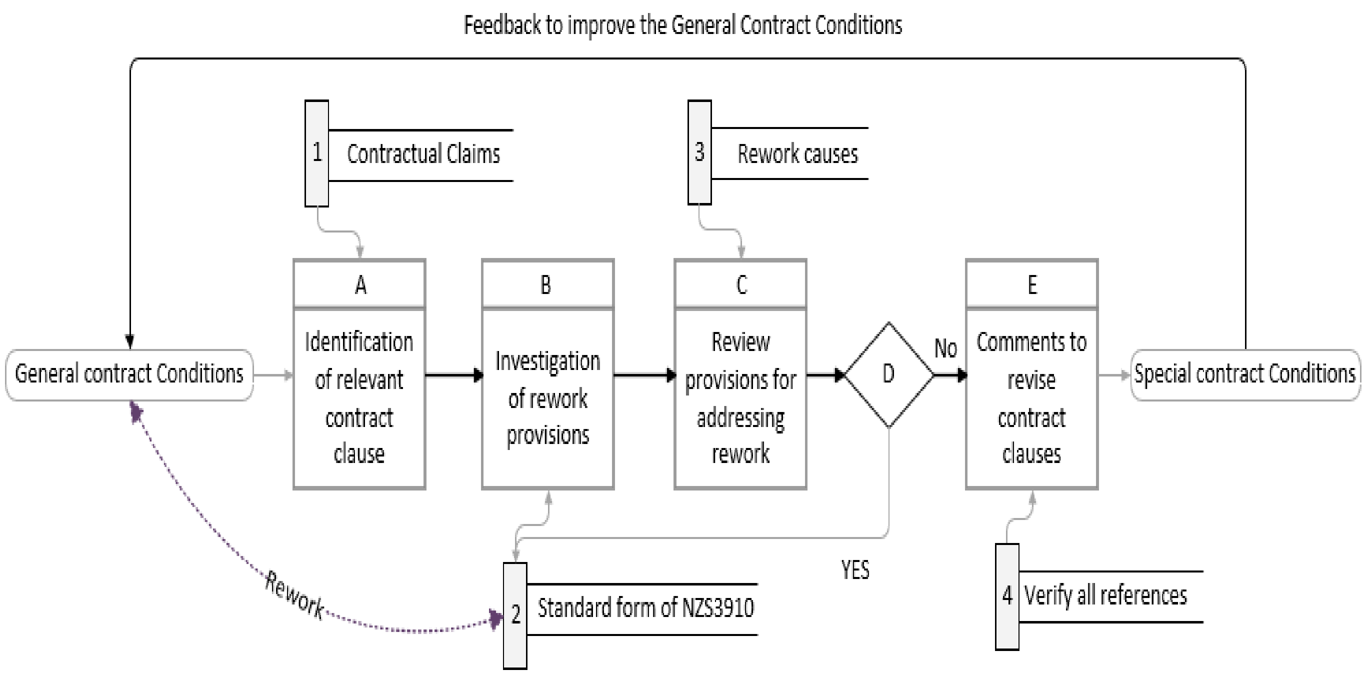


Figure 12.1: *Conceptual framework for validation of the study*

12.6 Conceptual framework

In this research, the general conditions of the contract (GCC) are reviewed and assessed to induce the relationship between the stipulated clauses of the contract and the rework issues. The improvement process of contract conditions by addressing rework in the relevant clauses of the contract is shown in Figure 12.1. The theoretical framework of this research is based on the processing map presented in the following model. The model encompasses four inputs and five activity steps. The process starts with function "A" to identify the rework-related clauses of the construction contract used in New Zealand referred as NZS3910:2013. An attempt to understand and evaluate the relationship between the contract conditions and rework that is usually encountered in contractual claims has been undertaken. This relationship is achieved through the common causes of rework and contractual claims. The significant common causes of rework extracted from the other study on the same contract (Asadi et al., 2022) are applicable in this stage. Function "B" investigates the rework provisions in the identified contract clauses. In this research, a document is evaluated as the general contract conditions and the case is the standard form of construction contracts in New Zealand “NZS3910:2013” that is used most often. Then in terms of addressing the rework issues in the identified clauses, the contract provisions are reviewed in function "C". Function "D" involves a decision regarding whether rework has been adequately addressed in the relevant provisions. No further action is required if the answer is yes; otherwise, the process continues to the function "E". Recommendations for revising the relevant clauses are presented in function “E”, which require verification of all cross-references to maintain the coherency of the contract. Recommendations can be implemented into the special conditions of the contract or can be transferred to the general conditions via feedback. The proposed solution using this model takes into account that: revising contract clauses may address rework that will prevent further contractual claims and disputes. The validity of this solution will be investigated by analysing the construction practitioner’s opinion through professional interviews.

12.7 Methodology

It is assumed that there is a link between rework causes and contract clauses. However, no more details are available to explain how this relationship is structured. A three-step methodology is carried out to explore the character of this relationship. A pre-survey revealed an association between rework and contract clauses (Asadi et al.,2022), and a post-interview process can be utilized as external validation. A similar approach has been adopted by others, specifically for mixed research approaches (Jelodar et al., 2022). The initial questions for conducting interviews were prepared based on the pre-survey results. The interview is chosen in the first step of the methodology to collect more details about rework in the contract clauses and provide evidence for validating the pre-conducted survey. The qualitative approach is the best way to collect empirical evidence relating to this concept (Jelodar et al., 2016). Utilising a qualitative approach, as shown in Figure 12.2, this study follows a multistep research methodology to explore the interrelationship of two separate categories of information. This method is considered appropriate for extracting the process from the participants' opinions (Creswell 2007). Data is collected from two sources; (1) professionals and (2) contract documents, and then the analysis will be undertaken to compare the collected data from both sources. The first step is professional interviews and the collected data from the performed interviews are analysed via the thematic analysis technique. This step presents the practical viewpoints of the participants regarding rework issues in construction contracts. The interview questions have been designed to identify the relevant rework contract clauses and address the rework issues in the relevant provisions. Based on the conceptual framework in Figure 12.1. the interview starts from Function “A” with initial questions to understand how rework is addressed within clauses of NZS3910. It consolidates the outcomes of the previous study (Asadi et al.,2022) conducted through a survey and verifies the identified contract clauses related to rework issues. The interview continues, then moves toward other functions to investigate rework provisions, the extent of addressing rework, and search for solutions to cover rework issues. This process is presented in three themes as addressing, processing and mapping rework as presented in result section.

The second step performs a conceptual analysis based on the framework function "C" in Figure 12.1. Rework-related provisions in each identified contract clause are reviewed considering the various themes from step one. Document reviews in this method are performed on NZS3910. The identified provisions related to rework are reviewed to conduct a conceptual analysis. Then in step three of methodology, the result of the conceptual analysis is compared with the result of the interview's thematic analysis via function "D". The extensive review and a comparison of the previous results confirms relationship that exist between rework and the contract conditions and helps to create a flowchart for mapping rework in the contract. A flowchart of rework processing in the contract is developed using a data flow diagram based on the feedback from 12 professional interviews where the standard form of NZS3910 has been discussed. The addressed and unaddressed rework issues are outlined in the proposed flowchart. Recommendations to fill the identified none-addressed gaps provide a checklist that will be used to improve contract conditions. The checklist includes the necessary revisions to the relevant clauses to minimise rework issues and the probable consequences such as contractual claims, conflict, and disputes.

In this multistep methodology, validity is achieved by removing the weaknesses from every single step and adding the strengths utilising triangulating data (Seneviratne and Michael, 2020). Professionals who have experience using NZS3910 are interviewed face-to-face or via online meetings. The participant's experience regarding rework in the construction contracts is investigated in relation to the contract clauses. A semi-structured interview questionnaire is used for this study with an opportunity given at the end for open discussion to advise recommendations for improving the contract conditions. The questionnaire maintained the consistency of the interviews to follow the mainstream of research. The semi-structured interview questionnaire helps identify the industry's new approach for improving the contract (Saseendran et al., 2020). The questionnaire was available in advance of the interview sessions, and each interview was conducted from an average of 45 minutes to one and half hour. Then the participant was asked how the contract conditions of NZS3910 could be improved to address rework issues. The interviews are completed once data reached saturation level (Jelodar et al., 2021). The analysis of the identified contract clauses in addressing rework is completed in conjunction with documentary review by referring to the contract conditions of NZS3910. The exploratory approach of this study involves data collection from interviews, followed by performing thematic analysis, conceptual analysis and comparative analysis. The method identifies the most relevant rework clauses in the New Zealand standard form of the contract. It also forms recommendations for revising the relevant provisions to improve the contract conditions. The following sections summarise the main points and observations from the conducted professional interviews.

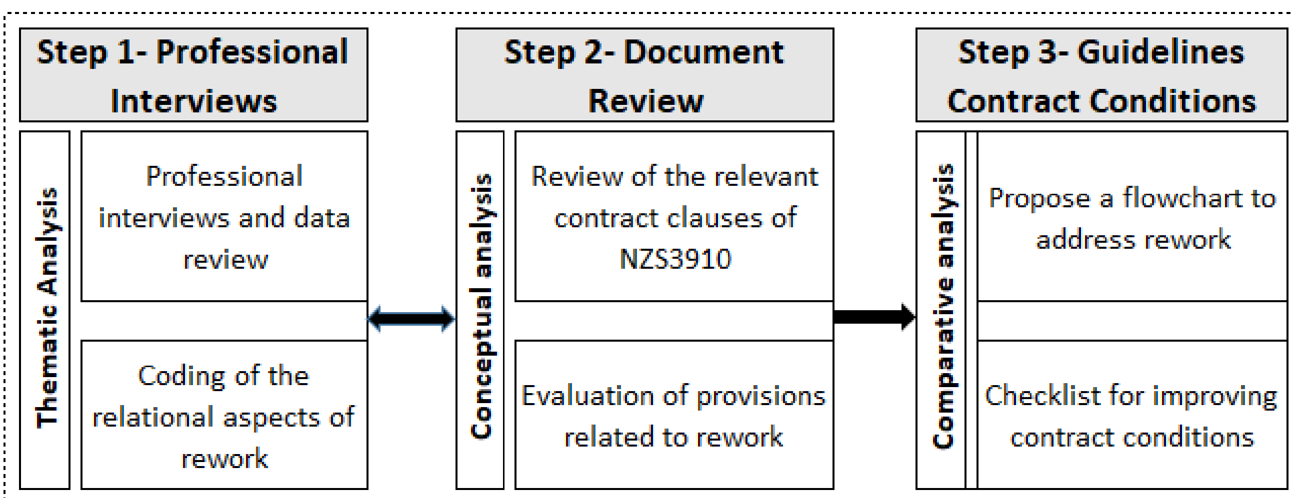


***Figure 12.2**: Research methodology adopted for this study*

12.8 Data analysis and results

In this study, the interview is performed to investigate contract conditions related to rework and get insight into how contract provisions address rework issues. The goal is to identify contract provisions and relevant clauses under rework events and investigate solutions to address rework issues. The analysis of contractual clauses in NZS3910 addressing the most common rework issues was performed by interviewing professionals in the construction industry. The qualitative approach is the best way to understand a phenomenon or concept when little empirical evidence is available (Creswell 2009; Jelodar et al., 2016). In the interview sessions, professionals were asked to provide information about addressing rework in the general contract conditions and then were asked to share their experience in rework events. In summary, the exploratory nature of the qualitative approach applied in this study involves thematic analysis, conceptual analysis, and comparative analysis of the rework-related issues in the New Zealand construction contracts

What needs to be explored in this study is facilitated by using an appropriate sotware for analyzing the collected data from interviews. Nvivo 12 is used very commonly to analyze qualitative data (Seo and Kang, 2020) and it utilized for conducting the thematic analysis in this study. The software allows different ways of experiments to understand the data, and it minimizes bias by coding the phrases. Thematic analysis in this study follows three stages: (1) coding to identify the themes, (2) selection of the relevant themes, (3) combining the selected themes and creating the category of findings (Hansen et al., 2020). The collected data is first transcribed in MS Word and then is imported into Nvivo 12 for analysis. Findings are then used to generate further qualitative descriptions and interpretations.

Table 12.1: Background of the participants

Participants	Years of experience	Background	Expertise
Interviewee 1	45	Architect and Construction Disputes Consultant	Client
Interviewee 2	21	Building Surveyor, Contract Engineer	Client
Interviewee 3	25	Consultant and Contract Engineer	Contractor
Interviewee 4	25	Construction Lawyer, Adjudication, Panellist of Building Dispute Tribunal	Legal
Interviewee 5	17	Commercial Manager in construction Company	Contractor
Interviewee 6	39	Dispute Board Member, Arbitrator, Adjudicator & Commercial Mediator	Legal
Interviewee 7	43	Senior Project Director, Contract Engineer	Contractor
Interviewee 8	25	Commercial Manager in construction Company	Contractor
Interviewee 9	25	Quantity Surveyor- Technical Director, consultant company	Contractor
Interviewee 10	25	Principal Consultant, Contract Engineer	Client
Interviewee 11	15	Projects Lawyer, Specialist Construction	Legal
Interviewee 12	20	Registered Quantity Surveyor, ADR Practitioner	Legal
Average of experience	27 years		

Note: Three of the interviewees were members of the committee for preparing NZS3910 editions of 2003 and 2013.

As shown in Table 12.1, the interviewees represent various backgrounds, from the client, contractor, and legal entities, including quantity surveyors, architects, contract engineers, lawyers, consultants, and commercial managers with an average of over 27 years of experience in construction contracts. The result of the thematic analysis presented in this section is based on the interview questions. First the collected data was coded into 14 themes. Then the selected themes were categorised in three groups, addressing, processing and mapping rework, based on the links between the information. Thus, the rework provisions under each clause are assessed. After that, as the practical aspect of the study, each category is divided into smaller groups extracted from the interviews. The comparative analysis between the identified contract clauses and the interview results is presented as follows.

12.8.1 Theme 1 - Addressing rework in the contract clauses

The interview results revealed that rework leads to disputes which mainly originate from the following reasons: lack of quality, lack of supervision, defects, unclear documentation, improper design, non-compliance, errors, late supply of material, lack of quality system, unqualified people, lack of contract knowledge and finally conflict of interest by the Engineer if rework occurs due to design error and the designer is the client representative. One participant said the design team does a 30 percent design at the time of tender, which is largely inadequate and comes with uncertainty, resulting in contingency and creating contractual claims. Under rework events, the responsibilities of the contract parties must be detailed to identify and note rework and close it. The responsibility of each party for processing rework first needs a common understanding of the rework. This understanding can be achieved by the definition of rework in the contract. The current version of the NZS3910 does not provide a specific definition for rework. According to the interviewees, rework is replaced and referenced with other interchangeable words in the contract, such as defect, non-conformance, making good, removal, and rectification. These words can be considered as rework provisions within an acceptable context related to the subject. Overall, six participants agreed to add a definition for rework to the contract. Participants stated that defect identification is needed before practical completion, which ought to be properly linked to the rework definition. The definition can be entitled under "the remedy of defect" (clause 11.2) or under general obligations (Clause 5) by expanding the usage of rework terminology. With this definition it is important to state the rework, particularly if the client requires a contractor to bring an item up to standard.

Over 30 percent of participants (four persons) claimed that rework is not addressed adequately in the contract conditions, and six claimed that it is addressed in relative terms. In contrast, two of the participants emphasised that whether rework is fully addressed, or it is not required to be added in the contract because variation (clause 9), defect liability (clause 11), and inspection (clause 6) cover rework issues. Nonetheless, during the professional interviews, the following clauses were introduced by the participants in relation to rework issues.

- Clause 5 “General obligation” and subclauses 5.4, 5.6.
- Clause 6 “Engineers’ powers and responsibilities” and subclauses 6.4 to 6.8,
- Clause 9 “Variations” and subclause 9.2,
- Clause 10 “Time for completion” and subclause 10.4,
- Clause 11 “Defect liability” and subclause 11.2,
- Clause 13 “Disputes”

Considering the relevant rework provisions in NZS3910, the participants highlighted some of their concerns that addressed other terms rather than rework. This is since there is no terminology for rework that is used in the contract conditions, however removal and making good is one of the terms that may refer to rework. As a general comment, it can be mentioned that NZS3910 is not very descriptive for rework regarding who is responsible for what; one of the participants claimed that it is all very reliant on an independent Engineer to assess. Another participant claimed that the whole contract documents do not need to go much further in terms of rework clauses because rework occurs due to lack of skills and supervision rather than the party's obligations. Clause 6.5 allows redoing works and materials that are not in accordance with the contract. While most of the participants referenced rework to the provisions under defect and variation clauses, some pointed out that part of the provisions can also be referenced to the inspection clause. It is advised that defect liability, defects notification period, and defect remedying address the contractor returning to do rework. NZS3910 uses generic terminologies, and a lot of the wordings are deliberately neutral; thus, a defect is assumed that includes rework. Nonetheless, some believe that rework prior to practical completion cannot be referred to the defect liability section as this clause serves different purposes, so rework needs to be discussed in other clauses. The other referenced provisions were under the variation clause, while none of the reasons mention rework as the keyword. Most participants said if the project parties damage something and cause rework, that is clear enough to be notified on clause 9. According to this clause, most participants believe that if rework occurs due to the client's fault, the contractor is reimbursed. The only grey area is failure to the material, which is not covered by the variation clause. Clause 9 is not linked to a specific event or interpretation, and it is a procedural clause. Table 12.2 presents the documentary review results and provides the list of provisions under the relevant clauses of the contract that can be linked to rework.

12.8.2 Theme 2- Processing rework in the contract clauses

The interview results for the other questions on rework and claims are assessed and the way NZS3910 addresses rework-associated risks can be categorised in the processing rework theme based on four subgroups: risk allocation, human resources attributes, design process, and the role of the Engineer. These are discussed in the following sections.

12.8.2.1 Rework risk allocation in NZS3910

Regarding risk allocation of rework in the contract provisions, seven participants approved that risk within clauses of the contract is fairly addressed to both sides. They used similar terms to describe how risks have been distributed in various clauses such as fair between parties, balanced document, neutral document, very evenhanded, and optimistic risk allocation. Rework risk provisions for addressing rework received mixed viewpoints from the participants. One participant emphasised those risks are fair without special conditions, while the other said risk is incomplete and does not refer to who bears the risk of ground conditions. In lump-sum contracts, many risks go to the contractor because the risk profile can always be changed through special conditions, and generally, clients ask their solicitors to change it for commercial developments. A lawyer claimed that creating many special conditions is a bad practice in New Zealand construction contracts. One participant argued that fair allocation of risks is not enough to achieve a successful project because risks need to be distinguished at the beginning and then distributed between the parties based on who can handle it better and then evaluate it in every project step.

Risks are addressed under clause five, and according to one of the participants, optimistic allocation of risk is inconsistent with the outcome of the project, and gaps in NZS3910 should be addressed around risk allocation. For example, instruction for advance notification on any matter that affects time and cost does not refer to the quality, in which most of the rework events deal with the quality of work. If a contractor fails to give such notifications, then he must battle for the resulting variations and the granted times under clauses 9.3 and 10.3, however the Engineer is never under pressure when fails to give such in-advance notifications. While the best approach for risk management is to see who can take the risk to the benefit of the project, the fair balance of shared risk is no more matter for project management. Contract document with balanced risks for contractual parties does not provide any advantage. Instead, a contract must bring the point of risk registers that include identifying risks during the construction that may increase the cost, and time of the project regardless of liability under the contract conditions. The identified risk then is evaluated in terms of occurrence, its impacts, and possible mitigation measures, and the person responsible for it. The risk register is not a document binding to the contract, and it is used for better project management as a live document to reflect the actual risk in real-time. All contract parties can use it in mutual meetings following the contract award to discuss their responsibilities.

Table 12.2: Relevant rework provisions in the identified clause of NZS3910:2013

Related provisions to the contractor	Related provisions to the client
(5.1.1) the contractor shall complete, handover to the principal, and remedy defects in the contract works and provide all required services…. *(5.4.6) The Contractor shall* ***make good*** *as soon as practicable damage to any adjoining property arising out of the carrying out of the Contract Works. Such making good shall be carried out at the expense of the Contractor unless the damage arises from any of the matters referred to in 7.1.2 in which event the making good …. shall be treated as a Variation.* *(5.6.1) The Contractor shall be responsible for the* ***care of the Contract Works*** *or any Separable Portion and all Plant from the time it obtains possession of the Site until the relevant time of Practical Completion.* *(5.6.2) (5.6.3) (5.6.4) The Contractor shall be responsible for the* ***care of all Materials / loss or damage to the contract works / loss or damage to the site*** *…*	*(5.1.6) The principal warrants that it has made available to the Contractor …. all information of which it is aware, …. relevant to the Contract Works. The Principal makes no warranty as to the* ***sufficiency or accuracy of such information****.* *(5.6.6.e) The expected risk:* *Any* ***fault, defect, error, or omission*** *in the design of the Contract Works for which the Contractor is not responsible under the Contract.*
(6.4.2) …. the ***work or Materials*** *are found to be* ***not in accordance*** *with the requirements of the Contract, the Cost, including any Costs incurred by the Engineer or the Principal, shall be borne by the Contractor.*	*(6.5.1) The Engineer may at any time prior to the expiry of the Defects Notification Period by notice in writing instruct the Contractor* ***to remove and re-execute or to make good*** *any work which in respect of* ***Materials or workmanship*** *is* ***not in accordance with the Contract****. The Contractor shall comply with the instruction at its own Cost.* *(6.5.5) If the Contractor* ***supplies any Materials*** *or carries out any* ***work not in accordance*** *with the Contract, the Engineer may at his or her discretion allow such Materials to be used or such work done ….* *(6.8.1.a) Engineer may instruct urgent work in the event of any* ***accident, emergency, or failure, or other similar event*** *occurring to or in connection with the Contract Works, …*
(9.2.3) Where the Contractor considers ***any matter*** *which is not described in 9.1 should* ***be treated as a Variation****, the Contractor shall within 1 Month of becoming aware of the matter or as soon as practicable thereafter give written notice to the Engineer to that effect.* *(9.5.2) If during the Contract the Contractor encounters on the* ***Site physical conditions*** *which it considers could not reasonably have been foreseen when tendering by an experienced contractor……increase its Costs, the Contractor shall as soon as practicable and where possible…. notify the Engineer and confirm such notification in writing.*	*(9.1.1) The Engineer may order any Variations to the Contract Works within the scope of the Contract that: (a)* ***Increase or decrease*** *the quantity of any work; (b)* ***Omit*** *any work; (c)* ***Change*** *the character or quality of any Material or work; (d) Require* ***additional work*** *to be done; or (e)* ***Change*** *the level, line, position, or dimensions of any part of the Contract Works* (*9.5.4) On receipt of such notice from the Contractor, the Engineer shall forthwith investigate the conditions and after discussion with the Contractor shall determine* ***whether or not the conditions are*** *such as the Contractor has notified under 9.5.2.*
(10.4.3.b) Within 5 Working Days of receipt of such notice or as soon as practicable thereafter the Engineer shall inspect the Contract Works or Separable Portion and shall thereupon; give the Contractor written notice of the ***work to be altered*** *or completed in order to qualify for a Practical Completion Certificate.*	*(10.3.1 The Engineer shall grant an extension of the time for completion of the Contract Works or for any Separable Portion if the Contractor is fairly entitled to an extension by reason of: (a) The net effect of any* ***Variation****; ….. (d)* ***Loss or damage*** *to the Contract Works or Materials; (e) Flood, volcanic, or seismic events; (f) Any circumstances not reasonably foreseeable by an experienced contractor at the time of tendering and* ***not due to the fault of the Contractor****; or (g)* ***Default by the Principal****, or any other Person for whose acts or* ***omissions*** *the Principal is responsible, which is not a Variation.*
(11.2.1) The Contractor shall ***remedy defects and damage*** *in the Contract Works resulting from* ***defective workmanship or Materials*** *that arise before the end of the Defects Notification Period. The Contractor shall* ***remedy any such defects or damage*** *within 5 Working Days of receipt of the Engineer's notice or within such other reasonable time as agreed by the Engineer in writing.* *(11.4.1) Notwithstanding the issue of the Final Completion Certificate, the Contractor shall* ***remain liable for the fulfilment*** *of any obligation of the Contractor under the Contract which then* ***remains unperformed or not properly performed****.*	*(11.2.1) The Engineer shall, during the Defects Notification Period or within 5 Working Days thereafter, give notice in writing to the Contractor of* ***defects or damage to be remedied.***

Source: NZ Standard, NZS3910:2013.

12.8.2.2 Human resources attributes in NZS3910

Most of the participants agreed that even though NZS3910 does not address the required attributes of the human resources adequately, they believed additional references were not necessary. However, one participant argued that contracts often use words such as reasonable, skilled care, or diligence, and these terms do not address the human resources factors. He advised that human resources attributes can be carefully added to the contract with safety measures to ensure the added clauses are interpreted properly by the contract parties. Others mentioned that such requirements should be sorted prior to the contracts. The client can ask for information about staff experience before the contract is awarded. Thus, it is already part of the contract as tender conditions and it is not required to be added to the contract. However, adding it to the contract does not make any difference because the contractor works to reasonable care and that inherently requires skilled people. The contract conditions place honesty on the contractor to provide skilled workers. The contractor is obligated to give the client a finished product without rework and obliged to have the right people to do it. The contract will not solve this problem, but a wider marketplace to hire people may help. It can end up with problems for recruiting in New Zealand due to the scarcity of skilled people. A relevant provision to this matter can be found under clause 5.9 as noted in the statement below.

"(5.9.1) The Contractor shall, except where otherwise specified in the Contract, supply at its own Cost everything necessary for the completion of the Contract Works and the performance of its obligations under the Contract including minor items not expressly mentioned in the Contract and of a type not normally detailed but necessary for completion and performance of the Contract Works. (5.9.2) All Materials and workmanship shall conform with the provisions of the Contract.

Unless otherwise specified in the Contract, all Materials used other than in Temporary Works shall be new. All work shall be carried out in a tradesman-like manner."

12.8.2.3 Design issues in NZS3910

Poor design processing in construction projects is quite a big issue in New Zealand construction contracts. In practice, tenderers are invited while the design is still under progress, and such incomplete design and documentation must be worked through the construction stage. Errors and omissions are common in real projects, all of which need to be corrected. Therefore, rework is emerged as part of this process. In many cases, a contract is signed where the drawings or the designs are not complete. As a result, the engineer or the architect is expected to complete the design as the project progresses. The consequences of such poor designs have led to rework and require serious revision in the tendering process.

12.8.2.4 The role of Engineer in NZS3910

Once a construction contract is issued, all supervision duties during the construction stage are delivered to an independent consulting person who is named "Engineer" in the conditions of contract NZS3910. Contract provisions for addressing rework primarily rely on the Engineer's decisions, and the Engineer's role is critical for rework processing. The interview result showed that there are different viewpoints in the industry regarding the role of Engineer as it relates to the contract. The Engineer in NZS3910 is the person who decides whether the rework will be paid or not, whether it will be at the contractor's cost or the client, so professionalism and experience are required to make such decisions properly. Once the Engineer makes a logical decision, no lengthy procedure is required to determine if the rework is a variation or not. The defect liability period (DLP) provisions are very much based on what the Engineer thinks. An Engineer needs to develop a good working relationship with the contractor to avoid problems before they happen. Engineers to the contract are supposed to be entirely impartial to make an independent decision or determination of something as rework that needs to be paid for by the client or the contractor. Even though this definition works conceptually, the Engineer is often the client's cost consultant or architect, this can place stress and pressures on the independent view of the Engineer. In the building sector, generally, an architect designs a project and administers the contract. If the architect makes a mistake, in practical terms, to avoid blame by the client, the architect may try to cover the mistake up. Another problem is there is not always a person who is assigned to administer the contract. One of the participants gave the example of four projects with an average contract of 70 million New Zealand dollars where an Engineer was not assigned to the contract, so project managers administrated the contract under the client's control.

According to clause 6 of the contract, the Engineer must exercise his duty impartially according to the stipulated provisions under various circumstances. The dual job of the Engineer as the client representative and independent administrator to certify works is criticised because of a conflict of interest in performing duties. One participant said, Engineers to the contract are leaning towards the client and, in the ideal scenario, is more of a referee such as a standby dispute resolution board (DRB), as someone who is sufficiently connected to the job. One of the lawyers stated that NZS3910 is acceptable in the way that it guides the Engineer, but it needs a provision to note that the Engineer is not the client's employee. He believed that, the dual role is an outdated method. The Engineer in clause 6 has a direct personal interest in many decisions over the client's interest, in preparing designs, tender management, contract administrating, instructing variations, awarding EOTs, certifying payments, and dealing with disputes. More conflicts of interest can be seen in the following statements. "clause 6.2" has limited the impartial role of the Engineer only to valuing work and issuing certificates. The Engineer is responsible for drawing and specification preparation "clause 1.2", measurement and adjustment of unit rates "clause 2.3", clarifying ambiguities in the contract documents "clause 2.7", inspection, testing and rectification of work "clauses 6.4 and 6.5", suspension of work "clauses 6.7", instructing variations "clause 9", the rectification of defects "clause 11.2", expending provisional sum, and contingency sum. At the same time, has authority for extension of time in "clause 10.3", estimation of the price for rectification of defects "clause 3.1.8", valuing variations "clause 9.3", reduction of liquidated damages "clause 10.5.2", reduction of retentions "clause 12.3.1", and so many other items that are interacted with conflict of interests. With all this evidence, it is time to reconsider the independent role of the Engineer by shifting towards project management and dispute resolution procedures that are more robust. The role of Engineer in the contract NZS3910 is defined as follows:

(6.2.1) The dual role of the Engineer in the administration of the Contract is: (a) As expert adviser to and representative of the Principal, giving directions to the Contractor on behalf of the Principal, and acting as agent of the Principal in receiving payment claims and providing Payment Schedules on behalf of the Principal; and (b) Independently of either contracting party, to fairly and impartially make the decisions entrusted to him or her under the Contract, to value the work, and to issue certificates.

12.8.3 Theme 3- Mapping rework in the contract clauses

The way rework is managed through the identified clauses of the contract highly depends on the clarity of provisions highlighted in Table 12.2. The wording of provisions was considered inadequate by a number of participants as discussed hereafter, and accordingly, some solutions and recommendations for covering rework issues are pointed out as the best practices for revising contract clauses and the relevant provisions. In terms of identifying the best practices it is always necessary to understand the problem. The problem associated to NZS3910 most often were investigated first, and then the best approach and strategies to manage rework were identified. Overall, the lack of an independent contract administrator or the lack of independent monitoring of the construction, the lack of training around the Engineer to the contract role, inadequate design, simplistic tendering process, lack of solid apprenticeships, as well as adding a long list of special conditions are the associated problems to the NZS3910 contract document in New Zealand. The participants identified the best strategies to tackle rework issues in which QA plans and ITPs have been referenced the most as they are directly connected to the quality aspects of the project. The other most referenced strategies were design processing and clarity in construction documents. However, the participants mentioned some other practices such as supervision and contract administration, education and qualification, good relationship and realistic expectations, client involvement, and the early involvement of the contractor in projects.

According to the participants, rework can be managed with a few changes in the provisions followed by the right process. In relative terms these provisions show the work process whenever rework occurs. Rework may be part of the defined categories under the variation clause, as it has no clear definition in the contract. Depending on different events, the rework may vary, it may be accepted as a variation or it may be rejected. Clause 9 does not clearly address such decisions, and it can be amended with one procedural sentence that rework can also can be treated as a variation if it occurs out of the contractors' liability. The contractor is also responsible for time-related matters in the contract based on the provisions of clause 10. These provisions give a very clear time bar regarding delay processing and extension of time; however, some comments can be added to this clause to make it more appropriate for rework events. Firstly, the contract needs to be adjusted based on the building Acts, and any inconsistency with the timings must be highlighted and then coordinated appropriately in the same direction. According to the Act guidelines, the client is entitled to call up defect remediation within 12 months, and contract provisions under this clause need to be aligned with 12 months. Basically, there is no mention of rework in clause 10. If rework is not under the contractor's responsibility, an extension of time should be awarded. Such a statement has not been mentioned in this clause. Since the variation clause does not cover rework, adopting provisions under clause 10 in line with variation and inspection clauses will address rework adequately. Overall, the time bars clauses create some commercial certainty, while some arguments around it also provide a claim-based culture.

Another clause that can slightly be revised to address rework is Engineer power under clause 6. In the current provision that refers to the independent role, the appointment process of the Engineer is not mentioned in detail. In practice, it was never enforced that the Engineer shall be an independent person, so rewording this provision is required, emphasising that the Engineer has to stay out of the design team, client, and contractor organisation. The Engineer shall also determine whether rework is required due to the contractor's fault or inability to deliver the works as designed, or whether it was a result of an ambiguity in the contract documents or something else. The inspection clause does not lead the Engineer to define the outcome of any inspection or testing, and there is no obligation for the Engineer to award this result, which for rework events is quite important. This evidence shows that while NZS3910 was designed well, even though, at some point, it still needs improvement. NZS3910 has introduced and highlighted the critical points of cost, time, and quality. However, without registering risk at the beginning of the projects, little can be achieved in practice. Thus, a checklist that briefly shows the process of reworking will be helpful to ensure all aspects are addressed.

12.9 Further discussion on NZS3910

Rework and changes are a fact of life in construction projects, even so their impacts must be limited. Alongside the interview sessions, participants proposed some general comments on

NZS3910 to improve the conditions of the contract. They mainly discussed risk registration, contract termination, and dispute resolutions. NZS3910 is not a collaborative contract; however, it is the most prominent selling standard in New Zealand and has been written to be used by everyone, not only the very experienced or knowledgeable people. This form of contract should be used as a document to encourage cooperation. It is a contract for vastly different types of work, from small buildings to the massive construction of civilian projects. It is also written to be aligned with NZ laws and contract clauses bound to the Construction Contracts Act (2002). However, some participants believe that it is still too legalistic, standard forms shall not be confused by many potential special conditions. An interviewee linked the process of reworking to a dispute clause and said lack of clarity in this clause is used as a delay tactic by practitioners and proposed that clarity around how an arbitrator is selected necessitates a better method to force the process. The other participant referred to the various time-limited combinations of Engineer review with the other methods that makes it complicated to get a neutral decision. The impartiality of the Engineer is under question when there are such strong bindings that exist under clause 13.2.

There was also a discussion on risk allocations to the contract parties. Participants advised simplifying the allocated risks as a matrix or an addendum that can be attached to the contract. Parties generally use special conditions to transfer risks from their neutral position, and in this case, transferred risks need to be clearly identified. Two participants also proposed setting up some meetings for risk reduction before starting the contract, to understand where there may be risks. A participant also brought up termination of the contract for discussion on clause 14, which gives another opportunity to the contract parties for the termination in a highly complex way. The termination request needs suspension by the Engineer, which is meaningless. The question is, how can a contract be terminated if the Engineer suspends it? Based on the above discussion and comparing interview results and contract provisions in addressing rework, a list of recommendations for improving the contract conditions of NZS3910 is presented in Table 12.3. As shown in the next sections, the identified weakness of the contract, and further guidelines to address rework and the final checklist are completed accordingly. Table 12.4 also shows the list of general suggestions to improve the contract process.

Table 12.3: List of recommendations to improve contract conditions by addressing rework

Row	Clause No.	Recommendations
Rec. 1	(5) (11.2)	Definition of rework, it can be added to remedying of defects or general obligation clauses
Rec. 2	(5.6.6)	Responsibility for loss and damage needs be to be added to the list of expected risks
Rec. 3	(6)	Discloser of the agreement between the client and the engineer in the contract, it pushes the engineer role to the maximum independency
Rec. 4	(6.2)	Selection of an enforced independent person as an Engineer to the contract
Rec. 5	(6.4)	Define the outcome of inspection and award the results
Rec. 6	(6.4)	Adding determination of rework as part of the Engineers' duty
Rec. 7	(9)	If rework is treated as variation, check whether it is suitably processed same as change orders or not
Rec. 8	(9.5)	Unforeseen physical conditions need reconsideration as it is one of the most dispute issues and make a clear statement to explain and adjust this section based on the scope of project
Rec. 9	(10.3)	Review Extension of Time to add rework in the list of reasons for delay
Rec. 10	(10.3.2)	Revising the statement says "the engineer shall not be bound" in time bar provisions with a suitable wording.
Rec. 11	(10.4)	Revise relevant subclauses to cover rework as part of defect
Rec. 12	(11.1)	Adjusting the contract according to the Building Act guidelines
Rec. 13	(13)	The Dispute clause is complicated, and the process of arbitrator selection can be written simply in few certain steps
Rec. 14	(13)	Improve the dispute provision by adding "if either party considers it necessary to take the matter further, then they go through arbitration"
Rec. 15	(13)	The whole business of a disputes review board should be accommodated in 3910 to facilitate rework, discuss it between parties and find an appropriate solution
Rec. 16	(14)	Simplify provisions for termination of the contract. Ambiguity in the clause 14.3.3 to give rights to the contractor for termination of the contract needs to be removed. How contractor will be able to terminate the contract when the progress of the whole of the contract works has been suspended in advance by the Engineer. This provision needs to be revised in the contract conditions.

During the professional interviews, other contract weaknesses were also identified, and experts proposed some general recommendations to address them. This part of the findings does not deal with rework issues, but they are significantly important for improving the contract conditions.

Identified weakness of the contract during the interviews

- The dispute clause is slightly complicated, and the decision process is not as clear as it could be,
- NZS3910 is too legalistic while standard forms shall not be confused by a lot of potential special conditions,
- The process of variation valuation is extraordinary expensive, and poor in terms of contract administration,
- The termination of the contract follows a very complicated way,
- The responsibility for loss and damage is a little bit unclear,
- The concept of reasonable foreseeability by contractors is not the best approach in clause 9.5,
- The provision around “the engineer shall not be bound” can be implied differently from “the engineer shall reject”, it makes debate on to be either bound or reject?
- No guidance for the concurrency events under extension of time,
- Excessive special conditions,
- No risk register system or the matrix of allocated risk,

Table 12.4: List of general suggestions to improve contract process

Row	General Suggestions
1	Generate a team attitude between the contract parties
2	Simplify the actual risk allocation to avoid special conditions / prepare a matrix of risks attached to contract / risk register
3	Meetings for risk reduction before signing the contract
4	Make an obligation to the parties to follow law changes,
5	Use plain English language for writing. For example, the insurance clauses are still very difficult. The payment clauses also are quite convoluted.
6	Tanning of the Engineer to the contracts
7	Auditing the independency of the engineer by a third party and a registration system for Engineers to the contract
8	Updating the contract with the requirements of Resource Management Act for health and safety updates
9	Force majeure can be added in the future editions of the contract
10	Variation clause needs to be simplified

12.10 Guidelines for processing rework in contract

It is acceptable for clients to use standard forms of the contract, yet in many cases, the general conditions of the contract are changed to the favor of one party. This part provides background information for revising contract clauses based on the supportive documents and information. Therefore, all suggestions for improving contract clauses in addressing rework after comparison analysis in the previous stages are presented in Table 12.3 and Table 12.4. It helps contract practitioners find gaps under each clause, and early identification of these gaps allows adding some notes to the contract, enhancing the contract conditions during contract formation. The chain of all advised activities can be followed in the flowchart that refers to the contract's rework processing map as shown in Figure 12.3. This flowchart shows which clauses of the contract need amendment and it is linked to the list of recommendations that address rework under each clause. The list of recommendations then leads to more detailed suggestions that act as guidelines and can be added or replaced in the current provisions of the contract, as shown in Table 12.6. A checklist is also developed based on the comparative analysis and the proposed flowchart. It includes a series of questions and suggestions that need to be considered before the commencement of work. The checklist answers various aspects of rework in the contract and will address rework issues. Therefore, it comprehensively covers the relevant rework issues discussed in this study. The checklist answers the contractual rework gaps, and so addresses rework concerns during contract preparation. This process removes ambiguities and therefore projects will encounter fewer disputes and contractual claims.

The poor process of rework management and its direct impacts on the project performance necessitates the necessity to establish a reliable and comprehensive contract assessment model that governs the construction project life cycle. This research study provides contractual guidelines for addressing the contracting parties' obligations to include the aspects of rework under the New Zealand standard forms of contract NZS3910. The analysis and associated recommendations will result in generating more practical construction contract documents in the future and will lead to more sustainable construction projects.

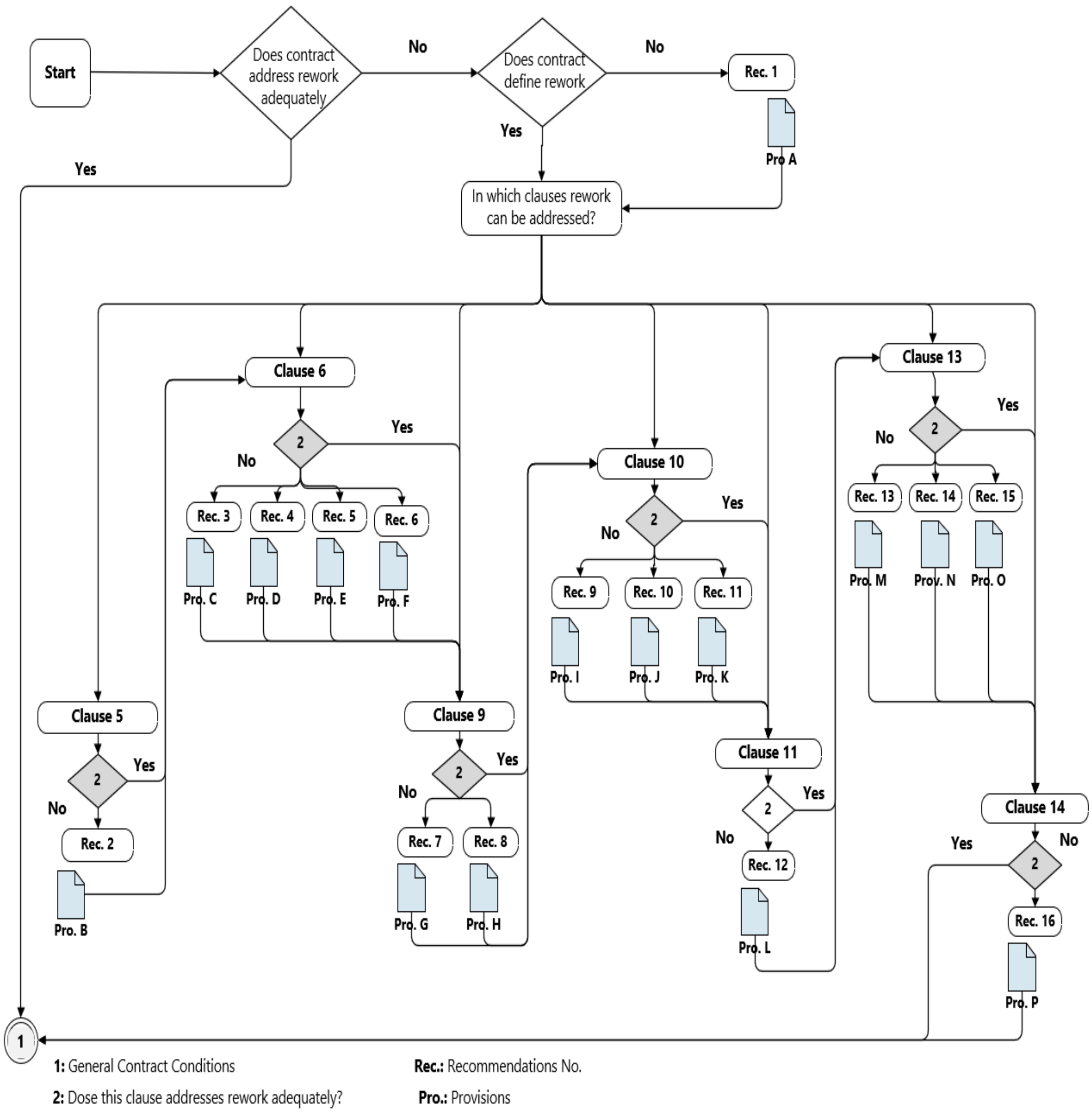


Figure 12.3: *Rework process map in General Contract Conditions NZS3910*

12.11 Implication of the study

This study enhanced the contractual understanding of the rework provisions in the standard form of contract NZS3910 from a practical and theoretical perspective. It provides adequate information for contracting parties regarding their responsibilities in rework events. This study promoted the relevant clauses of the contract to reduce or prevent rework-related issues such as contractual claims and disputes. Moreover, this study proposes a flowchart of rework processing in the contract clauses, which results in the provisions that need to be revised to overcome the gaps in addressing rework issues. Identifying such provision gaps leads to suggestions and recommendations for improving contract conditions that can be added to the contract at the early stages prior to construction commencement. The list of recommendations will then be developed as a checklist for drafting the new version of the contracts that addresses rework in future work as shown in Table 12.5.

Table 12.5: The checklist of items to be controlled for addressing rework in NZS3910

	List of questions
1	Is contract included an appropriate definition for rework? Does the terminologies and definitions in the contract interacted to relevant references from rework?
2	How does the contract deal with the responsibilities regarding loss and damage in subclause 5.6.6? Are they clearly defined to address parties' responsibilities if rework occurs?
3	Are the right and obligations of the Engineer defined independently in the clause 6? Does the contract state clearly that the Engineer is not employed by either party?
4	Does the contract include the Engineer's agreement for performing the role?
5	How the Engineer decide for an event to be considered as rework? Does any provisions of clause 6 present the method of rework processing?
6	Does the Engineer provide evidence for his/her decision regarding determination of rework resulted from inspection under clauses 6.4?
7	If rework treated as variation or caused by change orders, does the contract provisions clearly address how rework is processed under clause 9?
8	Does contract place an appropriate procedure for rework processing under relevant clauses to unforeseen circumstances? How such situation is followed up?

9	Does the list of delays under clause 10 cover any events for referencing as rework? Is the contractor entitled for an extension of time for delays and disruptions resulting from rework out of his/her obligations?
10	Is there any condition for the eligibility of the contractor in time-adjustment resulted from rework?
11	How are the cost and time effects of rework determined in the contract?
12	How rework is treated under clause 10.4? does defect definition in relevant provisions address to rework? How practical completion achieved when rework occurs? Does any provision need changes to address rework?
13	Are the contract provisions under defect liability period aligned with the time bars in Building Act regulations (clauses 11)?
14	Does dispute clause include a method that shows how contract parties act for any conflicts raised from rework? Does rework circumstances traceable under despite clause?
15	Is risk register attached to the contract? Is there any obligation for parties to prepare risk register during contract formation?
16	Does contract provide a guideline for auditing the Engineer? Is it required such provisions to be added to the contract?

The content of the checklists was based on the analysis of the interviews that were conducted and the contract documents review. In addition, the checklist questions help contracting parties avoid ambiguities in the contract documents, which can lead to interpretation and contractual claims. Ultimately, the presented questions can be a quick reference for the contracting parties while drafting a new contract or updating a standard form of contract. The implementation of the provided checklist during the contracting phase is essential. In addition, the research study is expected to motivate construction lawyers that prepare this form of contract to focus more on the practical aspects of contract clauses related to rework and reconsider some of the uncertain language. The study findings showed that there is room for improvement in the rework provisions in the New Zealand construction contract that reduce the uncertainty of the allocated risks. Table 12.6 summarizes required steps to achieve the guidelines for mapping rework in contract provisions of NZS3910.

Table 12.6: Guideline for mapping rework in relevant contract provisions of NZS3910:2013

Relevant contract clause	Rework issue originated from *	Addressing rework in related provisions	Required revisions or amendments based on the recommendation list (to be added / revised)
Clause 2 The contract	- Changes, modification and revisions	(2.3.4), (2.7.3)	-
Clause 5 General obligations	- Damage and defects	(5.1.1), (5.6.4)	-
	- Incomplete information	(5.1.6)	-
	- Incomplete contract documents	Not addressed	In this contract rework is referring to activities to correct construction errors when the performed work does not meet the requirements of the contract
	- Error in design/construction	(5.6.6), (5.8.5)	-
	- Incomplete design and omission	(5.6.6)	-
	- Unclear line of authority	Can be to be added to expected risks 5.6.6	(i) Any loss and damage caused by rework for which the contractor is not responsible under the Contract
	- Poor-quality material	(5.18.2)	-
	- Carelessness	(5.6.1) to (5.6.4)	-
Clause 6 Engineers' power and responsibilities	- Conflict of interests	Not addressed	The agreement between the Principal and Engineer shall be set out in the special conditions of the contract
	- Changes, modification and revisions	(6.3.3)	-
	- Engineers' expertise in design and construction	Not addressed	The criteria for selection of the Engineer shall be according to the requirements of the Contract and shall be set out in the special conditions
	- Defective materials	(6.4.1), (6.4.2), (6.5.1)	-
	- Ineffective use of quality management practices	Can be added to the end of 6.4.4.	In any case the report including the outcome of inspection, recording, measurement, and testing shall be recorded, and a copy of result shall be reflected to the Contractor
	- Replacement of material	(6.5.5)	-
	- Inefficient management process	Can be added to the end of 6.4.2.	The Engineer shall advice determination if the test report resulted in rework
Clause 8 Insurance	- Defective materials	(8.3.5), (8.7.1)	-
	- Incomplete design and omission	(8.3.4)	-
	- Error in design/construction	(8.3.5), (8.7.1)	-
Clause 9 Variations	- Unclear instructions	Can be added to the list under 9.1.1.	(f) Required rework to be performed based on the Engineers' determinations
	- Poor site management	(9.5.2), (9.5.4)	-
	- Changes, modification and revisions	(9.1.1), (9.1.2)	-
	- Unpredictable factors from different sources	Can be added to the end of 9.5.1.	A list of events that may encounter the Contractor on the site physical conditions need to be prepared based on the scope of work and shall be added to the special conditions
	- Poor-quality material	(9.1.1)	-
Clause 10 Time for completion	- Any approved rework causes	Can be revised under 10.3.1.	(d) Loss or damage to the Contract Works or Materials caused by rework
	- Defective materials	(10.3.1)	-
	- Time pressure	Can be added to sub-clause (b) under 10.3.2.	When rework is required to be performed, the notice is given within a reasonable time based on the Engineer's logical determination; and
	- Communication	(10.4.3)	-
	- Incomplete design and omission	Partially addressed (10.4.1), (10.4.2)	10.4.1. Practical Completion is …. except for minor omissions, rework and minor defects. and 10.4.2. When the Contract Works including the instructed reworks by the Engineer or any Separable Portion are ….
	- Poor-quality material	(10.3.1)	-
Clause 11 Defects liability	- Defective materials	(11.2.1)	-
	- Poor contract documents	Can be added to the end of clause 11.1.	If Building Act guidelines are used in the contract for any rework occurred after completion of work, the defect notification period shall be adjusted in the special conditions accordingly.
	- Incomplete design and omission	(11.3.1)	-
	- Unclear line of authority	(11.4.1)	-
Clause 13 Disputes	- Coordinating between members	Can be revised with simple steps in clause 13	If the dispute cannot be resolved by the parties, then they need to explore whether dispute can be resolved by use of mediation or other alternative techniques. The process must be added to special conditions.
	- Coordinating between members	Can be added to the end of clause 13.3.4.	If either party considers it necessary to take the matter further, then they go through arbitration

12.12 Conclusion

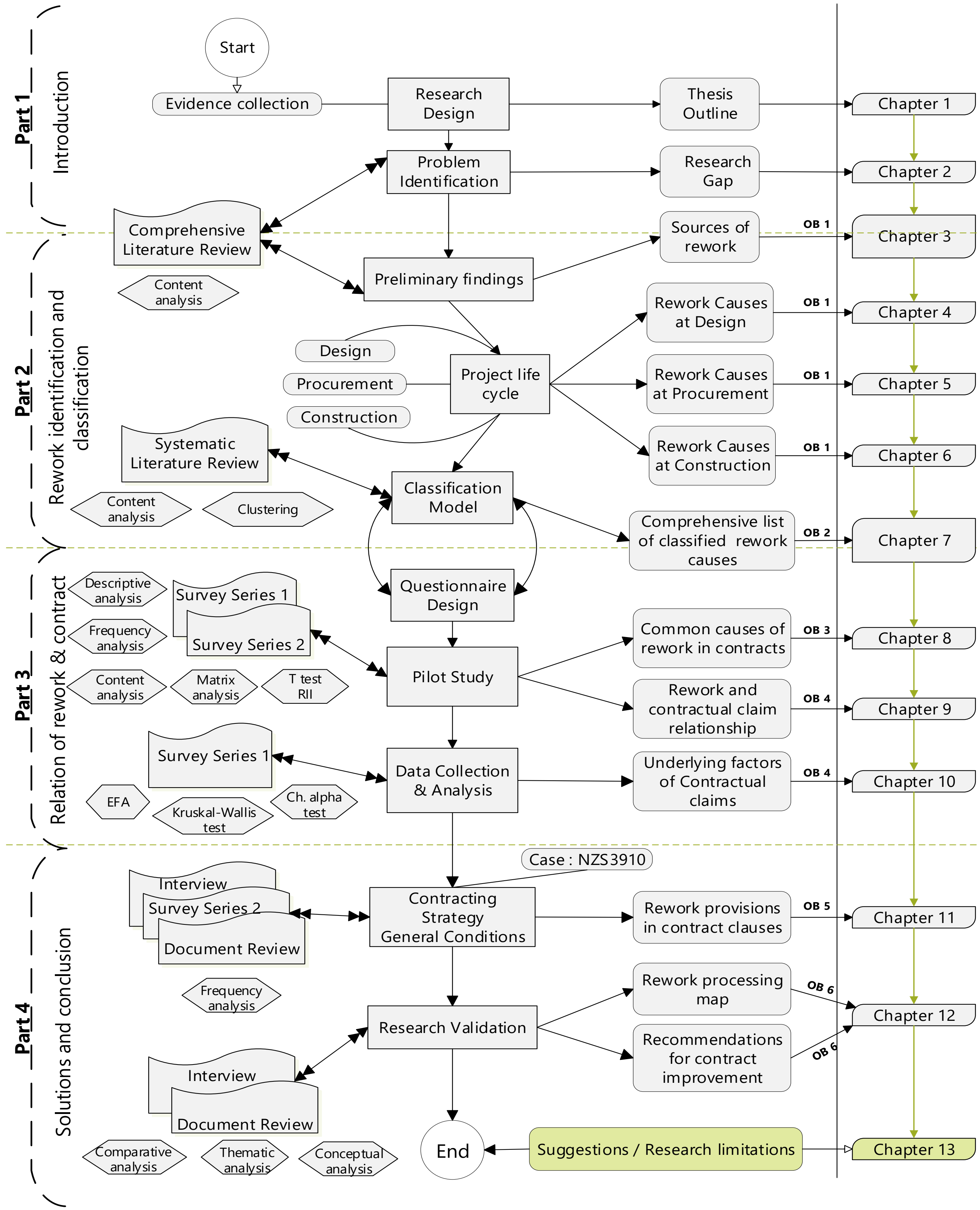
Since rework issues continuously distress construction projects, it is required to start a discussion with the construction practitioners searching for an appropriate way to address rework. This paper aimed to assess rework in construction contracts and propose guidelines for rework provisions in the most widely standard form of contract in New Zealand. The methodology used in this study involved the opinions of the participants who took part in interviews comparison and reviewing contract clauses. In addition to the conceptual analysis on the contract documents, the study employed professional interviews to add practical experiences based on the different viewpoints of those working in the construction industry. Professional comments were collected regarding how the contract conditions in construction contracts could be improved to address rework issues. Then a flowchart processing map was developed to address rework provisions in the contract. Based on the developed process map, a checklist was prepared to improve the conditions of the contract in terms of rework-related issues. Therefore, a clear set of responsibilities under rework events can be assigned to the project parties, which enhances the project's overall performance in reducing contractual claims, and disputes raised from rework. Using the provided checklists also fills the gaps in addressing rework for future contracts, and as a result it allows construction practitioners to focus on the rework-related clauses of the contract and remove any ambiguity around them.

Overall, this paper presented contractual guidelines for the appropriate rework management based on the analysis of the standard forms of contract NZS3190. The finding of this study revealed that NZS3910 does not provide a specific definition of rework; however, several clauses of the contract can be referenced to address rework issues. The result of the analysis showed rework-related provisions were addressed by six clauses. Discussion on the various contractual aspects of rework in each identified clause resulted in several recommendations for amending the related provisions that cover rework. Even though, this research contributes to contract management in the field of construction projects, some limitations to the study can be noted. One of the limitations is that the research was conducted utilising multiple qualitative approaches that can be comprehensively elevated by further quantitative techniques. Another limitation of the study is that the findings can be supported by several case laws. Adding the legal law cases in the construction industry to the results of this study is recommended as it brings more value to the findings. The third limitation of the study is that the developed flowchart and provided checklist have not been tested practically to measure the benefits that will be gained by using them in real construction projects.

12.13 Epilogue

This chapter suggested a process map for addressing rework in the contract based on the previous results and the logic behind the relationship between rework and contractual claims. The chapter focused on empirically understanding how rework relates to contract clauses. The chapter outcomes revealed five clauses that are associated with reworking events. The investigation of the identified clauses suggests that rework has not been addressed, so relevant provisions need improvement. A process map based on the recommendations from the interviews is proposed to cover identified gaps in the contract for addressing rework. The list of recommendations to change relevant provisions ultimately can be used for improving the contract conditions. The chapter then developed a checklist that can be used at contract formation. The process map for addressing rework is based on the standard form of contract NZS3910 and cannot be generalized for all types of contracts. However, the systematic approach is replicable for the other types and is advised to be conducted to provide more evidence and validate the proposed flowchart.

Thesis-at-a-Glance / Chapter 13



Chapter 13. Conclusion and research recommendations

13.1 Prologue

This chapter presents the research overview, followed by a discussion on achieving the research objectives. The original contribution of this study to the construction contracts management domain is also presented. The chapter then explains the study's limitations to offer recommendations for further research studies.

13.2 Research Overview

This research aimed to manage rework in New Zealand construction contracts through appropriate provisions in the conditions of the standard form of the NZS3910 contract, where limited information is available to address rework. Rework management enhances the overall construction performance by reducing contractual claims and disputes. The research is significant as the fulfillment of construction contracts primarily affects the success level of projects. Rework causes and their relationships with contractual claims were used as the main triggers to assess the conditions of the contract. Upgrading the contract conditions to address rework is an essential factor in construction project development.

Opportunities can be found to improve contract conditions by providing answers to how contract clauses address contractual issues such as delay, cost overruns, claim, and disputes. Rework is one of the common reasons to generate these issues in construction projects. This thesis evaluated rework in the New Zealand construction contracts towards improving the conditions of the standard form of contract NZS3910. The main question extracted from the research gap was considered in this thesis to address the stated problem in chapter 1 for updating the standard contract form. Based on this requirement and to design a practical approach that answers the research question, six research objectives were designed to be achieved through an empirical and systematic framework. All the objectives of this research were investigated through 11 papers as the publication outputs of the study. Thus, each chapter of the thesis presented one paper with the same title as used in the original manuscript. This thesis was structured in 13 chapters totally, including 11 prementioned papers, an introduction, and a conclusion.

Chapter 1 addressed research objectives and the methodology used to achieve them. In total, this chapter outlines six objectives to be met by the research study. The study's objectives were in chronological sequence, and to meet each objective, a continuing process was conducted step by step to achieve the research aim, which is discussed in the following sections.

Chapter 2 addressed the contracting strategy usage in rework events. This chapter identified research gaps in construction contracts' rework studies through a comprehensive literature review. The findings of this chapter provided the foundation for further investigation of contract rework issues. The results of this chapter suggested the process of contract assessment by addressing rework causes in the conditions of the contract. Thus, root causes of rework were required to be identified for conducting the next step of the research. As such, a systematic literature review is considered appropriate to identify rework root causes in construction projects.

Chapter 3 outlined rework management in the project's life cycle, and the initial results showed that rework occurs in all project stages, including design, procurement, and construction. In doing so, each project stage was reviewed in more detail to find rework causes contributing to both sides of the contract.

Chapters 4 to 6 covered this research requirement by providing a list of rework root causes under each stage separately extracted from previous studies. The combination of identified rework root causes from three project stages created a long list of items that contained similar causes under different categories. In order to generate a comprehensive list of rework causes for the next steps of the research, classification of identified causes to categorize the similar items considered to be performed. The classification model was designed in alignment with the research needs for addressing all causes to the liable contract parties.

Chapter 7 proposed a classification model based on the content analysis of the collected secondary data from the systematic literature review. The proposed model classified each cause under three levels: the contracting party, the project stage, and the relevant category of rework. This chapter created a comprehensive list of root causes that can be referenced for further investigation of rework in construction contracts. The comprehensive list of rework root causes in the project's life cycle revealed that the procurement stage needs further investigation. The results of this chapter validated the earlier identified research gap in chapter 2 and offered insights for considering strategies to address rework in the contracts, which significantly improve the process of rework management in construction projects. The identified causes of rework and the classified rework root causes in a comprehensive list met the first two objectives of the research.

From chapters 8 to 12, the focus of the research shifted towards contracts using the earlier classified rework causes. Chapter 8 addressed the third objective. This chapter aimed to extract the common causes of rework in the New Zealand construction industry. A pilot study with a sample of 42 participants was performed, and the frequency analysis of the collected data ranked the most significant causes of rework in New Zealand construction contracts. This was the first step in investigating rework in New Zealand's context to provide links to the contract part of the thesis.

Chapter 9 investigated the relationship between rework and contractual claims, as claims are referenced in the contract's clauses. Establishing the relationship between these two aspects showed the relational aspects of rework in contract conditions. The matrix analysis of rework causes in generating contractual claims not addressed in the contract prioritized the list of causes. The findings of this chapter provided a significant list of items in three clusters that required to be investigated in the contract clauses to improve the contract conditions. Completing these two pilot studies provided enough evidence to partially validate the relationship between rework and contract and partially meet the third and fourth objectives of the research. The fourth objective was ultimately achieved by performing an exploratory factor analysis with a broader range of participants in the survey.

Thus, **chapter 10** focused on the underlying factors of contractual claims originating from rework. It clearly sets out four contributing components, comprehensively in compliance with the earlier classified rework causes in chapter 7. As such, the result of this chapter validated the existing direct relationship between rework causes and contractual claims. Therefore, the next steps of the research were performed concurrently, considering both claims and rework in the same way concerning the contract's clauses. The last three chapters focus on the contract's clauses in addressing rework and its causes.

Chapter 11 addressed the most significant causes of rework in generating contrail claims in the contract conditions of NZS3910 was assessed. The survey result was compared with the frequency analysis of the contract document, and the comparison result was checked with the collected data from the professional interviews. The final result stated that some of the causes of rework had been addressed adequately in the contract NZS3910. It suggested that most of the causes must be addressed throughout the conditions of the contract. The relational aspects of rework and contract were indented and established to satisfy objective 5 of the research. The findings of this chapter firstly needed more investigation to be accepted as valid results, and secondly needed solutions to resolve the problem. Thus, investigation of solutions by addressing rework in the contract clauses continued to be performed by further data analysis.

Chapter 12 covered this last part of the research by analyzing the collected data from professional interviews in conjunction with the contract documentary review on the clauses of NZS3910. The findings of this chapter resulted in a platform for better administrating the contract under rework events. The chapter proposed a flowchart that refers to relevant clauses of the contract to address rework provisions. It also provided a list of recommendations that help construction practitioners during contract preparation to prevent rework occurrence during the construction stage. The result of this chapter meets objective 6 of the research by proposing a flowchart of rework processing that can be used for improving contract conditions.

This study revealed the number of contract clauses for addressing rework through relevant provisions that improve the conditions of the standard form of the NZS3910 contract. Thus, this study contributes to the body of knowledge in the construction contract management area. This chapter is the final section of the thesis to represent the research and some recommendations for future studies. Research objectives are achieved, followed by the research limitations statement.

13.3 Research Objectives achievement

The primary question in this research was what are the common causes of rework in New Zealand construction contracts and how addressing rework issues improves the general contract conditions of the most commonly used standard forms of construction contracts in New Zealand? To answer this question, the following process was designed to be performed sequentially through six objectives, as shown in Figure 13.1. Objective one investigated rework causes in a project's life cycle and identified root causes under three project stages design, procurement, and construction.

The identified rework causes were further studied and classified under specific categories based on the research needs. Objective two of the study proposed a classification model and generated a comprehensive list of classified rework causes. Object three started to investigate the common causes of rework in construction contracts. To achieve this goal, the classified causes of rework from the previous step were examined based on the standard form of the contract in New Zealand.

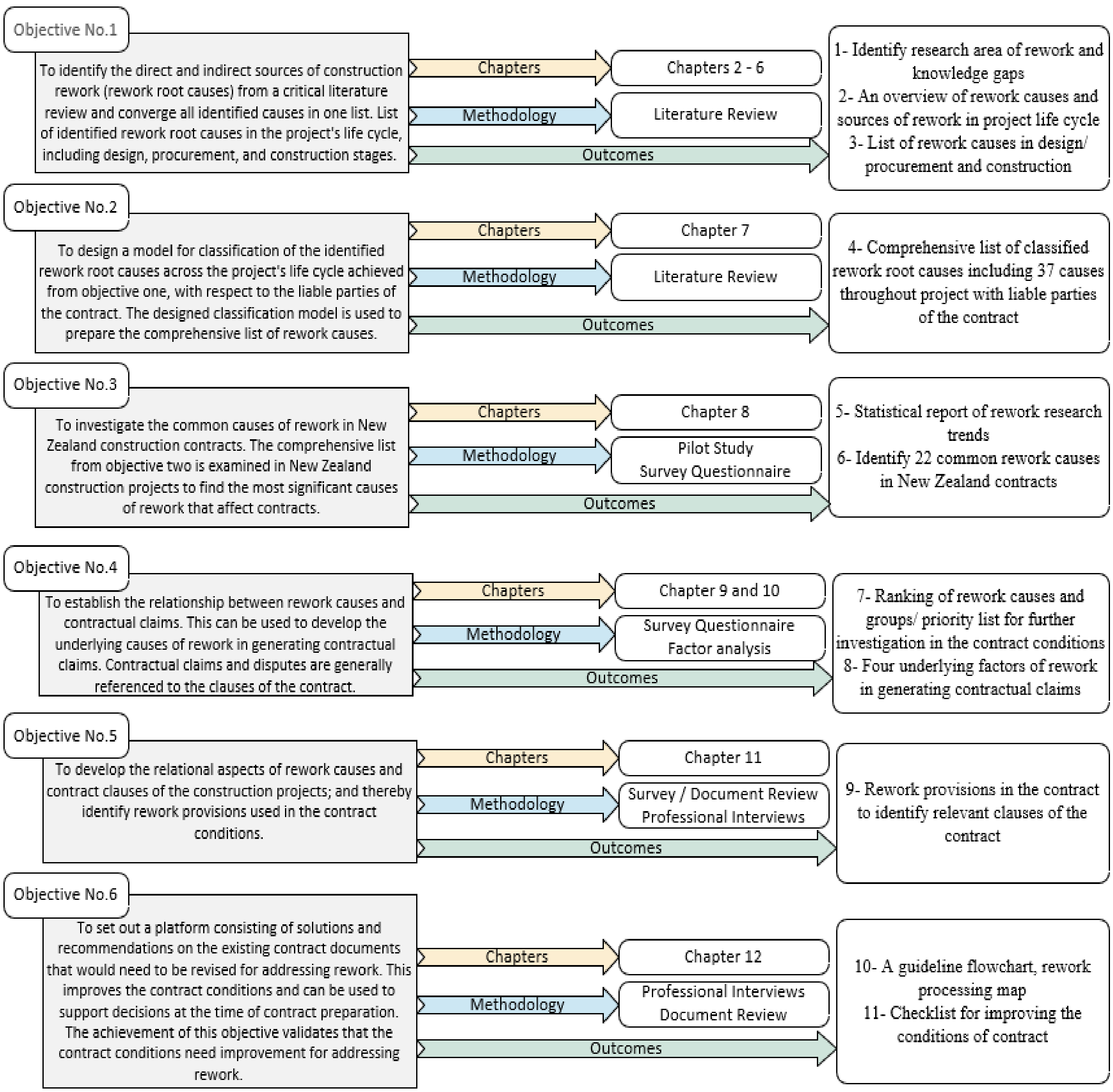


Figure 13.1: *Research objectives, methodologies and outcomes*

The common causes of rework in construction contracts were then used to determine the relationship between rework causes and contractual claims. Contractual claims are connected to the contract conditions, and this connection between contractual claims and contract clauses can be used to establish the relational aspects of rework into the contract clauses. Objective four of the study established this relationship and verified that rework causes have the same root as contractual claims in the contract conditions. Objective five then developed this relationship to identify rework provisions under contract clauses of a standard contract form in New Zealand construction projects. Addressing rework in the contract conditions was then examined through objective six of the study. Identifying rework provisions facilitated the process of addressing rework issues in contract conditions. Therefore, the identified contract clauses can be revised based on the project's need to address rework, which is used to improve contract conditions in the next step. Such improvements will be achieved by recommendations on the current provisions that refer to rework issues.

This kind of investigation into the contract clauses to improve the conditions of the standard forms of NZS3910 in New Zealand was unique in terms of evaluation and approach. Since NZS3910 contracts in construction projects are signed between two parties, the client and the contractor, this thesis validated the process of contract improvement in response to the contract parties' responsibilities and obligations. This thesis developed a rework process map to help the identification of the contract weaknesses and provided the opportunity for the construction projects to review the contract terms during the contact formation between the parties. Furthermore, this thesis contributed to the Standard New Zeeland's need to revise and update the contract's current version. Standard New Zealand is searching for comments through the construction industry to assess whether a major revision to the contract is required or not. This contribution is essential because there is no academic research on this matter in New Zealand. The results of this research study can be compared with the recent survey conducted by Standard New Zealand on the construction contracts NZS3910. Any alignment between the two results can be used to validate the process used in this thesis. In addition, the same approach can be implemented in the other standard contract forms. The thesis results can be examined and experienced in the future construction project to measure their impacts, and also other countries that use the other standard forms of contract can take the same approach and learn from the New Zealand experience.

13.4 Contribution of research

This study contributes to the body of knowledge in construction contracts theoretically and practically. The theoretical aspect of this research contributes by identifying rework causes in New Zealand contracts and establishing the relationship between rework causes and contractual claims in the standard form of NZS3910 contract. Thus, this research added to the body of knowledge by studying rework in the New Zealand construction industry and identifying the common causes of rework in construction contracts. The practical contribution of the study proposed guidelines for improving the contract conditions of NZS3910 in developing a rework processing map and the flowchart for addressing rework based on the interview recommendations. In addition, this research provides a checklist that helps construction practitioners ensure rework has been addressed adequately during contract negotiation and preparation. In real-word scenario, the recommendations of this research can be used by NZ Standards to revise NZS3910.

The practicality of the proposed flowchart and checklist will be tested and strengthened by conducting further research referenced at the end of this chapter. This research developed a new concept to link the rework causes and the contract clauses to improve the contract conditions further. This concept was tested by combining various methodologies used in the research, including literature review, pilot study, two series of questionnaire surveys, professional interviews, and documentary review. Throughout all previously mentioned steps, the study's finding has provided adequate evidence to validate the research results.

13.5 Research limitations and recommendations for future research studies

Numbers of limitations were identified and acknowledged during this research. The constraints encountered with this thesis's accomplishment are listed in this section, which provides bases for future research. This section discusses research limitations in two parts. First, the main limitation to the fundamental research is presented, and then the identified limitation under each chapter are discussed with some potential recommendations for future studies.

13.5.1 Limitations to the research

- One of the limitations of this study was related to the first steps of the research to identify the leading causes of rework in construction contracts. All identified rework causes were based on the comprehensive and systematic literature review. More identification of the rework causes from the other sources, such as interviewing the construction experts, surveying construction practitioners, or exploring the New Zealand Construction industry's previous record, will complete the acquired knowledge. The literature review showed limited research information about rework in the New Zealand construction section.
- The study's second limitation refers to the constraint of the involvement of only two parties in the research as the contract is signed off between the client and contractor. Considering a more comprehensive range of stakeholders in the construction supply chain, such as consultants, subcontractors, and suppliers in the process of contract improvement, will result in more robust proposals for improving the overall performance of the construction projects. This research only covers part of the construction contracts.

- The third limitation of the study is that the research has only focused on rework as one of the contractual issues in the construction industry. This concept requires further development by including the other contractual issues that need to be evaluated, such as delay, safety, change orders, and disputes.

- The fourth limitation of the study is the selection of contract form, as it only reviews the conditions of NZS3910. Thus, the scope of this research is limited to a specific contract in New Zealand. This documentary review can be expanded to compromise the other standard contract forms in New Zealand and worldwide. As such, more reliable outcomes can be achieved by comparing various findings and research results. Some examples are NZS3916, NZIA, NEC, and FIDIC
- Therefore, it can be stated that the study findings will not be generalized for all types of contracts. However, the thesis findings, including the proposed rework processing map in the contract and the checklist of required steps for improving contract conditions, can be used as a template for other contract types. As such, each standard form of contract needs to update the process map and checklist based on its clauses and stipulated provisions.
- Furthermore, the same approach can be utilized to evaluate other construction issues rather than rework, such as delays, change orders, safety issues, and disputes. Therefore, more frameworks can be developed considering the whole picture of construction issues throughout the contract conditions. Combining all the developed frameworks can be used as a procedure for regularly updating and upgrading the standard contract forms by NZ Standards. Future studies also can examine the implication of the developed process maps in the construction projects through case studies or by studying the number of law cases in the same area.
- It is also recommended to develop the list of rework causes by adding more explored rework causes in the current New Zealand construction industry. Conducting a similar study for the

other countries using standard forms of contract would also be interesting to see how the new findings are replicable in the context of New Zealand. Another recommendation for further research is to evaluate the other construction stakeholders' contracts. For example, the suppliers' contract is of interest as they provide material and equipment for construction projects; also, consultant contracts to evaluate the design and engineering role will contribute to the body of knowledge in construction contracts.

- The concepts of Industry 4.0/5.0, progressions of IoT, and their impact on Circular Economy, AI, and Digital Twins also are very important issues in the current status of construction projects and they need to be taken into consideration for future research studies. The effects of such issues have not been assessed in this study. Another critical point for future studies may focus on building automation, robotic construction, and minimization of human involvement to reduce rework in construction projects. How this can be reflected in the contracts to manage conflicts is an area to be investigated.

13.5.2 The chapters limitations

The study's other limitations based on each step of work have been proclaimed in the conclusion section of the chapters.

- In the first step of the study, through conducting the comprehensive literature review, a lack of using the complex combination of similar keywords was imposed on the study, and the results were subject to the limited keyword of rework. Future research could explore more interchangeable words such as defects, variations, and change orders.
- In the next step and for identifying rework causes in the project's design, procurement, and construction stages, only journal papers were reviewed, and the limitation in this part of the

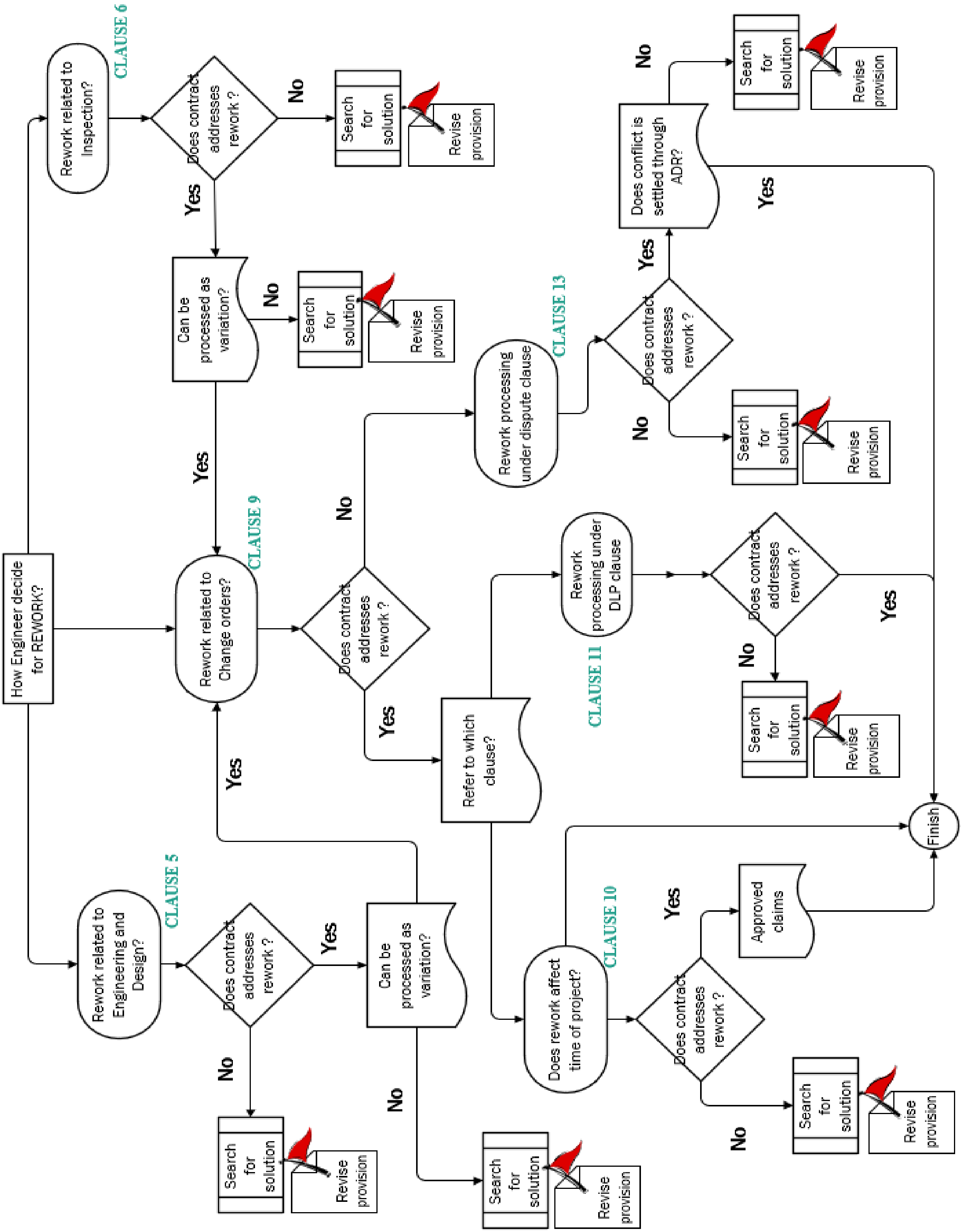
research was due to the exclusion of conference papers from the scope of work. A systematic literature review then covered this limitation to prepare a comprehensive list of rework causes.

- The last step of the literature review was also limited to identifying rework causes, and the other study areas such as theories, models, strategies, and solutions were excluded. Further research on each identified study area in rework management is recommended. In doing so, the same approach used for performing a systematic literature review will be helpful.
- In the study of the relationship between rework causes and contractual claims, results were assumed to be skewed towards the client as the number of survey participants from the client-side was higher than contractor-side. For conducting a pilot study using a survey questionnaire, a small sample size was considered one of the limitations that did not allow the researcher to generalize the results. This limitation was covered in the project's next step by using a bigger sample size for data collection.
- For conducting Exploratory Factor Analysis, a total number of 124 responses to the survey was conserved enough. However, the study's main limitation was the lack of data for developing a comprehensive model using Confirmatory Factor Analysis to cover all causes of claims. Further study to propose Structural Equation Modelling is another recommendation that would complete this section and validate the result of factor analysis for underlying causes of contractual claims. The accuracy of the developed model then could be improved using a more extensive data set in future research studies.
- Lack of proposing a framework to show the process of rework handling among various clauses of the contract was stated as the main limitation of work when the research was at the stage of identifying rework provisions to evaluate the contract conditions. This study limitation was covered in the next step of the research.

- The last step of the research was limited by conducting multiple qualitative approaches, so adding quantitative techniques to elevate the final results was considered appropriate. Supporting the study's findings only by reviewing contract documents is another limitation, and finally, the lack of assessment for measuring the applicability of the proposed flowchart and checklist was mentioned as the last limitation in this research study. Future studies can investigate integrating the proposed flowchart and checklist by taking longitude case studies or studying case laws.

13.6 Epilogue

Overall, the accuracy of the contract terms is a fundamental concern in construction projects. Such accuracy can be achieved by revising provisions in addressing contractual issues. Based on the findings of this research to improve the conditions of the contract, the proposed rework map and developed checklist should help construction practitioners increase the contract's accuracy under rework events. In addition, the suggested measures could improve the contract conditions, resulting in fewer contractual claims and disputes. The lack of research on such issues in New Zealand construction contracts required a systematic approach to recommend guidelines to improve contract conditions and facilitate contract administration. This research study addressed this gap through an in-depth assessment of the contract. A framework also can be concluded as the final achievement of the study to be used for future research in New Zealand, which needs more investigation to be validated.



Framework for improvement of NZS3910 contract conditions in addressing rework

References

Abbaszadegan A. and Grau, D. (2015). Assessing the influence of automated data analytics on cost and schedule performance. *Creative Construction Conference (CCC2015), Procedia Engineering* 123 (2015) 3-6.

Abdul-Malak, M.A.U., Srour, A.H., and Demachkieh, F.S. (2020). Decision-Making Governance Platforms for the Progression of Construction Claims and Disputes. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(3), 04520025.

Abdul Nabi, M., El-adaway, I.H, Fayek, S., Howell, C., and Gambatese, J. (2020). Contractual Guidelines for Construction Safety–Related Issues under Design–Build Standard Forms of Contract. *Journal of Construction Engineering and Management*, 146(7), 04020074.

Abdul-Rahman, H. (1995). The cost of non-conformance during a highway project: A case study. *Construction Management and Economics*., 13(1), 23-32.

Abdul-Rahman, H. (1993). The management and cost of quality for civil engineering projects. PhD thesis.

Adafin, J., Rotimi, J.O.B., and Wilkinson, S. (2021). An evaluation of risk factors impacting project budget performance in New Zealand. *Journal of Engineering, Design and Technology*. 19(1), pp. 41-61.

Ahmed, S.A., and Naik, B.H. (2016). Rework management in construction projects and comparison with time and cost. *International Journal of Innovative Research in Science, Engineering and Technology*, 5(10), pp. 17973-17980.

Aiyetan, A.O. (2013). Causes of rework on building construction projects in Nigeria. *Interim, Interdisciplinary Journal*, 12(3), pp. 1-15.

Aiyetan, O.A., and Das, D. (2015). Using system dynamics modelling principles to resolve problems of rework in construction projects in Nigeria. *Journal of Construction Project Management and Innovation*, 5(2), pp. 1266-1295.

Aiyewalehinmi, E.O., and Nkumah, L. (2019). Evaluation of construction contract dispute between the clients and contractor in Nigeria: Ondo state as a case study. *European Journal of Engineering and Technology*, 7(3), ISSN 2056-5860, pp. 40-55.

Ajayi, O.M. (2017). Occurrence of rework on components of building project in Lagos state, Nigeria. *International Journal of Sustainable Construction Engineering & Technology*, (ISSN: 2180-3242) 8(1), pp. 84-93.

Ajayi, O., and Oyeyipo, O. (2015). Effect of rework on project performance in building project in Nigeria. *International Journal of Engineering Research & Technology*, 4(02), pp. 294-300.

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A., and Owolabi, H.A. (2017). Critical management practices influencing on-site waste minimization in construction projects. *Waste Management*, 59, pp. 330-339

Alaghbari, W., Al-Sakkaf, A.A., and Sultan, B. (2018). Factors affecting construction labour productivity in Yemen. *International journal of construction management*, 19(1), pp 79-91.

Ali, N., and Wilkinson, S. (2010). Modernizing Construction Contracts Drafting – A Plea for Good Sense. W113 - *Special Track 18th CIB World Building Congress*, May 2010 Salford, United Kingdom, pp. 323-345.

Al-Janabi, A.M., Abdel-Monem, M.S., and El-dash, K.M. (2020). Factors causing rework and their impacts on projects performance in Egypt. *Journal of Civil Engineering and Management*, 26(7), pp. 666-689.

Aljailawi, H. and Shariatmadar, H. (2017). The reasons for rework occurrence in construction projects and prioritizing them by using AHP method. In: *2nd International Conference on Civil Engineering*, Architecture and Urban Design, 31 August 2017, Bangkok, Thailand. Bangkok (Thailand): Kasem Bundit University, 1–10.

Al-Mohsen, M. (2012). Claim Analysis of Construction Projects in Oman. *International Journal on Advanced Science Engineering and Information Technology*, 2(2), ISSN:2088-5334, pp.73-78.

Al-Qershi, M.T., and Kishore, R. (2017). "Claim Causes and Types in Indian Construction Industry - Contractor's Perspective." A*merican Journal of Civil Engineering and Architecture*, 5(5), pp 196-203.

Alwi, S., Hampson, K., and Mohamed, S. (1999). Investigation into the relationship between rework and site supervision in high rise building construction in Indonesia. In: *The Second International Conference on Construction Process Reengineering*, 12–13 July 1999 Sydney, 189–195.

Al-Zanati, A.R. and Bajracharya, A. (2017). Causes and effects of rework: a study on a major water supply pipe-line construction project in Libya. *International journal of innovation, management and technology*, 8 (6), 440–465.

Anjum, S., and Azam, F. (2019). Time and cost impacts of rework in building construction projects. *Journal for Innovative Development in Pharmaceutical and Technical Science*, 2(4), pp.74-84.

Apollo, M., Siemaszko, A., and Kristowski, A. (2018). Risk sharing in the construction work contracts. Proceedings of the Creative Construction Conference (2018), *Creative Construction Conference 2018*, CCC 2018, 30 June - 3 July 2018, Ljubljana, Slovenia.

Arashpour, M., Wakefield, R., Blismas, N., and Lee, E.W.M. (2014). Analysis of disruptions caused by construction field Rework on productivity in residential projects. *Journal of Construction Engineering and Management*, (140)2, 04013053.

Arcadis, (2020). Global Construction Disputes Report. *10th Anniversary Edition*, collaborating to achieve project excellence.

Arundachawat, P., Roy, R., Al-Ashaab, A., and Shehab, E. (2009). Design Rework Prediction in Concurrent Design Environment: Current Trends and Future Research Directions. *Proceedings of the 19th CIRP Design Conference – Competitive Design*, Cranfield University, 30-31 March 2009, pp 237.

Asadi, R., Wilkinson, S., and Rotimi J.O.B. (2021a). The common causes of rework in construction contracts: a diagnostic approach. Journal of Engineering, *Design and Technology*. 1726-0531, DOI 10.1108/JEDT-04-2021-0215.

Asadi, R., Wilkinson, S., and Rotimi J.O.B. (2021b). Towards contracting strategy usage for rework in construction projects: a comprehensive review. *Construction Management and Economics,* https://doi.org/10.1080/01446193.2021.2004609.

Asadi, R., Rotimi J.O.B., and Wilkinson, S. (2022). Investigating the relationship between rework and contractual claims: The salience of contract conditions. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, ASCE*, 14(1), 04521046.

Asadi, R., Wilkinson, S., Rotimi, J. (2019). Contract document appraisal and rework root causes classification in tendering stage of projects. *Proceeding of the 43rd AUBEA conference*, pp. 86-98.

Assaad, R., Elsayegh, A., Ali., G., Abdul-Nabi., M., and El-adaway., I. H. (2020). Back-to-Back Relationship under Standard Subcontract Agreements: Comparative Study. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(3): 04520020.

Ashford, J.L. (1992). The management of quality in construction. E & F Spon, London

Atanda, A.O., and Fabi J.K. (2015). Assessment of claims management on building projects in Nigeria. *5th National Conference of the School of Environmental Studies*, Federal Polytechnic, Ilaro. 15th – 17th July 2015, pp 1-12.

Aulia, T.B., Mubarak, and Irfan, R. (2012). Factors Causing Rework at Building Construction in The Department of Highways and Settlements of Aceh Province. *Proceedings of the 2nd Annual International Conference Syiah Kuala University*, The 8th IMT-GT Uninet Biosciences Conference, Banda Aceh, 22-24 November 2012.

Ayodele, O.A., Richards, A.C., and Gonzalez, V. (2020). Factors Affecting Workforce Turnover in the Construction Sector: A Systematic Review. *Journal of Construction Engineering and Management*, 146(2), 03119010.

Aziz, R.F., and Hafez, S.M. (2013). Applying Lean Thinking in Construction and Performance Improvement. *Alexandria Engineering Journal*, 52(4), pp. 679-695.

Badenfelt, U. (2011). Fixing the contract after the contract is fixed: A study of incomplete contracts in IT and construction projects. *International Journal of Project Management*. 29, pp. 568–576

Balnaves, M. and P. Caputi (2001). Introduction to quantitative research methods: An investigative approach. Thousand Oaks, CA, Sage.

Balouchi, M., Gholhaki, M., and Niousha A. (2019). Reworks causes and related costs in construction case of Parad mass housing project in Iran. *International Journal of Quality & Reliability Management*, 36(8), pp. 1392-1408.

Banwo, O., Parker, K., and Sagoo, A. (2015). Principles of Contract Claims Management – A Review of the Nigerian Construction Industry. *International Conference on Industrial Engineering and Operations Management*, Dubai, (UAE), March 3-5.

Bao, F., Albert, P.C., Chen, C., and Darko, A. (2018). Review of Public–Private Partnership Literature from a Project Lifecycle Perspective. *Journal of Infrastructure Systems*, 24(3), 04018008.

Barber, P., Graves, A., Hall, M., Sheath, D., and Tomkins, C. (2000). Quality failure costs in civil engineering projects. *International Journal of Quality Reliability Management*, 17(4/5), 479-492.

Beale, J., and Smallwood, J.J. (2019). The potential of industry 4.0 to enhance construction health and safety (H&S) performance. *Proceedings of 14th international postgraduate research conference. Contemporary and future directions in the built environment*, 16-17 December 2019, pp 233-244.

Bertelsen, S., and Koskela, L. (2004). Construction beyond lean: a new understanding of construction management. Paper presented at the *Proceedings of the 12th annual conference in the International Group for Lean Construction*.

Besaiso, H., Fenn, P., Emsley, M., and Wright, D. (2018). A comparison of the suitability of FIDIC and NEC conditions of contract in Palestine. *Engineering, Construction and Architectural Management*, 25(2), pp. 241-256.

Bhatl, A., Pradhan, B., and Choi, J.O. (2016). Identifying Wastes in Construction Process and Implementing the Last Planner System in India. *Journal of Construction Engineering and Project Management,* Online ISSN 2233-9582, pp. 11-19.

Blacud, N.A., Bogus, S.M., Diekmann, J.E., and Molenaar, K.R. (2009). Sensitivity of construction activities under design ncertainty. *Journal of Construction Engineering and Management*, 10.1061/(ASCE)0733-9364-135:3(199),199-206.

Brito Mello, L.C.B., Mello Bandeira, R.A., and Brandalise, N. (2018). Selection of rework measurement methodology utilizing AHP method. Gest. Prod., Sao ~ Carlos, 25 (1), 94–106.

Broome, J.C., and Hayes, R.W. (1997). A comparison of the clarity of traditional construction contracts and of the New Engineering contracts. *International Journal of Project Management*, 15(4), pp. 255-261.

Bubshait, A.A., and Almohawis, S.A. (1994). Evaluating the general conditions of a construction contract. *International Journal of Project Management*, 1994 12 (3) 133-136.

Burati J.L., Farrington J.J. and Ledbetter W.B. (1992). Causes of quality deviations in design and construction. *Journal of Construction Engineering in Management*, 118(1), 34-49.

Burati, J.L. and Farrington, J.J. (1987). Cost of Quality Deviations in Design and Construction, Report to the Construction Industry Institute. University of Texas at Austin, Austin, TX, USA.

Chan, A.P.C., Tetteh, M.O., and Nani, G. (2020). Drivers for international construction joint ventures adoption: a systematic literature review. *International Journal of Construction Management*, 10.1080/15623599.2020.1734417, pp.1-13.

Chan, D.W.M., and Chan, J.H.L. (2017). Pilot Case Study of New Engineering Contracts (NECs) in Hong Kong, Joy or Tears? *21st International Symposium on Advancement of Construction Management and Real Estate*, pp. 1103-1111.

Chen, L.J., and Luo, H. (2014). A BIM-based construction quality management model and its applications. *Automation in Construction*, 46 (2014) 64-73.

Chen, Y., Wang, W., Zhang, S., and You, J. (2018). Understanding the multiple functions of construction contracts: the anatomy of FIDIC model contracts. *Construction Management and Economics*, 36(8), 472-485.

Cheng, J.C., Lw, K.H., Bjornsson, H., Jones, A., Sriram, R. (2009). A Service Oriented Framework for Construction Supply Chain Integration. *Automation in Construction*, 245-260.

Choi, S.H., and Kim, Y.S. (2016). Priority Analysis of Dispute Factors in Overseas Construction Based on FIDIC Contract Conditions. *KSCE Journal of Civil Engineering*, 20(6), pp 2124-2133.

Coleman, E., Nooni, I.K., Fianko, S.K., Ebenezer, L.D., Neequaye, N., Agyemang, J.O., and Ansa-Asare, E.O. (2020). Assessing contract management as a strategic tool for achieving quality of work in Ghanaian construction industry A case study of FPMU and MMDAs. *Journal of Financial Management of Property and Construction*, 25(1), 41-60.

Construction Industry Development Agency, (1995). Measuring Up or Muddling Through: Best Practice in the Australian Non-Residential Construction Industry, CIDA, Sydney, pp. 59-63.

Cnudde, M. (1991). Lack of quality in construction - economic losses. *European Symposium on Management, Quality and Economics in Housing and Other Building Sectors*, Lisbon, September 30 - October 4, 1991. Proceedings, pp. 508-515.

Creswell, J.W. (2016). Research design, qualitative, quantitative and mix method approaches. Book.

Creswell, J.W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches, Sage, Thousand Oaks, CA.

Creswell, J.W. (2007). Qualitative inquiry and research design: Choosing among five approaches. 2nd ed. Thousand Oaks, CA: Sage Publications.

Crook, E., Pope, P., and Taylor, M. (2018). How to get it right from the ground up. Russell MvVeagh, Industrual report pp 9,10.

Crook, E., Taylor, M., and Fillion, A. (2019). NZS 3910 – No longer fit for purpose for the Construction industry? Construction Law Update – March 2019, Russell MvVeagh, Industrial publications.

Dahanayake, B., Ramachandra, T., and Thurairajah, N., (2016). Assessment on rework costs probability of housing projects in Sri Lanka. *Proceedings of the 32nd Annual ARCOM Conference*, 5–7 September 2016, Manchester, UK. London, UK: Association of Researchers in Construction Management, 1265–1273.

Dallasega, P., Marengo, E., and Revolti, A. (2021). Strengths and shortcomings of methodologies for production planning and control of construction projects: a systematic literature review and future perspectives. *Production Planning & Control*, 32(4), 257-282.

Davies, A., Gann, D., and Douglas, T. (2009). Innovation in Megaprojects: Systems Integration at London Heathrow Terminal 5. California Management Review, 51.

Davis, K., Ledbetter, W.B. and Burati, J.L. (1989). Measuring design and construction quality costs. *Journal of Construction Engineering Management*, 115(3), 385-400.

Dehghan R. and Ruwnapura, J.Y. (2014). Model of Trade-Off between Overlapping and Rework of Design Activities. *Journal of Construction Engineering and Management*, ASCE, ISSN 0733-9364/04013043 (13).

Dehghan R., Hazini K., Ruwanpura, J. (2015). Optimization of overlapping activities in the design phase of construction project. *Automation in Construction*, 59, 81-95.

Dixit, S., Mandal., S.N., Thanikal, J.V., and Saurabh, K. (2019). Evolution of studies in construction productivity: A systematic literature review (2006–2017). *Ain Shams Engineering Journal*, 10, 555-564.

Dosumu, O.S. (2018). Perceived Effects of Prevalent Errors in Contract Documents on Construction Projects. *Construction Economics and Building*, 18(1), pp. 1-26.

Egbelakin, T., Wilkinson, S., and Ingham, J. (2015). Integrated framework for enhancing earthquake risk mitigation decisions. *International journal of construction supply chain management*, 5(2), 34-51.

Ekhator, O.J. (2016). Investigating causes of disputes in building construction projects in Nigeira. *International Journal of Science, Environment and Technology*, 5(5), pp 3516-3527.

El-adaway, I., Vance, R.A., and Abotaleb, I.S. (2020). Understanding Extension of Time under Different Standard Design-Build Forms of Contract. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(1): 04519031.

El-adaway, I.H., Abotaleb, I.S., Eid, M.S., May, S., Netherton, L., and Vest, J. (2018). Contract Administration Guidelines for Public Infrastructure Projects in the United States and Saudi

Arabia: Comparative Analysis Approach. *Journal of Construction Engineering and Management*, 144(6), 04018031.

El-adaway, I.H., Fawzy, S., Allard, T., and Runnels, A. (2016). Change Order Provisions under National and International Standard Forms of Contract. J*ournal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 8(3), 03716001.

El-adaway, I.H., Fawzy, S., Burrell, H., and Akroush, N. (2017). Studying Payment Provisions under National and International Standard Forms of Contracts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Constructio*n, 9(2), doi.org/10.1061/(ASCE)LA.1943-4170.0000200.

Enshassi, A., Choudhry, R.M., and El-Ghandour, S. (2009). Contractor's perception towards causes of claim in construction projects. *The International Journal of Construction Management*, 9(1), pp 79-92.

Enshassi, A., Sundermeier, M., and Abo Zeiter, M. (2017). Factors contributing to rework and their impact on construction projects performance. *International Journal of Sustainable Construction Engineering & Technology*, 8(1), 12-33.

Evans, M., Farrel, P., Zewwin, W., and Mashali, A. (2020). Analysis framework for the interactions between building information modelling (BIM) and lean construction on construction mega-projects. *Journal of Engineering, Design and Technology*, 1726-0531.

Eze, E.C. and Idiake, J.E., (2018a). Impact of Rework on Building Project and Organisation Performance; A View of Construction Professionals in Nigeria. *International Journal of Sustainable Construction Engineering & Technology*, 9(1), 29-44.

Eze, E.C. and Idiake, J.E., (2018b). Analysis of cost of rework on time and cost performance of building construction projects in Abuja, Nigeria. *International Journal of Built* Environment and Sustainability, IJBES, 5(1), 56-67.

Eze, E.C., Idiake, J.E., and Ganiyu, B.O. (2018a). Analysis of rework risk triggers in the Nigerian construction industry. *Organization, Technology and Management in Construction*, 10, pp. 1778–1793.

Eze, E.C., Idiake, J.E., and Ganiyu, B.O. (2018b). Rework risks triggers in the Nigerian construction industry a view of built environment professionals. *Independent Journal of Management & Production*, 9(2), pp 448-472.

Fearne, A., and Fowler, N. (2006). Efficiency Versus Effectiveness in Construction Supply Chain: The Dangers of Lean Thinking in Isolation. Supply Chain Management. *An International Journal*, 283-287.

Fellows, R.F., and Liu, A.M. (2015). Research methods for construction. John Wiley & Sons.

Finnie, D. (2013). Comparison of time adjustment clauses between DZ3910, AS4000 and STCC. *Australasian Journal of Construction Economics and Building*, 13(1), pp. 66-84.

Flanagan, T., Johnson, S.T., and Dojen, R. (2008). Leveraging dependency structure matrix (DSM) and system dynamics in combination to reduce project rework. *Proceedings of 26th International Conference of the System Dynamics Societ*y 2008, 20–24 July 2008, Athens, Greece. Red Hook, NY: Curran Associates.

Forcada, N., Alvarez, A.P., Love, P.E.D., Edwards, D.J. (2016). Rework in urban renewal projects in Colombia. *Journal of Infrastructure Systems*, 23(2) 04016034.

Forcada, N., Gangolells, M., Casals, M., and Macarulla, M. (2017). Factors affecting rework costs in construction. *Journal of Construction Engineering and Management*, 143(8): 04017032.

Forcada, N., Rusinol, G., Macarulla, M., and Love, P.E.D. (2014). Rework in highway projects. *Journal of Civil Engineering and Management*, 20(4), 455–465.

Friedrich, D.R., Daly, J.P., and Dick, W.G. (1987). Revisions, Repairs, and Rework on large projects. *Journal of Construction Engineering and Management*, 113(3), 488-500.

Gad, G.M., Shane, J.S., Strong, K.C., and Choi, J. (2016). Rethinking Trust in Construction Contract Formation: Dispute Resolution Method Selection. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction,* 8(3): 04516003.

Gajaman, K., Disaratna, V., Ganeshu, P., and Nazeer, F.S. (2019). Conflict Avoidance in Construction Stage Through Proper Practice in Pre-Contract Stage. *Proceedings of the*

International Conference on Industrial Engineering and Operations Management, Bangkok, Thailand, March 5-7, pp 2624-2635.

Gamil, Y., and Rahman, I.A. (2020). Assessment of critical factors contributing to construction failure in Yemen. *International journal of construction management*, 20(5), pp 429-436.

Gibson, W., and Brown, A. (2009). Working with qualitative data. Sage.

Gunduz, M., and Elsherbeny, H.A. (2020). Operational Framework for Managing Construction-Contract Administration Practitioners' Perspective through Modified Delphi Method. *Journal of Construction Engineering and Management*, 146(3), 04019110.

Guo, H. (2009). Rethinking Construction Project Management using the VP-based Manufacturing Management Model" The Hong Kong Polytechnic University, Hong Kong.

Habibi, M., and Kermanshachi, S. (2018). "Phase-based analysis of key cost and schedule performance causes and preventive strategies, Research trends and implications. *Engineering, Construction and Architectural Management*, 25(8), pp. 1009-1033.

Habibi, M., Kermanshachi, S, and Safapour, E. (2018). Engineering, Procurement, and Construction Cost and Schedule Performance, Leading Indicators: State-of-the-Art Review. *Proceedings construction research congress*, pp. 378-388.

Halligan, J. (2019). Transcending new public management. Chapter three of book, Reform design and performance in Australia and New Zealand, pp 62.

Hamilton, L.M.J., José, R.F.F, Helder, G.C, and Pereira, V. (2018). Reduction of rework in complex projects - A Preventive Planning Tool (PPT). *Proceedings of the 2018 IISE Annual Conference,* 1324-1329.

Han, S., Love, P.E.D., Pena-Mora, F. (2013). A system dynamics model for assessing the impacts of design errors in construction projects. *Math. Comput. Model*. 57(9-10), pp.2044-2053.

Harper, C.M., Molenaar, K.R., and Cannon, J.P. (2016). Measuring Constructs of Relational Contracting in Construction Projects: The Owner's Perspective. *Journal of Construction Engineering and Management*, 142(10): 04016053.

Hansen, S. (2016). Investigation of Types and Causes of Construction Claims in Indonesia. *Prosiding Seminar Nasional Aplikasi Teknologi Prasarana Wilayah* IX (ATPW), Surabaya, 02 Juni 2016, ISSN 2301-6752.

Hansen, S., Rostiyanti, S.F., and Rifat, A. (2020). Causes, Effects, and Mitigations Framework of Contract Change Orders: Lessons Learned from GBK Aquatic Stadium Project. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12 (1) 05019008.

Hassan, F., and Le, T. (2020). Automated Requirements Identification from Construction Contract Documents Using Natural Language Processing. J*ournal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(2): 04520009.

Hayati, K., Latief, Y. and Jaka, S.A. (2019). Risk-based Contract Management on the Design and Build Construction to Minimize Disputes in Infrastructure Projects. *IOP Conf. Series: Materials Science and Engineering*. 506 (2019) 012047.

Hegazy, T., Said, M., Kassab, M. (2011). Incorporating rework into construction schedule analysis. *Automation in Construction*, 20 (8), 1051-1059.

Hemanta, D., Sawhney, A., Iyer, K.C., Rentala, S. (2011). Analysing factors affecting delays in Indian construction project. International Journal of project management, 30(12) pp. 479-489.

Henderson, D. (2004). The status and potential of alliancing and partnering procurement methods in New Zealand construction. Christchurch, University of Canterbury.

Hertogh, M., and Westerveld, E. (2010). Playing with Complexity. Management and organization of large infrastructural projects. AT Osborne / Transumo.

Hong, Y., Chan, D.W.M., Chan, A.P.C., and Yeung, J.F.Y. (2012). Critical analysis of partnering research trend in construction journals. Journal of Management in Engineering, 28(2), 82-95.

Horvath, A. (2004). Construction Materials and the Environment. *Annual Review of Environment and Resources*, 181-204

Hossain M.A. and. Chua, D.K.H (2010). Autogeneration of Simulation Network of the Design Process. *Journal of Computing in Civil Engineering*, 24(5), ASCE, ISSN 0887-3801/2010/5-452–461.

Hossain M.A., and Chua, D.K.H. (2014). Overlapping design and construction activities and an optimization approach to minimize rework. *International Journal of Project Management* 32 (6).

Husin, S., Abdullah, M.R and Afifuddin, M. (2019). Assessment of External Risk Factors on Construction Project Schedule Using Risk Importance Index (RII). *Pertanika J. Sci. & Technol*, 27 (4): pp 2031-2047.

Hwang, B.G., Thomas, S.R., and Haas, C.T. (2009). Measuring the impact of rework on construction cost performance. *Journal of Construction Engineering and Management*, 135(3), pp. 187-198.

Hwang, B.G., Zhao, X., and Goh, K.J. (2014). Investigating the client-related rework in building projects; The case of Singapore. *International Journal of Project Management*, 32, pp. 698-708.

Hwang, B.G., Shan, M., and Tan, E.K. (2016). Investigating reworks in green building construction projects magnitude influential factors, and solutions. *International Journal of Environment Research*, 10(4), pp. 499-510.

Hwang, B.G., Zhao, X., and Yang, K.W. (2019). Effect of BIM on rework in construction projects in Singapore status Quo, magnitude, impact, and strategies. *Journal of Construction Engineering and Management*, 145(2), 04018125.

Hwang, B.G., and Yang, S. (2014). Rework and schedule performance; A profile of incidence, impact, causes and solutions. *Engineering, Construction and Architectural Management*, 21(2), 190-205.

Illankoon, I.M.C.S., Tam, V.W.Y., Le, K.N., and Ranadewa, K.A.T.O. (2019). Causes of disputes, factors affecting dispute resolution and effective alternative dispute resolution for Sri Lankan construction industry. *International Journal of Construction Management*, https://doi.org/10.1080/15623599.2019.1616415.

Isnaini, J.N.A., Ahmad, N., Ismail, F. (2015). Clients' Involvement in Purchasing Process for Quality Construction Environment." Public Participation: Shaping a sustainable future" *Procedia - Social and Behavioral Sciences*, 168, pp.30-40.

Jadidoleslami, S., Saghatforoush, E., and Ravasan, Z. (2018). Constructability obstacles: an exploratory factor analysis approach. *International Journal of Construction Management*, DOI: 10.1080/15623599.2018.1534044

Jalali, M.P., and Moharreri, H. (2020). Model for Preparing Optimal Contracts to Prevent or Reduce Claims in Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(2): 04520004.

Jelodar, M.B., Yiu, T.W., and Wilkinson, S. (2016). Dispute Manifestation and Relationship Quality in Practice. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 8(1), C4515003.*

Jelodar, M.B., Raut, P.H., and Saghatforoush, E. (2021). Contractor-Delay Control in Building Projects: Escalation of Strategy from Primary Proactive to Secondary Reactive. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*. DOI: 10.1061/(ASCE)LA.1943-4170.0000449.

Jelodar, M.B., Yiu, T.W., and Wilkinson, S. (2022). Empirical Modeling for Conflict Causes and Contractual Relationships in Construction Projects. *Journal of Construction Engineering and Management*, Vol 148, Issue 5. 04022017-1.

Ji, W.A.M., and AbouRizk, S.M. (2018). Data-driven simulation model for quality-induced rework cost estimation and control using absorbing Markov Chains. *Journal of Construction Engineering and Management,* 144(8), 04018078.

Jingmond, M., and Agren, R. (2015). Unravelling causes of defects in construction. *Construction Innovation*, 15(2), pp.198-218.

Johannesson, P., and Perjons, E. (2014). An introduction to design science. Springer.

Jorgensen, B. and Emmitt, S. (2009). Investigating the integration of design and construction from a "lean" perspective. *Construction Innovation*, 9(2), pp. 225-240.

Josephson, P.E., Larsson, B., and Li, H. (2002). Illustrative benchmarking rework and rework costs in Swedish construction industry. *Journal of Management in Engineering*, 18(2), pp.76-83.

Josephson, P.E. and Hammarlund, Y. (1999). The causes and costs of defects in construction: a study of seven building projects. *Automation Construction,* 8(6), 681-687.

Juhari, M.L., Arifin, K. (2020). Validating measurement structure of materials and equipment factors model in the MRT construction industry using Confirmatory Factor Analysis. *Safety Science*, 131, 104905.

Kakitahi, J.M., Alinaitwe, H.M., Landin, A., and Rodrigue, M.J. (2014). A Comparison of construction related rework in Uganda and Mozambique. *Journal of Construction Project Management and Innovation,* 4(1), pp 770-781.

Kakitahi, J.M., Alinaitwe, H.M., Landin, A., and Mone, S.J. (2016). Impact of construction-related rework on selected Ugandan public projects. *Journal of Engineering, Design and Technology*, 14(2), 238-251.

Kasperiuniene, J., and Zydziunaite, V. (2019). A Systematic Literature Review on Professional Identity Construction in Social Media. SAGE Open, Jan-Mar. 2019, pp.1-11.

Kassem, M.A., Khoiry, M.A., and Hamzah, H. (2019). Using probability impact matrix (PIM) in analyzing risk factors affecting the success of oil and gas construction projects in Yemen. *International Journal of Energy Sector Management*, 14(3), pp 527-546.

Kassem, M.A., Khoiry, M.A., and Hamzah, H. (2020). Using Relative Importance Index Method for Developing Risk Map in Oil and Gas Construction Projects" *Jurnal Kejuruteraan*, 32(3) pp 441-453.

Ke, Y., Wang, S., Chan, A.P.C., and Cheung, E. (2009). Research trend of public-private partnership in construction journals. *Journal of Construction Engineering and Management,* 135 (10) pp. 1076-1086.

Kermanshachi, S., Thakur, R., and Govan, P., (2018). Discovering the impact of late change orders and rework on labour productivity: A water treatment case study analysis using system dynamics modelling. *Proceedings of Construction Research Congress*, New Orleans, Louisiana, 691-701.

Kiani, H., Hosseini, S.H., and Abdi, F. (2018). A model to investigate the effect of work ethic culture on dynamics of rework in management of projects. *Interdisciplinary description of complex systems*, 16 (1), 40–59.

Kim, Y.J., and Skibniewski, M.J. (2020). Cash and Claim: Data-Based Inverse Relationships between Liquidity and Claims in the Construction Industry. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(3): 04520021.

Kisi, K.P., Lee, N., Kayastha, R., and Kovel, J. (2020). Alternative Dispute Resolution Practices in International Road Construction Contracts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12 (2): 04520001.

Koskela, L, and Huovila, P. (2000). On foundations of concurrent engineering. *International Journal of Computer Integration Design Construction*, 2(1), 2-8.

Koushki, P., Al-Rashid, K. and Kartam, N. (2005). Delays and cost increases in the construction of private residential projects in Kuwait. *Construction Management Economics*, 23(3), 285-294.

Larsen, K.R., Hovorka, D.S., Dennis, A.R., and West, J.D. (2019). Understanding the Elephant: The Discourse Approach to Boundary Identification and Corpus Construction for Theory Review Articles. *Journal of the Association for Information Systems*, 20(7), 887-927.

Lee, Z.P., Rahimi, A.R., and Doh, S.I. (2020). Critical success factors for implementing design-build: analysing Malaysian public projects. *Journal of Engineering, Design and Technology*, 1726-0531.

Lessing, B., Thurnell, D., and Durdyev, S. (2017). Main factors causing delays in large construction projects: Evidence from New Zealand. *Journal of Management, Economics, and Industrial Organization*, 1(2), pp.63-82.

Li, H., and Love, P.E.D. (1998). Visualization of building interior design to reduce rework. *IEEE Proceedings, International conference on information visualization*, 31 July 1998, London, UK, 2-7.

Li, Y. and Taylor, T.R.B. (2014a). The Impact of Design Rework on Construction Project Performance. *The 29th International Conference of the System Dynamics Society*, 25-35.

Li, Y., and Taylor, T.R.B. (2014b). Modelling the impact of design rework on transportation infrastructure construction project performance. *Journal of Construction Engineering and Management*, 140(9), 04014044.

Liu, Q., Ye, G., Feng, Y., Wang, C., and Peng, Y. (2020). Case based insights into rework costs of residential building projects in China. *International Journal of Construction Management*, 20(4), pp. 347-355.

Liu, Y., Nederveen, S.V., and Hertogh, M. (2017). Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International Journal of Project Management,* 35(4), Pages 686-698.

Lopez, R., and Love, P.D.E. (2012). Design Error Costs in Construction Projects. *Journal of Construction Engineering and Management*, 138(5): 585-593.

Love, P.E.D., Li, H., and Mandal, P. (1999). Rework a symptom of a dysfunctional supply chain. *European Journal of Purchasing & Supply Management*, 5, pp.1-11.

Love, P.E.D., Mandal, P., Smith, J., and Georgious, J. (2000a). A design and construction rework minimization model. *1st International Conference on System Thinking in Management*, 377-382.

Love, P.E.D., Mandal, P., Smith, J., and Li, H. (2000b). Modelling the dynamics of design error induced rework in construction. *Construction Management and Economics,* 18, pp. 567–574.

Love, P.E.D., and Li, H. (2000). Quantifying the causes and costs of rework in construction. *Construction Management and Economics*. 18, 479-490.

Love P.E.D. (2002a). Auditing the indirect consequences of rework in construction: A case based approach. *Managerial Auditing Journal,* 17(3), 138-46.

Love, P.E.D., (2002b). Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects. *Journal of Construction Engineering and Management*, 128(1), 18-29.

Love, P.E.D., Holt, G.D., Shenb, L.Y., Li, H., and Irani, Z. (2002). Using systems dynamics to better understand change and rework in construction project management systems. *International Journal of Project Management*, 20, pp. 425-436.

Love, P.E.D., Irani, Z., Edwards, D.J. (2003). Learning to Reduce Rework in Projects Analysis of Firm's Organizational Learning and Quality Practices. *Project Management Journal*, 34(3), pp.13-25.

Love, P.E.D., and Smith, J. (2003). Benchmarking, bench-action, and bench-learning rework mitigation in projects. *Journal of Management in Engineering*, 19(4), 147-159.

Love P.E.D., and Edwards D.J. (2004a). Determinants of rework in building construction projects. *Engineering, Construction and Architectural Management*, 11 (4): 259-274

Love, P. E. D., and Edwards, D. J. (2004b). Forensic project management; The underlying causes of rework in construction projects. *Civil Engineering and Environmental Systems*, 21(3), pp. 207-228.

Love P.E.D., Edwards D.J., and Irani Z. (2004). A rework reduction model for construction. *IEEE Transactions on Engineering Management*, 51 (4): 426-440.

Love, P.E.D., Edwards, D.J., Smith, J. (2005). A forensic examination of the causal mechanisms of rework in a structural steel supply chain. *Managerial Auditing Journal*, 20(2), 187-197.

Love, P.E.D. and Edwards, D.J. (2005). Calculating total rework costs in Australian construction projects. *Civil Engineering and Environmental Systems*, 22(1), 11–27.

Love, P.E.D., Edwards, D.J., and Smith, J. (2006). Contract documentation and the incidence of rework in projects. *Architectural Engineering and Design Management*, 1, 247-259.

Love, P.E.D., Edwards, D.J., and Irani, Z. (2008). Forensic project management; an exploratory examination of the casual behaviour of design induced rework. *IEEE transactions on engineering management*, 55(2), 234–247.

Love, P.E.D, Edwards, D., Smith, J. and Walker, D. (2009a). Divergence or congruence? A path model of rework for building and civil engineering projects. *Journal of Performance of Constructed Facilities*, 23(6), pp.480-488.

Love, P.E.D., Edwards, D. J., Irani, Z., and Walker, D.H.T. (2009b). Project pathogens: The anatomy of omission errors in construction and engineering projects. *IEEE Transaction Engineering and Management*, 56(3), pp. 425–435.

Love, P.E.D., Mandal, P., and Li, H. (2010a). Determining the causal structure of rework influences in construction. *Construction Management and Economics*, 17(4):505-517.

Love, P.E.D., Edwards, D.J, Watson, H., and Davis, P. (2010b). Rework in civil infrastructure projects determination of cost predictors. *Journal of Construction Engineering and Management*, 136(3), 275-282.

Love, P.E.D., Smith, J., and Han, S. (2011). Systemic rework risk classification for offshore projects. *27 annual Association of Researchers in Construction Management (ARCOM) conference*, 1023-1032.

Love, P.E.D. and Edwards, D.J. (2013). Curbing rework in offshore projects systemic classification of risks with dialogue and narratives. *Structure and Infrastructure Engineering*, 9(11), 1118-1135.

Love, P.E.D. and Sing, C.P. (2013). Determining the probability distribution of rework costs in construction and engineering projects. *Structure and Infrastructure Engineering*, 9(11), 1136-1148.

Love, P. E. D., Edwards, D.J., Irani, Z., and Forcada, N. (2014). The latent causes of rework in floating production storage and offloading projects. *Journal of Civil Engineering and Management*, 20(3), pp. 315–329.

Love, P.E.D. Ackermann, F., Teo, P., and Morrison, J. (2015). From individual to collective learning; A conceptual learning framework for enacting rework prevention. *Journal of Construction Engineering and Management*, 141(11), 05015009.

Love, P.E.D., Ackermann, F., Carey, B., Morrison, J., Ward, M., and Park, A. (2016a). Praxis of rework mitigation in construction. *Journal of Management in Engineering*, 32(5), 05016010.

Love, P.E.D., Edwards, D.J., and Smith, J. (2016b). Rework causation emergent theoretical insights and implications for research. *Journal of Construction Engineering and Management*, 142(6), 04016010.

Love, P.E.D., and Smith, J. (2018). Unpacking the ambiguity of rework in construction making sense of the literature. *Civil Engineering and Environmental Systems*, 35(1–4), pp. 180-203.

Love, P.E.D. Smith, J., Ackermann, F., and Irani, Z. (2018a). The praxis of stupidity an explanation to understand the barriers mitigating rework in construction. *Production Planning & Control, The Management of Operations*, 29(13), 1112-1125.

Love, P.E.D., Smith, J., Ackermann, F., Irani, Z., and Teo, P. (2018b). The costs of rework insights from construction and opportunities for learning. *Production Planning & Control, The Management of Operations*, 29(13), 1082-1095.

Love, P.E.D., and Curtin, J. (2019). Creating a mindfulness to learn from errors enablers of rework containment and reduction in construction. *Developments in the Built Environment*, S2666-1659 (19), 30001, pp.1-8.

Love, P.E.D., Ika, L.A., Ahiaga-Dagbui, D.D., Locatelli, G., and Sing, M.C.P., (2019a). Make or break during production shedding light on change orders rework and contractors' margin in construction. *Production Planning & Control*, 0953-7287 (Print) 1366-5871, 285-298.

Love, P.E.D., Smith, J., Ackermann, F., and Irani, Z. (2019b). Making sense of rework and its unintended consequence in projects; The emergence of uncomfortable knowledge. *International Journal of Project Management*, 37, 501-516.

Luo, T., Wu, C., and Duan, L. (2018). Fishbone diagram and risk matrix analysis method and its application in safety assessment of natural gas spherical tank. *Journal of Cleaner Production*, 174 pp 296-304.

Ma, D., Li, X., and Cheng, C. (2020). The impact of the international construction standard application capability on contractor's competitiveness: Chinese Contractors experience. *Journal of Civil Engineering and Management*, 26(8), pp. 757–774.

Ma, G., Jiang, S., Zhu, T., and Jia, J. (2019a). A novel method of developing construction projects schedule under rework scenarios. *Sustainability*, 11(20), 5710.

Ma, G., Jia, J., Zhu, T., and Jian, S. (2019b). A critical design structure method for project schedule development under rework risks. *Sustainability*, 11(24), 7229.

Ma, G., Hao, K., Xiao, Y., and Zhu, T. (2019c). Critical chain design structure matrix method for construction project scheduling under rework scenarios. *Mathematical Problems in Engineering*, ID 1595628, pp. 1-14.

Mahamid, I. (2016a). Analysis of rework in residential building projects in Palestine. *Jordan Journal of Civil Engineering*, 10(2), pp. 197-208.

Mahamid, I. (2016b). Effect of change orders on rework in highway projects in Palestine. *Journal of Financial Management of Property and Construction*, 22(1), pp. 62-76.

Mahamid, I. (2020). Impact of rework on material waste in building construction projects. *International Journal of Construction Management*, ISSN: 1562-3599 2331-2327. pp.1-8.

Maheswari, J.U., Paul, V.C., Charlesraj, G., Kumara, S., and Padala, S. (2016). A Study on Assessment of Nonconformance Using Multiple Domain Matrix, A Case Study from Metro Projects. I*nternational Conference on Sustainable Design, Engineering and Construction, Procedia Engineering*, 145 pp. 622-629.

Malek, J., and Desai, T.N. (2020). A systematic literature review to map literature focus of sustainable manufacturing. *Journal of clear production*, 256 (2020) 120345, pp. 1-20.

Mazlum, S.K., and Pekerici, M.K. (2016). Lean design management, An evaluation of waste items for architectural design process. METU JFA (33:1) 1-20.

Mazzurco, A., Jesiek, B.K., and Godwin, A. (2020). Development of Global Engineering Competency Scale: Exploratory and Confirmatory Factor Analysis. *Journal of Civil Engineering Education*, 46(2): 04019003

Mendis, D., Hewage, K.N., and Wrzesniewski, J. (2015). Contractual obligations analysis for construction waste management in Canada. *Journal of Civil Engineering and Management*, 21(7), pp. 866–880.

Mendis, D., Hewage, K.N., and Wrzesniewski, J. (2013). Reduction of construction wastes by improving construction contract management: a multinational evaluation. *Waste Management & Research*, 31(10) pp.1062–1069.

Mills, A., Love P.E.D., Williams P. (2009). Defect Costs in Residential Construction. *Journal of Construction Engineering Managemen*t, 135(1): 12-16.

Mills, A., Williams, P., and Yu, D. (2010). Benchmarking construction rework in Australian housing. *International Journal for Housing Science*, 34(3), 207-220.

Miri, M., and Khaksefidi, M. (2015). Cost management in construction projects rework and its effects. *Mediterranean Journal of Social Sciences*, 6(6), S6, pp. 209-215.

Mohamad, M.I., and Madon, Z. (2006). Understanding contract documentation. *6th Asia-Pacific Structural Engineering and Construction Conference*, 5-6 September 2006, KL, Malaysia pp.C12-18.

Mohamed, H.H., Ibrahim, A.H., and Soliman, A.A. (2014). Reducing Construction Disputes through Effective Claims Management. *American Journal of Civil Engineering and Architecture*, 2(6), pp 186-196.

Mohandes, S.R., Zhang, X., and Mahdyar, A. (2019). A comprehensive review on the application of artificial neural networks in building energy analysis. *Neurocomputing,* 340, 55-75.

Mohiuddin, M. (2011). Research on offshore outsourcing: A systematic literature review. *Journal of International Business Research,* Volume 10, Special Issue.

Mollasalehi, S., Fleming, A., Talebi, S., and Underwood, J. (2016). Development of an experimental waste framework based on BIM-LEAN concept in construction design. *24th Ann. Conf. of the Int'l. Group for Lean Construction*, Boston, MA, USA, sect.4 pp. 193–202.

Moza, A., and Paul, V.K. (2018). Analysis of Claims in Public Works Construction Contracts in India. *Journal of Construction in Developing Countries*, 23(2), pp 7–26.

Ndwandwa, S., Simpeh, E.K., and Smallwood, J.J. (2017). Factors influencing the occurrence of rework in construction. *Proceedings of international research conference* 2017, sharping tomorrow's built environment, University of Salford, UK., pp. 757-770.

O'Brien, P., and Degerholm, P. (2019). NZS3910, about time for an update, keeping NZS3910 relevant, effective and fair. NZIQS presentation.

Oke, A.E. and Ugoje, O.F. (2013). Assessment of rework cost of selected building projects in Nigeria. *International Journal of Quality & Reliability Management*, 30(7), 799-810.

Olanipekun, A.O., Xia, B., Hon, C., and Hu, Y. (2017). Project Owners' Motivation for Delivering Green Building Projects. *Journal of Construction Engineering and Management*, 143(9): 04017068

Oyegoke, A.S., and Dickinson, M. (2009). Construction project procurement routes: an in-depth critique. *International Journal of Managing Projects in Business,* 2(3), pp. 338-354.

Oyewobi, L.O., and Ogunsemi D.R. (2010). Factors influencing rework occurrence in construction; A study of selected building projects in Nigeria. *Journal of Building Performance*, 1(1), pp. 1-20.

Oyewobi, L.O., Ibironke, O.T., Ganiyu, B.O., and Ola-Awo, A.W. (2011). Evaluating rework cost - A study of selected building projects in Niger State' Nigeria. *Journal of Geography and Regional Planning*, 4(3), pp. 147-151.

Oyewobi, L.O., Falemu, O., and Ibironke, O.T. (2016). The impact of rework and organisational culture on project delivery. *Journal of Engineering, Design and Technology*, 14(2), pp. 214-237.

Palaneeswaran, E., Kumaraswamy M.M., Ng, S.T., and Love, P.E.D. (2005). A framework for monitoring rework in building projects. *Proceedings of Tall Buildings, from engineering to sustainability*, Edition: 2005, part XIII, pp 710-715.

Palaneeswaran, E. (2006). Reducing rework to enhance project performance levels. *Proceedings of the One-day Seminar on Recent Developments in Project Management*,12 May 2006, Hong Kong, pp. 1-10.

Palaneeswaran, E., Kumaraswamy, M.M., Ng, S.T., and Love, P.E.D. (2006). Neural network modelling for rework related cost overrun and contractual claims in construction projects. *International Conference on Computing and Decision Making in Civil and Building Engineering*, June 14-16, 2006 - Montréal, Canada, pp. 1393-1402.

Palaneeswaran, E., Ramanathan, M., and Chi-ming, T. (2007). Rework in Projects: Learning from Errors. *Surveying and Built Environment*, 18(2), 47-58.

Palaneeswaran, E., Love, P.E.D., and Kumaraswamy M.M. (2008). Mapping rework causes and effects using artificial neural networks. *Building Research & Information*, 36(5), 450-465.

Palaneeswaran, E., Love, P.E.D., Kumaraswamy, M.M., and Ng, T.S.T. (2014). Causal ascription of rework in building and civil engineering projects; A multivariate exploration. *Engineering, Construction and Architectural Management*, 21(1), pp. 111-126.

Papajohn, D., El-Asmar, M., Molenaar, K.R., and Alleman, D. (2020). Comparing Contract Administration Functions for Alternative and Traditional Delivery of Highway Projects. *Journal of Management in Engineering*, 36(1): 04019038.

Park, J., and Tucker, R. (2017). Overcoming barriers to the reuse of construction waste material in Australia: a review of the literature. *International Journal of Construction Management*, Vol. 17, No. 3, pp. 228-237.

Parvan, K. (2012). Estimating the impact of building information modeling (BIM) utilization on building project performance. (PhD Thesis).

Parvan, K., Rahmandad, H., Haghani, A. (2015). Interphase feedbacks in construction projects. *Journal of Operations Management* 39-40, pp. 48-62.

Patterson, P.G., and Spreng, R.A. (1997). Modelling the relationship between perceived value, satisfaction and repurchase intentions in business to business, services context: an empirical examination. ISS 1324-681X, ISBN 0 7334 0463 4.

Pena-Mora, F., and Li, M. (2001). Dynamic planning and control methodology for design/build fast track construction projects. *Journal of Construction Engineering Management*, 10.1061/(ASCE)0733-9364,127:1(1), 1-17

Pesamaa, O., Eriksson, P.E., Hair, J.F. (2009). Validating a model of cooperative procurement in the construction industry. *International Journal of Project Management*, 27, pp. 552–559.

Pesek, A.E., Smithwick, J.B., Saseendran, A., and Sullivan, K.T. (2019). Information Asymmetry on Heavy Civil Projects: Deficiency Identification by Contractors and Owners. *Journal of Management in Engineering*, 35(4): 04019008.

Pilehchian, B., Staub-French, S., and Nepal, M.P. (2015). A conceptual approach to track design changes within a multi-disciplinary building information modeling environment. *Canadian Journal of Civil Engineering*, 42(2), 139-152. dx.doi.org/10.1139/cjce-2014-0078.

Priemus, H., and Wee, V.B. (2013). International Handbook on Mega-projects: Edward Elgar Publishing.

Puspita, A.W.Y., Suharyanto, A., and Indradi, W. (2019). Risk management rework and repair implementation phase in building project to improve project quality performances. *International Research Journal of Advanced Engineering and Science*, 4(2), 525-529.

Rahmandad, H., and Hu, K. (2010). Modeling the rework cycle: Capturing multiple defects per task. *System Dynamics Review,* 26(4), 291–315.

Raj, S., Hillig, J.B., and Hughes, W. (2009). Responsiveness to change by standard-form contract drafters in the construction industry A case study of the FIDIC White Book. *International Journal of Law in the Built Environment,* 1(3), pp. 205-220.

Rezahoseini, A., Noori, S., Ghannadpour, S.F., and Bodagi, M. (2019). Reducing rework and increasing the civil projects quality, through Total Quality Management (TQM), by using the concept of Building Information Modelling (BIM). *Journal of industrial and systems engineering*, 12, 1–27.

Robertson, S. (2018). The Engineer to the Contract: How the role evolved, and the part played in dispute resolution. *Society of Construction Law*, New Zealand, 1 March 2018 and 5 April 2018, pp. 1-24.

Robinson, F.A., Dissanayake, M., and Campero, O. (2004). Developing a standard methodology for measuring and classifying construction field rework. *Canada Journal of Civil and Engineering,* l(31), pp 1077-1089.

Rotimi J.O.B, Wahid, I., and Shahzad, W. (2019). Factors limiting performance of the construction industry, a New Zealand Perspective. *Proceeding 43rd AUBEA conference*, pp 629-637.

Rogge, D.F., Cogliser, C., Alaman, H., and McCormack, S. (2001). An investigation of field rework in industrial construction. Research Report 153-11, Construction Industry Institute, University of Texas at Austin, Austin, Texas.

Sacks, R., Treckmann M. and Rozenfeld, O. (2009). Visualization of work flow to support lean construction. *Journal Construction Engineering Management*, 135(12), 1307(1315).

Safapour, E., and Kermanshachi, S. (2019). Identifying early indicators of manageable rework causes and selecting mitigating best practices for construction. *Journal of Management in Engineering*, 35(2), 04018060.

Safapour, E., Kermanshachi, S., and Taneja, P. (2019). Investigation and analysis of the rework leading indicators in construction projects state-of-the-art review. *7th CSCE International Construction Specialty Conference (ICSC),* June 12-15, 2019, CON-294, pp.1-10.

Salihu, C., and Babarinde, S.A. (2020). Strategies for reduction of design-related rework in the Nigerian construction industry. *PM World Journal*, IX(II), pp. 1-11.

Saseendran, A., Bigelow, B.F., Rybkowski, Z.K., and Jourdan, D.E. (2020). Disputes in Construction: Evaluation of Contractual Effects of Consensus DOCS. J*ournal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(2): 04520008.

Saunders, M., Lewis, P., and Thornhill, A. (2009). Business research methods. Financial Times, Prentice Hall: London.

Schon, E.M., Thomaschewski, J., and Escalona, M.J. (2017). Agile requirements engineering; A systematic literature review. *Computer Standards & Interfaces*, 49, 79-91.

Seadon, J., Tookey, J.E. (2019). Drivers for construction productivity. *Engineering, Construction and Architectural Management*, 26, pp. 945-96.

Seneviratne, K., and Michael, G.V. (2020). Disputes in time bar provisions for contractors' claims in standard form of contracts. *International Journal of Construction Management*, 20(4), pp. 335-346.

Seo, W., and Kang, Y. (2020). Performance Indicators for the Claim Management of General Contractors. *Journal of Management in Engineering*, 36(6): 04020070.

Shah, K.K, Shah, R.A., and Sharma, N.D. (2016). Development of field rework index to minimize the impact of rework for effective construction work. *International Journal of Scientific Development and Research*, 1(5), pp. 370-375.

Shestakova Y. (2005). The Analysis of the Use of Collaborative Procurement Systems in New Zealand Construction-Partnering, Alliancing, Joint Ventures. Auckland, The University of Auckland.

Shinde, M.R., and Kulkarni, P.S. (2016). Impact of Supervision on Rework in Construction Industry. *International Journal on Recent and Innovation Trends in Computing and Communication*. 4(1), pp. 268-270.

Simpeh, E.K., Ndihokubwayo, R., Love, P.E.D., and Thwala, W.D. (2015). A rework probability model: a quantitative assessment of rework occurrence in construction projects. *International Journal of Construction Management*, 15(2), pp. 109-116.

Simpeh, E.K., Ndihokubwayo, R., and Love, P.E.D. (2011). An analysis of the impact of rework on project performance Views from the field. *Proceedings 6th Built Environment Conference in South Africa*, ISBN:978-0-86970-713-5, 87-98.

Siraj, N.B., and Robinson, F.A. (2019). Risk Identification and Common Risks in Construction: Literature Review and Content Analysis. J*ournal of Construction Engineering and Management*, 145(9): 03119004.

Soewin, E., and Chinda, T. (2018). Factors affecting construction performance: exploratory factor analysis. *IOP Conf. Series: Earth and Environmental Science* 140 (2018) 012102.

Sohi, A.J., Hertogh, M., Rekveldt, M.B., and Blom, R. (2016). Does lean and agile project management help coping with project complexity. *Procedia - Social and Behavioral Sciences*. 226, 252-259.

Sommerville, J. (2007). Defects and rework in new build an analysis of the phenomenon and drivers. *Structural Survey*, 25(5), 391-407.

Sorde, M.S., and Sawant, P.H. (2015). Analysis of Contract Clauses Affecting the Cost Performance of a Construction Project. *Journal of Civil Engineering and Environmental Technology*, 2(5), pp. 437-440.

Standard NZ, (2021). NZS 3910 Scoping report. NZS 3910 Conditions of contract for building and civil engineering. By Inge Mautz-Cooreman. Ministry of Business, Innovation and Employment.

Standard New Zealand. (2013). Conditions of contract for building and civil engineering construction published. NZS 3910-2013. Wellington, New Zealand.

Syal, M., and Bora, M. (2016). Change Order Clauses in Standard Contract Documents. *Practice Periodical on Structural Design and Construction,* 21(2): 04015021.

Taggart, M., Koskela, L., and Rooke, J. (2014a). The role of the supply chain in the elimination and reduction of construction rework and defects an action research approach. *Construction Management and Economics*, 32(7–8), pp. 829–842.

Taggart, M., Koskela, L., and Rooke, J. (2014b). An improvement strategy for the defects and rework management process within an SME; An action research approach. *30th Annual ARCOM Conference in Portsmouth*, 1–3 September 2014, Portsmouth, UK. Reading, UK: Association of Researchers in Construction Management, 1059–1068.

Tague, Mc.B., and Jergeas, G. (2002). Productivity improvements on Alberta major construction projects. Alberta Economic Development.

Tezel, A., Taggart, M., Koskela, L., Tzortzopoulos, P., Hanahoe, J. and Kelly, M. (2020). Lean construction and BIM in small and medium-sized enterprises (SMEs) in construction: a systematic literature review. *Canadian Journal of Civil Engineering*, 47, 186-201.

Totterdill B. (2006). FIDIC user's guide: a practical guide to the 1999 red and yellow books. London, Thomas Telford. Manchester Institute of Science and Technology (UMIST), Manchester, UK.

Trach, R., Pawluk, K., and Lendo-Siwicka, M. (2019). Causes of rework in construction projects in Ukraine. *Archives of civil engineering,* 65(3), pp. 61-74.

Tribelsky, E. and Sacks, R. (2011). An Empirical Study of Information Flows in Multidisciplinary Civil Engineering Design Teams using Lean Measures. *Architectural Engineering and Design Management,* 7, pp 85-101.

Umar, A.A., Zawawi, N.A., and Abdul-Aziz, A.R. (2019). Exploratory factor analysis of skills requirement for PPP contract governance. *Built Environment Project and Asset Management*, 9(2), pp. 277-290

Vachara, P., and Cheang, L. (2015). Identifying issues of change leading to cost conflicts case study in Cambodia. *Procedia Engineering*, 123 (2015) 379-387.

Walkman, S., and Conway, P. (2017). Innovation and the performance of New Zealand firms. Industry paper, pp 5.

Wang, C., Yap, J.B.H., Wood, L.C. and Abdul-Rahman, H. (2019). Knowledge modelling for contract disputes and change control. *Production Planning and Control*, 30(8), 650-664.

Wang, T., Chan, A.P.C., He, Q., and Xu, J. (2020). Identifying the gaps in construction megaproject management research: a bibliographic analysis. *International Journal of Construction Management*, 15623599.2020.1735610.

Wasfy, M.A. (2010). Severity and impact of rework, a case study of a residential commercial tower project in the eastern province-KSA.

Wilson, J.U., and Odesola, I.A. (2017). Design-related causes of rework and the performance of oil and gas projects in Nigeria" *International Journal of Sustainable Construction Engineering & Technology,* 8(1), 60-76.

Windapo, A., and Adediran, A. (2017). The influence of procurement strategy on SME contractor development in the construction industry. *International Research Conference 2017, Shaping tomorrow's-built environment*, 11-12 September 2017, University of Salford.

Wright, J.N., and Fergusson, W. (2009). Benefits of the NEC ECC form of contract: A New Zealand case study. *International Journal of Project Management*, 27, pp.243–249.

Xia, N., Zou, P.X.W., Griffin, M.A., Wang, X., and Zhong, R. (2018). Towards integrating construction risk management and stakeholder management: A systematic literature review and future research agendas. *International Journal of Project Management*, 36, 701-715.

Xiong, B., Skitmore, M., Xia, B., Masrom, M.A., Ye, K., and Bridge, A. (2014). Examining the influence of participant performance factors on contractor satisfaction: A structural equation model. *International Journal of Project Management*, 32, 482–491

Xue, X., Shen, Q., and Ren, Z. (2010). Critical Review of Collaborative Working in Construction Projects: Business Environment and Human Behaviors. *Journal of Management in Engineering*, 26(4), pp 196-208.

Yana, A.A., Agung, G., Rusdhi, H.A., Wibowo, M.A. (2015). Analysis of factors affecting design changes in construction project with PLS. *The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)* Procedia Engineering 125 (2015) 40-45.

Yap, J.B.H., Low, P.L., and Wang, C. (2017). Rework in Malaysian building construction impacts causes and potential solutions. *Journal of Engineering, Design and Technology*, 15(5), pp. 591-618.

Yap, J.B.H., Abdul-Rahman, H., Wang, C., and Skitmore, M. (2018). Exploring the underlying factors inducing design changes during building production. *Production Planning & Control*, 29(7), pp. 586–601.

Yap, J.B.H., Chong, J.R., Skitmore, M., and Lee, W.P. (2020). Rework Causation that Undermines Safety Performance during Production in Construction. Journal of Construction Engineering and Management, 146(9): 04020106.

Yap, J.B.H. and Tan, S.M. (2021). Investigating rework: insights from the Malaysian construction industry. *ASM Science Journal*, Vol. 14.

Ye, G., Jin, Z., Xia, B., and Skitmore, M. (2015). Analysing causes for reworks in construction projects in China. *Journal of Management in Engineering*, (31)6, 04014097.

Yeo, K.T., and Ning, J.H. (2002). Integrating supply chain and critical chain concepts in engineer-procure-construct (EPC) projects. International Journal of Project Management, 20, 253–262.

Yeung, J.F.Y., Chan, A.P.C., and Chan, D.W.M. (2007). “The definition of alliancing in construction as a Wittgenstein family-resemblance concept.” International Journal of Project Management, 25(3), 219-231.

Yi, W., and Chan, A.P.C. (2014). Critical review of labor productivity research in construction journals. *Journal of Management in Engineering*, 30(2), 214-225.

Zaghloul, R. and Hartman, F. (2003). Construction contracts the cost of mistrust. *International Journal of Project Management*, 21, pp. 419–424

Zaneldin, E.K. (2020). Investigating the types, causes and severity of claims in construction projects in the UAE. *International Journal of Construction Management*, 20(5), pp. 385-401.

Zhang, D., Haas, C.T., Goodrum, P.M., Caldas, C.H., and Granger, R. (2012). Construction small-projects rework reduction for capital facilities. *Journal of Construction Engineering and Management*, 138(12), pp. 1377-1385.

Zhang, S., Duan, H., Zhao, X., Xia, B., Feng, Y., and Galvin, S. (2018). Learning on rework management of construction projects a case study. *International Journal of Construction Management*, 1562-3599 (Print) 2331-2327, 1-15.

Zheng, F. (2018). Application Research on Construction Project Management Contract Management. *4th International Conference on Innovative Development of E-commerce and Logistics*. Published by CSP.

Zuo, K.X. (2010). Procurement and contractual arrangement for post disaster reconstruction. (PhD Thesis).

Appendix A: Ethic approval

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Date: 19 February 2020

Dear Ramin Asadi

Re: Ethics Notification - **4000022210 - Rework management in New Zealand construction contracts to achieve higher performance**

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 contact a Research Ethics Administrator.

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 Professor Craig Johnson, Director - Ethics, telephone 06 3569099 ext 85271, email humanethics@massey.ac.nz."

Please note, if a sponsoring organisation, funding authority or a journal in which you wish to publish requires 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 for 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.

Yours sincerely

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand **T** 06 350 5573; 06 350 5575 **F** 06 355 7973
E humanethics@massey.ac.nz **W** http://humanethics.massey.ac.nz

Human Ethics Low Risk notification

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

Appendix B: Questionnaire survey

Invitation to participate in a research survey

Research Title: Rework management in New Zealand construction contracts

Hi,

I am a research student at Massey University undertaking a Ph.D. research entitled: "Rework management in New Zealand construction contracts" and I would like to invite you to participate in a survey, as part of the research, which aims to investigate the relations between the clauses of standard contract documents of NZS3910 and the root causes of rework in New Zealand construction projects. The purpose of this questionnaire is to obtain your opinion on how rework can be managed through evaluating contract documents. A copy of the survey questions is attached. The time is estimated to last for about 15 minutes.

Section A: Information on the respondents and the organization's profile

Section B: Assessing the standard contract documents of NZS3910 to investigate the extent of contract coverage on rework causes and explore the required changes

Data obtained from the interview will be treated with strict confidence and used for academic purposes only. No records will bear your personal and your company's name.

Your contribution to answering the questions would be most appreciated. If you have any queries, please do not hesitate to contact me. Thank you very much in advance for your time and valuable assistance in this research.

Yours sincerely,

Ramin Asadi
Doctoral Research Candidate
School of Built Environment,
Massey University, New Zealand
Mob: 0276463976
Email: r.asadi@massey.ac.nz

“Questionnaire”

Section A: “General questions”
Profile of Respondent / Organization

1- How many years of experience do you have in the construction industry or project management? Please tick [✓] only one box.

☐ Less than 5 years ☐ 5 to 10 years ☐ 10 to 15 years
☐15 to 20 years ☐ 20 to 25 years ☐ Over 25 years

2- For how long have you been involved in contractual activities in projects? Please tick [✓] only one box.

☐ Less than 1 year ☐ 1 to 2 years ☐ 3to 5 years
☐ 6 to 10 years ☐ Over 10 years

3- Which of the following best describes your position in the company? Please tick [✓] only one box.

☐ Project Director ☐ Project Manager ☐ Construction Manager ☐ Site Manager
☐ Contract Manager ☐ Procurement Manager ☐ Commercial Manager ☐ Quantity Surveyor
☐ Other, (Please Specify):

4- Which of the following type of companies describe your organization the most? Please tick [✓] only one box.

☐ Client ☐ Consultant ☐ Contractor
☐ Designer ☐ Supplier ☐ Subcontractor

5- What is the main activity of your company’s business?

☐ Design ☐ Procurement ☐ Project management
☐ Construction ☐ Design and Built projects ☐ Others

6- What values do your projects mostly engage in? Please tick [✓] only one box

☐ Less than 10 Million NZD ☐ 10 to 50 Million NZD ☐ 50 to 100 Million NZD
☐ 100 to 500 Million NZD ☐ Over 500 Million NZD

7- Please indicate from which side of the contract are you answering the following questions? Please tick [✓] only one box

☐ Client-side ☐ Contractor-side

Section B: Assessing the standard contract documents of NZS3910 to investigate the extent of contract coverage on rework causes and explore the required changes

The following items have been identified as rework root causes within the project life cycle. In each question please rate your opinion by tick [✓] on the figures between 1 and 5.

Question 1- To what extent do you agree that the following rework root causes lead to claims and other contractual issues?

		1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
Process	1.1-Changes, modification and revisions in design or construction changes					
	1.2-Error in design, drawings and specifications / error in construction					
	1.3-Incomplete design, any omission in the design or construction process					
	1.4-Inadequate procurement methods / poor contract execution					
	1.5-Improper contractor and subcontractor selection					
	1.6-Lack of document control					
Human resources	2.1-Lack of experience and personal expertise in design and construction					
	2.2-Inadequate supervision staff					
	2.3-Inadequate manpower to complete the task / Staff turnover					
	2.4-Insufficient skilled level manpower					
	2.5-Poor knowledge of team member, lack of education and training					
	2.6-Lack of employee motivation and rewards, Carelessness					
	2.7-Poor workmanship approach and inappropriate personal attitude					
	2.8-The absence of job security and other safety rules					
	2.9- Labor reallocation, alteration and staff turnover					
	2.10-Conflict of interests					
Material & Equipment	3.1-Defective materials, Non-adherence to material specifications					
	3.2-Poor-quality material or substandard products / Prefabrication errors					
	3.3-Replacement or misplacement of material and equipment					
	3.4-Inefficient equipment use or altered material					
	3.5-Untimely deliveries of material and equipment					
Technical	4.1-Ineffective use of quality management practices / deviation due to poor monitoring					
	4.2-Poor technology application and lack of information technology use					
	4.3-Poor communication system for coordinating between members					
	4.4-Inefficient management process, poor site management practice					
	4.5-Poor project documents, unclear instructions, poor contract documents					
	4.6- Conflicting and incomplete information					
	4.7-Inadequate planning and poor scheduling of workload					
Other factors	5.1-Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure					
	5.2-Lack of client involvement					
	5.3-Unclear line of authority					
	5.4-Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation					
	5.5-Lack of constructability					
	5.6- Damage / defects / Deviations in the product due to poor handling and safety considerations					
	5.7-Governmental regulations / changes and policies					
	5.8-Environmental conditions, poor site condition					
	5.9-Unpredictable factors from different sources					

Question 2- To what extent do you agree that the conditions of contract of NZS3910:2013 adequately address the following rework root causes?

Category	Root cause	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
Process	1.1-Changes, modification and revisions in design or construction changes					
	1.2-Error in design, drawings and specifications / error in construction					
	1.3-Incomplete design, any omission in the design or construction process					
	1.4-Inadequate procurement methods / poor contract execution					
	1.5-Improper contractor and subcontractor selection					
	1.6-Lack of document control					
Human resources	2.1-Lack of experience and personal expertise in design and construction					
	2.2-Inadequate supervision staff					
	2.3-Inadequate manpower to complete the task / Staff turnover					
	2.4-Insufficient skilled level manpower					
	2.5-Poor knowledge of team member, lack of education and training					
	2.6-Lack of employee motivation and rewards, Carelessness					
	2.7-Poor workmanship approach and inappropriate personal attitude					
	2.8-The absence of job security and other safety rules					
	2.9- Labor reallocation, alteration and staff turnover					
	2.10-Conflict of interests					
Material & Equipment	3.1-Defective materials, Non-adherence to material specifications					
	3.2-Poor-quality material or substandard products / Prefabrication errors					
	3.3-Replacement or misplacement of material and equipment					
	3.4-Inefficient equipment use or altered material					
	3.5-Untimely deliveries of material and equipment					
Technical	4.1-Ineffective use of quality management practices / deviation due to poor monitoring					
	4.2-Poor technology application and lack of information technology use					
	4.3-Poor communication system for coordinating between members					
	4.4-Inefficient management process, poor site management practice					
	4.5-Poor project documents, unclear instructions, poor contract documents					
	4.6- Conflicting and incomplete information					
	4.7-Inadequate planning and poor scheduling of workload					
Other factors	5.1-Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure					
	5.2-Lack of client involvement					
	5.3-Unclear line of authority					
	5.4-Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation					
	5.5-Lack of constructability					
	5.6- Damage / defects / Deviations in the product due to poor handling and safety considerations					
	5.7-Governmental regulations / changes and policies					
	5.8-Environmental conditions, poor site condition					
	5.9-Unpredictable factors from different sources					

Appendix C: Interview questionnaire

Invitation to participate in a research interview

Research Title: Rework management in New Zealand construction contracts

Hi,

I am a research student at Massey University undertaking a Ph.D. research entitled: "Rework management in New Zealand construction contracts" and I would like to invite you to participate in an interview/meeting, as part of the research, which aims to investigate the relations between the clauses of standard contract documents of NZS3910 and the root causes of rework in New Zealand construction projects. The purpose of this interview/meeting is to obtain your opinion on how clauses of NZS3910 address rework? A copy of the interview questions is attached. The time is estimated to between 30 to 45 minutes.

Section A: Information on the respondents and the organization's profile

Section C: Establishment of the relations between rework causes and clauses of NZS3910 to explore the recommendations that can be used in the contract to address rework (Descriptive questions)

Data obtained from the interview will be treated with strict confidence and used for academic purposes only. No records will bear your personal and your company's name.

Your contribution to answering the questions would be most appreciated. If you have any queries, please do not hesitate to contact me. Thank you very much in advance for your time and valuable assistance in this research.

Yours sincerely,

Ramin Asadi
Doctoral Research Student
School of Built Environment,
Massey University, New Zealand
Mob: 0276463976
Email: r.asadi@massey.ac.nz

“Questionnaire”

Section A: “General questions”

Profile of Respondent / Organization

1- How many years of experience do you have in the construction industry or project management? Please tick [✓] only one box.

□ Less than 5 years □ 5 to 10 years □ 10 to 15 years
□15 to 20 years □ 20 to 25 years □ Over 25 years

2- For how long have you been involved in contractual activities in projects? Please tick [✓] only one box.

□ Less than 1 year □ 1 to 2 years □ 3to 5 years
□ 6 to 10 years □ Over 10 years

3- Which of the following best describes your position in the company? Please tick [✓] only one box.

□ Project Director □ Project Manager □ Construction Manager □ Site Manager
□ Contract Manager □ Procurement Manager □ Commercial Manager □ Quantity Surveyor
□ Other, (Please Specify):

4- Which of the following type of companies describe your organization the most? Please tick [✓] only one box.

□ Client □ Consultant □ Contractor
□ Designer □ Supplier □ Subcontractor □ Others

5- What is the main activity of your company’s business?

□ Design □ Procurement □ Project management
□ Construction □ Design and Built projects □ Others

6- What values do your projects mostly engage in? Please tick [✓] only one box

□ Less than 10 Million NZD □ 10 to 50 Million NZD □ 50 to 100 Million NZD
□ 100 to 500 Million NZD □ Over 500 Million NZD

7- Please indicate from which side of the contract are you answering the following questions? Please tick [✓] only one box

□ Client-side □ Contractor-side

Section C: Establishment of the relations between rework causes and clauses of NZS3910:2013 to explore the recommendations that can be used in contract to address rework (Descriptive questions)

A survey within New Zealand construction projects in the last few months was conducted to investigate which root causes of rework lead to contractual issues and claims and explore if the clauses of NZS3910:2013 adequately address those causes. The initial result of the survey prioritized the causes of rework as the attached list that is used for reference to answer the following interview questions. The interview aims to find whether addressing rework has been stated in the clauses of NZS3910 clearly or not? It would be appreciated to answer the questions based on your best experience and knowledge of NZS3910:2013.

Question 1. Please describe how your company reduces rework in construction projects?

Question 2. How is rework addressed within clauses of NZS3910? Which clauses relate to the causes of rework?

Question 3. Please recommend any clauses of NZS3910 that can be ammended/changed based on the priority index of the attached reference.

Question 4. How claimes and other contractual issues originated from rework are assessed in your company?

Question 5. Do you believe that the risks of reworking within clauses of NZS3910:2013 have been addressed adequately?

Question 6. Please describe how clauses of NZS3910:2013 can be revised to prevent claims and disputes originated from rework? What are your recommendations?

Optional questions:

Question 7. Would it be appropriate if an extra section is added to the contract documents of NZS3910:2013 for more clarification on rework assessment and why?

Question 8. How can the role of Engineers facilitate the process of rework management?

Please feel free to give any further general comments or advice to improve the contract documents of NZS3910 and manage rework in construction projects.

Reference list: The importance index of rework causes

Row	Root causes of rework	Category	Note
1	Lack of experience and personal expertise in design and construction	Human resources factor	
2	Insufficient skilled level manpower	Human resources factor	
3	Inadequate supervision staff	Human resources factor	
4	Poor knowledge of team member or lack of education and training	Human resources factor	
5	Lack of constructability	General factors	
6	Poor workmanship approach and inappropriate personal attitude	Human resources factor	
7	Inadequate manpower to complete the task / Staff turnover	Human resources factor	
8	Inefficient management process and poor site management practice	Technical factor	
9	Inadequate planning and poor scheduling of workload	Technical factor	
10	Improper contractor/subcontractor selection	Process factor	
11	Poor communication system for coordinating between members	Technical factor	
12	Time pressure, schedule acceleration to finish the task, insufficient time to prepare contract documentation	General factors	
13	Inadequate procurement methods / poor contract execution	Process factor	
14	Lack of document control	Process factor	
15	Lack of employee motivation and rewards, Carelessness	Human resources factors	
16	Ineffective use of quality management practices / deviation due to poor monitoring	Technical factor	
17	Poor project documents, unclear instructions and poor contract documents	Technical factor	
18	Financial issues such as lack of funding, low contract or payment fee, delay in payment and cost pressure	General factors	
19	Damage / defects / Deviations in the product due to poor handling and safety considerations	General factors	
20	Error in design, drawings and specifications / error in construction	Process factor	
21	Lack of client involvement	General factors	
22	Incomplete design, any omission in the design or construction process	Process factor	
23	Unpredictable factors from different sources	General factor	
24	Poor technology application and lack of information technology use	Technical factor	
25	Labor reallocation or alteration and staff turnover	Human resources factors	
26	Untimely deliveries of material and equipment	Material & equipment factor	
27	Inefficient equipment use or altered material	Material & equipment factor	
28	Replacement or misplacement of material and equipment	Material & equipment factor	
29	Environmental conditions, poor site condition	General factors	
30	Conflicting and incomplete information	Technical factor	
31	Poor-quality material or substandard products / Prefabrication errors	Material & equipment factor	
32	Defective materials, Non-adherence to material specifications	Material & equipment factor	
33	Conflict of interests	Human resources factors	
34	Changes, modification and revisions in design or construction changes	Process factors	
35	The absence of job security and other safety rules	Human resources factors	
36	Governmental regulations / changes and policies	General factors	
37	Unclear line of authority	General factors	

Listed items have been prioritized based on the high generating rate of claims and contractual issues while have not been addressed by NZS3910 clauses adequately.

Appendix D: Statement of contribution to publications

1- Doctoral research contribution for the paper used in chapter 2
2- Doctoral research contribution for the paper used in chapter 3
3- Doctoral research contribution for the paper used in chapter 4
4- Doctoral research contribution for the paper used in chapter 5
5- Doctoral research contribution for the paper used in chapter 6
6- Doctoral research contribution for the paper used in chapter 7
7- Doctoral research contribution for the paper used in chapter 8
8- Doctoral research contribution for the paper used in chapter 9
9- Doctoral research contribution for the paper used in chapter 10
10- Doctoral research contribution for the paper used in chapter 11
11- Doctoral research contribution for the paper used in chapter 12

As stated in the attached statements

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Towards contracting strategy usage for rework in construction projects: A comprehensive review	
In which Chapter is the Manuscript /Published work:	Chapter 2
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted literature review and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Published in the Journal of Construction Management and Economics	
Candidate's Signature:	Ramin — Digitally signed by Ramin Date: 2021.12.13 14:57:29 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson — Date: 2021.12.14 09:41:10 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Rework management in life cycle of project: An outline for construction contracts	
In which Chapter is the Manuscript /Published work:	Chapter 3
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted literature review and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Published in the NZBERS 2020 proceedings	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:10:54 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:03:01 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Classification of rework root causes in the design stage of projects for contract assessment	
In which Chapter is the Manuscript /Published work:	Chapter 4
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted literature review and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Submitted to the CIB World Building Congress (2022)	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:14:55 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:33:41 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Contract documents appraisal and rework root causes classification in tendering stage of project	
In which Chapter is the Manuscript /Published work:	Chapter 5
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted literature review and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Published in the AUBEA 2019 Conference proceedings	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:19:26 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:34:31 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Contracts evaluation through classified rework root causes in the construction stage of projects	
In which Chapter is the Manuscript /Published work:	Chapter 6
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted literature review and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Published in the International Structural Engineering and Construction proceedings	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:25:31 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:35:35 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Rework classification model in the project life cycle with liable parties of the contract	
In which Chapter is the Manuscript /Published work:	Chapter 7
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted Systematic literature review and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Submitted to the Journal of Construction Management and Economics	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:29:03 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:36:15 +13'00'
Date:	14./12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
The common causes of rework in construction contracts: A diagnostic approach	
In which Chapter is the Manuscript /Published work:	Chapter 8
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted questionnaire survey and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Published in the Journal of Engineering, Design and Technology	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:32:12 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:36:51 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Investigating the relationship between reworks and contractual claims: The salience of contract conditions	
In which Chapter is the Manuscript /Published work:	Chapter 9
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted questionnaire survey and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Published in the Journal of Legal Affairs and Dispute Resolution in Engineering and	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:37:58 +13'00'
Date:	12/13/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:37:26 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Analyzing underlying factors of contractual claims raised from rework in construction contracts	
In which Chapter is the Manuscript /Published work:	Chapter 10
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted questionnaire survey and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Submitted to the Journal of Construction Engineering and Management (ASCE)	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:41:39 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 10:37:58 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Evaluating provisions within standard conditions of contracts for addressing rework: A mixed-method approach	
In which Chapter is the Manuscript /Published work:	Chapter 11
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted professional interviews and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Submitted to Journal of Legal Affairs and Dispute Resolution in Engineering and Con	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:43:50 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 11:47:21 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)

DRC 16

MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Ramin Asadi
Name/title of Primary Supervisor:	Professor Suzanne Wilkinson
Name of Research Output and full reference:	
Guidelines for mapping rework in the contract conditions of construction projects: Solutions and Recommendations	
In which Chapter is the Manuscript /Published work:	Chapter 12
Please indicate:	
• The percentage of the manuscript/Published Work that was contributed by the candidate:	85 percent
and	
• Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Participated in the research to investigate solutions through collection of data and analysis. Conducted professional interviews and prepared the manuscript first draft.	
For manuscripts intended for publication please indicate target journal:	
Submitted to Journal of Legal Affairs and Dispute Resolution in Engineering and Con	
Candidate's Signature:	Ramin Digitally signed by Ramin Date: 2021.12.13 15:46:02 +13'00'
Date:	13/12/2021
Primary Supervisor's Signature:	Suzanne Wilkinson Date: 2021.12.14 11:48:28 +13'00'
Date:	14/12/2021

(This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/ publication or collected as an appendix at the end of the thesis)