CONSTRUCTION REAL TIME INFORMATION AND COMMUNICATION SYSTEM FOR SAFETY

by

Gustavo Enrique Aguilar

B.Sc., Costa Rica Institute of Technology, Costa Rica, 2000

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE

in

THE COLLEGE OF GRADUATE STUDIES

(Civil Engineering)

THE UNIVERSITY OF BRITISH COLUMBIA

(Okanagan)

December 2012

Abstract

Despite stronger regulations for health and safety implemented throughout the years, the construction industry (CI) remains one of the most hazardous industries. Just in British Columbia, an average of 16,000 workers suffer from work related injuries and diseases on a yearly basis. An average of 33 workers die yearly for the same reason. Current health and safety (H&S) information made available by regulating bodies may not provide an accurate picture of the hazards and key focus areas in the CI. As a consequence, construction stakeholders do not necessarily rely on published data for decision making, training, and H&S management of their construction projects. This thesis describes a research project which aimed to develop and test a web-based communication and information system called the construction real-time information and communication system for safety (C-RTICS^2). Information sent from multiple construction projects is gathered in a centralized database where real time safety indicators can be obtained for projects and for project types (e.g., Commercial, Industrial, Residential, and Transportation). A preliminary version of the proposed system was developed and tested in a one on one session with seven industry professionals with experiences in the construction industry ranging from 1 year to more than 25 years. 43% of participants considered that implementing C-RTICS^2 would "definitely" improve safety in their projects, while 57% considered it as "probably". The on-the-spot training capabilities provided by the proposed system would be a definite advantage of the C-RTICS^2 system. Informed safety oriented decision making can be accomplished with the use of the proposed system. Furthermore, industry-wide H&S information sharing can lead to a

positive change to the current safety status of the CI. C-RTICS^2 can be the starting point for a safer CI.

Preface

A paper summarizing the contents of chapters 1 and 2 of this thesis have been published - Aguilar, G., and Hewage, K. (2011) Real Time Information and Communication System to Improve Construction Safety (C-RTICS^2), 2011 CSCE Annual Conference Proceedings, 3rd International/ 9th Construction Specialty Conference, CN-052.

A paper summarizing chapters 1 and 2 of this thesis have been submitted to ASCE's Journal of Automation in Construction. Reviewers' comments have been received and are being addressed at the time of printing this thesis.

Chapter 1 of this thesis provides an introduction to the research topic. A literature and market review for health and safety oriented solutions for the construction industry, the research question, objectives, and methodology are included in this chapter.

Chapter 2 describes the proposed system and its components. It also includes details pertaining to an analytical hierarchy process used to select a portable electronic device to test the operation of the proposed system.

Chapter 3 describes the procedure used to test the proposed system at its early development stage. It also includes responses to a questionnaire survey sent out to construction industry professionals to obtain information regarding the use of technology for health and safety tasks and monitoring in construction sites.

The questionnaires used on this research project were approved by the Behavioural Research Ethics Board of the University of British Columbia, Okanagan campus (minimal risk amendment certificate number H10-01000). Copies of the questionnaires and the amendment are included in Appendix A

Appendix E describes an investment analysis for the proposed system using an engineering economics approach. The analysis seeks to justify the investment on the proposed system by British Columbia's Workers Compensation Board.

Table of Contents

Abstract .... **ii**

Preface .... **iv**

Table of Contents .... **vi**

List of Tables .... **xiv**

List of Figures .... **xv**

List of Symbols and Abbreviations .... **xviii**

Glossary .... **xx**

Acknowledgements .... **xxii**

Dedication .... **xxiii**

1 Chapter: Introduction **1**

1.1 Literature Review 1

1.1.1 Safety indicators 8

1.1.2 Real-time information and communication, and wireless communication 11

1.1.3 Real-time information and communication systems for construction safety 14

1.1.4 Construction safety instruction and training 16

1.1.5 Safety monitoring and management with commercial software 18

1.2 Research Project Overview 23

1.2.1 Methodology 25

1.2.2 Literature Review 25

1.2.3 Identification of available electronic equipment for field data transfer 26

1.2.4 Designing the information and communication system 26

1.2.5 Programming 28

1.2.6 PED selection 28

1.2.7 Testing 28

1.2.8 Industry feedback 29

2 Chapter: Construction Real-time Information and Communication System for Safety (C-RTICS2) **31**
2.1 Structure and interfaces of C-RTICS^2 33
2.1.1 Data input component 34
2.1.1.1 PED module 35
2.1.1.2 Monitoring module 36
2.1.1.3 Training module 38
2.1.2 Data processing and communication component 39
2.1.3 Data output component 43
2.1.4 Data input templates 48
2.1.5 Incident, accident, and safety observation reports 48
2.1.6 Personnel report 51
2.1.7 Equipment report 53
2.1.8 Training report 55
2.2 Selection of the portable electronic device 56
2.2.1 Motion computing 65
2.2.2 Panasonic 66
2.2.3 OQO 66
2.2.4 Xplore 67
2.2.5 Apple 68
2.2.6 Hewlett Packard 69
2.2.7 Rugged Notebooks RNB T10 70
2.2.8 GTAC E100 70
2.2.9 GTAC Rugged PDA 71
2.2.10 Trimble 71
2.2.11 Nexcom 74
2.2.12 Final round of analysis 74
2.2.13 Limitations 77
2.3 Programming language and database type 78

3 Chapter: Industry Feedback and System testing **79**
3.1 Industry Feedback 79
3.2 System Testing: Questionnaire 2a 83
3.3 System testing: Powerpoint ™ presentation and software interaction 103

3.4 System Testing: Questionnaire 2b 104
3.5 System Testing: Questionnaires analysis 110

4 Chapter: Conclusions and Future Research 113
4.1 Future research 115

Appendices 124
Appendix A 124
A.1 Consent form 124
A.2 Questionnaire survey 2a 127
A.3 Questionnaire survey 2b. 133
A.4 UBC ethics board amendment 136
Appendix B Portable electronic devices and its specifications 137
Appendix C Pair-wise comparison matrices for the AHP analysis performed on the PED 140
C.1 Pair-wise comparison matrix and normalized matrix for the twenty three decision making criteria used in the AHP 140
C.2 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x1 (Cost). 141
C.3 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x4 (Memory). 142
C.4 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x5 (processor type and speed). 143
C.5 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x6 (RFID reader). 144
C.6 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x7 (Barcode reader). 145
C.7 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x10 (Digital Camera). 146
C.8 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x19 (Web Camera). 147
C.9 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x20 (Mobile Internet connectivity). 148
C.10 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x1 (Cost). 149

C.11 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x2 (Weight). 150
C.12 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x3 (Screen size). 151
C.13 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x6 (RFID reader). 152
C.14 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x7 (Barcode reader). 153
C.15 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x10 (Digital camera). 154
C.16 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x1 (Cost). 155
C.17 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x4 (Memory). 156
C.18 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x5 (Processor type). 157
C.19 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x18 (Screen size). 158
C.20 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x20 (Mobile internet connectivity). 159
C.21 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x21 (Hard drive capacity). 160
C.22 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x1 (Cost). 161
C.23 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x4 (Memory). 162
C.24 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x18 (Screen type). 163
C.25 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x20 (Mobile internet connectivity). 164
C.26 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x21 (Hard disk drive). 165
C.27 Pair-wise comparison matrix and normalized matrix for Apple models, based on factor x1 (Cost). 166

C.28 Pair-wise comparison matrix and normalized matrix for Apple models, based on factor x4 (Memory)....... 167
C.29 Pair-wise comparison matrix and normalized matrix for Apple models, based on factor x20 (Mobile internet mobility)....... 168
C.30 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x1 (Cost)....... 169
C.31 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x2 (Weight)....... 170
C.32 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x3 (Screen size)....... 171
C.33 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x4 (Memory)....... 172
C.34 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x18 (Screen type)....... 173
C.35 Pair-wise comparison matrix and normalized matrix for GTAC E100 models, based on factor x1 (Cost)....... 174
C.36 Pair-wise comparison matrix and normalized matrix for GTAC E100 models, based on factor x20 (Mobile internet connectivity)....... 175
C.37 Pair-wise comparison matrix and normalized matrix for GTAC E100 models, based on factor x2 (Hard disk drive)....... 176
C.38 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x1 (Cost)....... 177
C.39 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x2 (Weight)....... 178
C.40 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x4 (Memory)....... 179
C.41 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x10 (Digital camera)....... 180
C.42 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x16 (Battery life)....... 181
C.43 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x20 (Mobile internet connectivity)....... 182
C.44 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x21 (Hard disk drive)....... 183

C.45 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x1 (Cost). 184
C.46 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x2 (Weight). 185
C.47 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x3 (Screen size). 186
C.48 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x4 (Memory). 187
C.49 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x7 (Bar code reader). 188
C.50 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x10 (Digital camera). 189
C.51 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x13 (Operating system). 190
C.52 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x16 (Battery life). 191
C.53 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x17 (Wi-Fi internet connectivity). 192
C.54 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x18 (Screen type). 193
C.55 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x19 (Web camera). 194
C.56 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x20 (Mobile internet connectivity). 195
C.57 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x21 (Hard disk drive). 196
C.58 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x22 (Temperature of operation). 197
C.59 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x6 (RFID reader). 198
C.60 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x6 (RFID reader). 199
C.61 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x6 (Bar code reader). 200

C.62 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x20 (Mobile internet connectivity). 201
C.63 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x1 (Cost). 202
C.64 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x2 (Weight). 203
C.65 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x3 (Screen size). 204
C.66 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x4 (Memory). 205
C.67 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factors x6 (RFID reader) and x7 (Bar code reader). 206
C.68 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x9 (Ruggedized construction). 207
C.69 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x10 (Digital camera). 208
C.70 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x13 (Operating system). 209
C.71 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x14 (Environment protection). 210
C.72 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x15 (Handwriting recognition). 211
C.73 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x16 (Battery life). 212
C.74 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x19 (Web camera). 213
C.75 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x20 (Mobile internet connectivity). 214
C.76 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x21 (Hard disk drive). 215
C.77 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x22 (Temperature of operation). 216
C.78 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x23 (Warranty). 217

Appendix D Slide show presented to subjects during the testing phase of the proposed system. 218
Appendix E Investment Analysis 229
Step 1: Estimation of the present worth value under current practices (PW_{CP}) 229
Step 2: Estimation of C-RTICS^2 Present Worth ($PW_{C\text{-}RTICS2}$) 236
Step 3: Estimation of the minimum required annual savings to justify the investment in C-RTICS^2 248

List of Tables

Table 1.1. Occupational fatalities by economy and region, 2002. 2
Table 1.2. WCB's CI accepted claims and their cost, 2000 – 2010. 4
Table 1.3. Amount paid due to accepted claims in BC's CI as a percentage of the capital investment. 6
Table 1.4. US construction sector fatalities, 2010. 8
Table 1.5. Recorded incident ratio for different construction company sizes, 2009 and 2010. 10
Table 2.1. Access to the system according to user type. 45
Table 2.2. Priority vector obtained for the twenty three factors. 63

List of Figures

Figure 1.1. Number of accepted fatal claims and GDP in BC, Canada, 2000 – 2010. 3
Figure 1.2. Time lost injuries for Canadian provinces, 2008 - 2010 (AWCBC 2012). 5
Figure 1.3. Amount paid due to construction claims as a percentage of the capital investment in BC's CI, 2006 - 2009.. 7
Figure 1.4. Research project action areas. 27
Figure 2.1. Construction real-time information and communication system for safety. 34
Figure 2.2. Portable electronic device (PED) module. 36
Figure 2.3. Monitoring module. 37
Figure 2.4. Training module. 39
Figure 2.5. Flowchart for calculation of the RIRPP. 41
Figure 2.6. Communication component. 42
Figure 2.7. User-cluster concept. 44
Figure 2.8. Incident, accident, and safety observation reports data fields. 49
Figure 2.9. Personnel, equipment, and training reports data fields. 51
Figure 2.10. AHP decision making criteria. 62
Figure 2.11 Methodology used for AHP. 64
Figure 2.12. Final decision matrix for Motion Computing. 65
Figure 2.13. Final decision matrix for Panasonic. 66
Figure 2.14. Final decision matrix for OQO. 67
Figure 2.15. Final decision matrix for Xplore. 68
Figure 2.16. Final decision matrix for Apple. 69
Figure 2.17. Final decision matrix for Hewlett Packard. 69
Figure 2.18. Final decision matrix for GTAC E100. 70
Figure 2.19. Final decision matrix for GTAC Rugged PDA. 71
Figure 2.20. Final decision matrix for Trimble. 73
Figure 2.21. Final decision matrix for Nexcom. 74
Figure 2.22. AHP final decision matrix. 76
Figure 2.23. Summary of final PED analysis. 77

Figure 3.1. Industry questionnaire, question 1.1. 79
Figure 3.2. Industry questionnaire, question 1.2. 80
Figure 3.3. Industry questionnaire, question 1.5. 80
Figure 3.4. Industry questionnaire, question 2.4. 81
Figure 3.5. Industry questionnaire, question 3.8. 82
Figure 3.6. Industry questionnaire, question 3.9. 82
Figure 3.7. Questionnaire 2a, question 1.1. 83
Figure 3.8. Questionnaire 2a, question 1.2. 84
Figure 3.9. Questionnaire 2a, question 1.3. 84
Figure 3.10. Questionnaire 2a, question 1.4. 85
Figure 3.11. Questionnaire 2a, question 1.5. 86
Figure 3.12. Questionnaire 2a, question 1.6. 87
Figure 3.13. Questionnaire 2a, question 2.1. 88
Figure 3.14. Questionnaire 2a, question 2.2. 89
Figure 3.15. Questionnaire 2a, question 2.3. 90
Figure 3.16. Questionnaire 2a, question 2.4. 91
Figure 3.17. Questionnaire 2a, question 2.5. 92
Figure 3.18. Questionnaire 2a, question 2.6. 93
Figure 3.19. Questionnaire 2a, question 2.7. 94
Figure 3.20. Questionnaire 2a, question 2.8. 95
Figure 3.21. Questionnaire 2a, question 2.9. 96
Figure 3.22. Questionnaire 2a, question 2.10. 97
Figure 3.23. Questionnaire 2a, question 2.11. 98
Figure 3.24. Questionnaire 2a, question 2.12. 99
Figure 3.25. Questionnaire 2a, question 2.13. 100
Figure 3.26. Questionnaire 2a, question 2.14. 101
Figure 3.27. Questionnaire 2a, question 2.15. 102
Figure 3.28. Questionnaire 2a, question 2.16. 103
Figure 3.29. Questionnaire 2b, question 1.1. 105
Figure 3.30. Questionnaire 2b, question 2.1. 106
Figure 3.31. Questionnaire 2b, question 2.2. 106

Figure 3.32. Questionnaire 2b, question 2.3. 107
Figure 3.33. Questionnaire 2b, question 2.4. 108
Figure 3.34. Questionnaire 2b, question 2.5. 109
Figure 3.35. Questionnaire 2b, question 2.6. 110
Figure 3.36. Training location before and after the implementation of C-RTICS2. 111
Figure 3.37. Training location after an incident/accident, before and after the implementation of C-RTICS2. 112

List of Symbols and Abbreviations

AHP: Analytical Hierarchy Process

BC: British Columbia

BIM: Building Information Model

CI: Construction Industry

CM: Construction Manager

DART: Days Away, Relocated or Transferred

FAP: Future Annual Payment

FE: Field Engineer

GB: Giga Byte

GHz: Giga Hertz

H&S: Health and Safety

ICT: Information and Communication Technologies

II: Initial Investment

IT: Information Technologies

MCS: Monte Carlo Simulation

MSL: Microsoft Server License

MB: Mega Byte

MP: Mega Pixel

LTCR: Lost Time Case Ratio

$LTCR_C$: Lost Time Case Ratio for commercial projects

$LTCR_I$: Lost Time Case Ratio for industrial projects

$LTCR_{PP}$: Lost Time Case Ratio per project

$LTCR_R$: Lost Time Case Ratio for residential projects

$LTCR_T$: Lost Time Case Ratio for transportation projects

OSHA: Occupational Safety and Health Administration, United States Department of Labor

RFID: Radio Frequency Identification Devices

RIR: Recorded Incident Ratio

RIR_C: Recorded Incident Ratio for commercial projects

RIR_I: Recorded Incident Ratio for industrial projects

RIR_{PP}: Recorded Incident Ratio per project

RIR_R: Recorded Incident Ratio for residential projects

RIR_T: Recorded Incident Ratio for transportation projects

SC: Subcontractor

SO: Safety Officer

SP: Software Programming

Sup.: Superintendent

Glossary

Accident: For the context of this thesis, an accident is an event occurred at a construction project, where injuries to human beings are reported and accounted for.

Fatality: For the context of this thesis, a fatality is an event occurred at a construction project, where a human life was lost as a consequence of the event.

Incident: For the context of this thesis, an incident is an event occurred at a construction project, where no injuries to human beings occurred as a consequence of the event.

Safety observation: For the context of this thesis, a safety observation is a report submitted by an authorized party within the construction project, relative to a conduct, attitude, behaviour, or action of any of the personnel involved in the project which may lead to a potential unsafe event. It also includes a deficiency, failure, state of repair, or condition of materials or equipment within the construction project that may lead to a potential unsafe event.

Recorded incident ratio: Safety indicator used for tracking a company's health and safety performance on a yearly basis. It is calculated by multiplying the total amount of incidents occurred in one year by a constant factor of two hundred thousand. This product is then divided by the total amount of hours worked by the employees of the company for the same year.

Lost time case ratio: Safety indicator used for tracking a company's health and safety performance on a yearly basis. It is calculated by multiplying the total amount of accidents occurred in one year by a constant factor of two hundred thousand. This product is then divided by the total amount of hours worked by the employees of the company for the same year.

Real-time information: For the context of this thesis, real-time information is considered as information generated by the proposed system based on data inputs up to the day before a query is requested by a user (e.g., information related to safety indicators for a project).

Acknowledgements

My sincere and endless gratitude to the faculty, staff and my classmates at UBC. They all contributed in different ways to my work in this field.

Special thanks to Dr. G. Lovegrove and Dr. S. Tesfamariam, whose feedback and objective comments throughout my research and evaluation meetings taught me to question more deeply, and visualize perspectives I was not able to identify at first.

I thank Dr. K.N. Hewage for orienting me through the process, enlarging my vision of research, providing guidance to my many questions and advice to overcome the many obstacles I faced throughout my degree.

I thank my in laws (Opa and Abis) for their tremendous support, and their care and attention for my wife and daughter while I was away pursuing my degree. Their support was essential for the undertaking of this life project.

Special thanks are owed to my parents (Edwin and Bernardita), who have inspired me and supported me throughout my years of education and professional career, and have motivated me to pursue my dreams.

Endless gratitude to my wife Maria Antonieta, for her never ending support and all the sacrifice and challenges she went through, for me to be able to accomplish this goal.

Dedication

To my daughter Alina.

1 Chapter: Introduction

1.1 Literature Review

It is widely acknowledged that the construction industry (CI) accounts for the greatest number of accidents, and in particular life-threatening accidents and fatalities, on an annual basis, compared to other industries. In the Canadian province of British Columbia (BC), health and safety (H&S) workplace accident statistics are significant despite the numerous efforts that have been made in the past to reduce the number of accidents and fatalities (WorkSafeBC 2011). In addition, increases in the number of work related (occupational) diseases in Canada (CSLS 2006) indicate that prevalent instructions regarding workplace hazards have been generally ignored. The rise in morbidity and critical illnesses related to occupational exposures in seniors in Canada shows that some workplace risks have long-term impacts (CSLS 2006).

In a global scale, occupational fatalities per total employment for the year 2002 indicate considerable differences between regions and economies, as observed in Table 1.1.

Table 1.1. Occupational fatalities by economy and region, 2002.

Economy/ Region	Total employment	Occupational fatalities	% of fatalities per total employment
Established market economies	380,833,643	297,534	0.08%
Formerly socialist economies of Europe	162,120,341	166,265	0.10%
India	419,560,000	310,067	0.07%
China	699,771,000	460,260	0.07%
Other Asia and islands	328,673,800	246,720	0.08%
Sub-Saharan Africa	10,540,604	257,738	2.45%
Latin America and the Caribbean	114,604,962	137,789	0.12%
Middle Eastern crescent	48,635,240	125,641	0.26%
World	2,164,739,590	2,001,717	0.09%

Source: International Labor Organization, 2003.

For BC, between 2006 and 2008, a total of 29,887 claims related to CI accidents were reported, amounting to $549 million in claims (WorkSafeBC 2011). In 2010, a total of 136,742 work related injuries and 143 fatalities were reported in BC. Of these totals, the BC CI accounted for 14,405 injuries and 32 fatalities, ranking second in both categories across all industries in BC (WorkSafeBC 2011). General construction, a subsector of the CI as defined by BC's Workers' Compensation Board (WCB), accounted for the most injuries (13,299) and fatalities (27) across all subsectors (WorkSafeBC 2011). Statistics for the industry have remained high throughout the years. From 1994 to 2008, there were 11,153 occupational disease claims, ranking second after the wood & paper products subsector that had 11,543 occupational disease claims (WorkSafeBC 2011). On the basis of the value of claims, the general construction subsector ranked first during the same period of time, with a total of $153 million paid by BC's WCB (WorkSafeBC 2011).

From 2000 to 2010, an average of 33 workers died on an annual basis in BC's CI (WorkSafeBC 2010a).

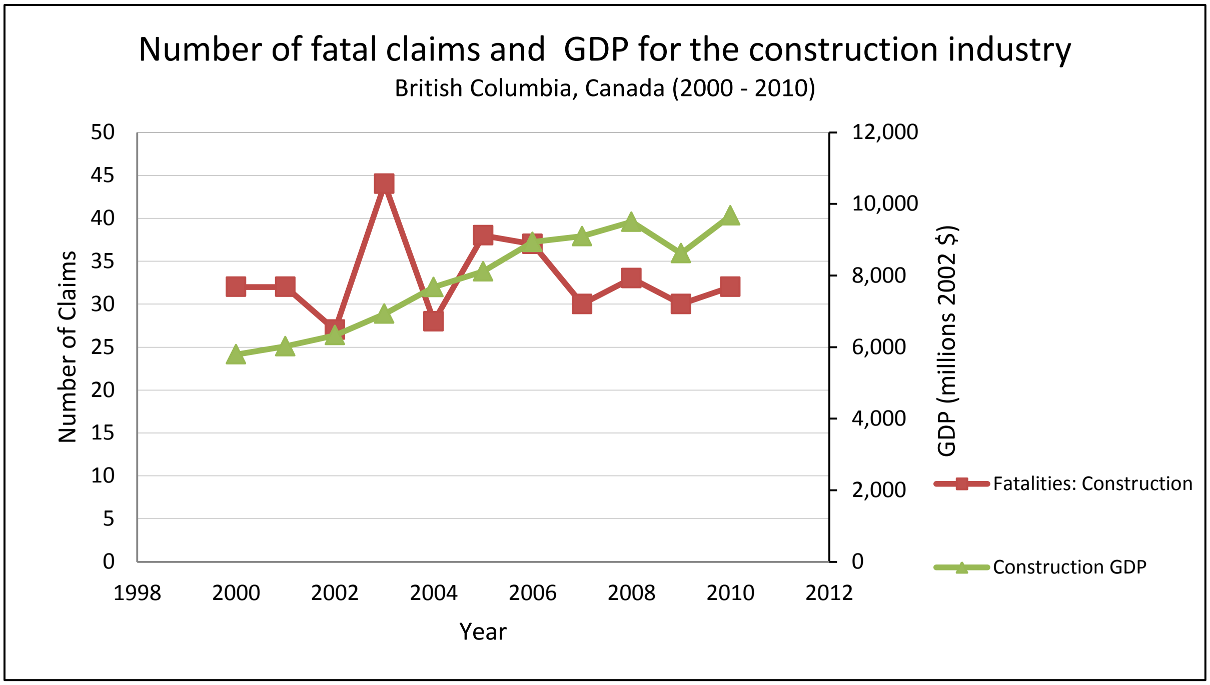


Figure 1.1. Number of accepted fatal claims and GDP in BC, Canada, 2000 – 2010.

As shown on Figure 1.1, there has been no significant change in this trend. An average of 16,810 construction workers have been injured on an annual basis for the past ten years in BC, with a peak in 2007 for 22,821 workers injured, as shown in Table 1.2.

.

Table 1.2. WCB's CI accepted claims and their cost, 2000 – 2010.

Year	Number of accepted claims	% change from previous year	Total paid due to accepted claims (million $)
2000	14,878	n/a	$135.1
2001	13,543	-9%	$141.3
2002	12,755	-6%	$130.9
2003	14,000	10%	$124.8
2004	16,142	15%	$122.8
2005	19,030	18%	$127
2006	20,626	8%	$121.9
2007	22,821	11%	$125.4
2008	22,538	-1%	$144.3
2009	14,166	-37%	$139.3
2010	14,407	2%	$147.8

Source: WorkSafeBC 2010a.

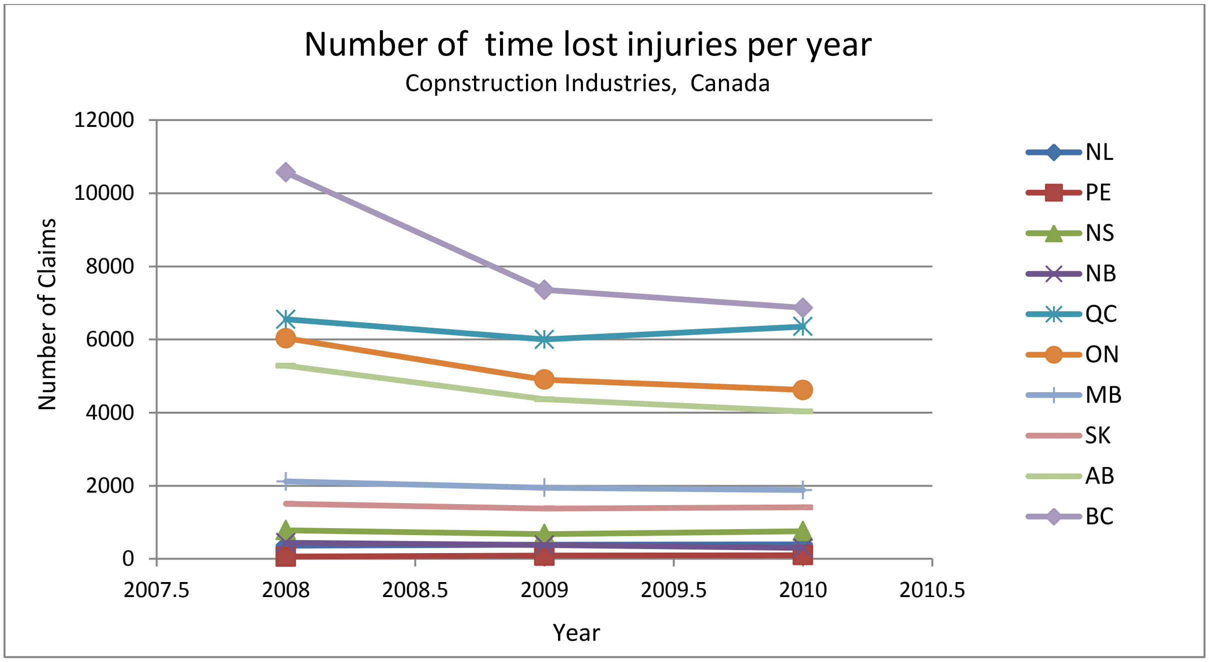


Figure 1.2. Time lost injuries for Canadian provinces, 2008 - 2010 (AWCBC 2012).

BC's WCB divides the construction sector into three subsectors: general construction, heavy construction, and road construction and maintenance. The general construction subsector accounts for the highest percentage of claims, an average of 92% of the total annual claims from 2000 to 2010 (WorkSafeBC 2011). Claims from the CI rose 2% between 2009 and 2010, from 14,166 to 14,407 respectively (WorkSafeBC 2011).

The scenario is no different at the national level.

Figure 1.2 shows how BC leads other Canadian provinces in terms of lost time injuries in the CI from 2008 to 2010 (AWCBC 2012). The incidence of workplace fatalities in Canada rose from 5.9 to 6.8 per 100,000 workers between 1993 and 2005 (CSLS 2006). At the same time, the incidence of workplace fatalities due to occupational disease rose from 1.5 to 3.4 per 100,000 workers between 1996 and 2005 (CSLS 2006). The number of seniors who died from occupational related diseases increased by 172% between 1996 and 2004, contributing to a 72% rise in the total of work related deaths (CSLS 2006).

In monetary terms, from 2000 to 2010, accidents in BC's CI accounted for more than $1.4 billion in compensation for accepted claims (WorkSafeBC 2011). Comparing the annual capital investment in BC's CI from 2006 to 2010 and the total paid in compensation claims for the same period, the amount paid in compensation represents a higher percentage of the total investment in the industry every year from 2006 to 2009. A slight decrease was observed in 2010, as shown in Table 1.3 and Figure 1.3.

Table 1.3. Amount paid due to accepted claims in BC's CI as a percentage of the capital investment.

Year	Capital Investment in BC's CI (million CAN$)	Amount paid due to Construction Claims (million CAN$)	%
2006	$17,082	$121.85	0.71%
2007	$16,947	$125.38	0.74%
2008	$16,750	$144.28	0.86%
2009	$13,888	$139.33	1.00%
2010	$16,127	$147.86	0.92%

Source: WorkSafeBC 2011, CSC 2010a,b.

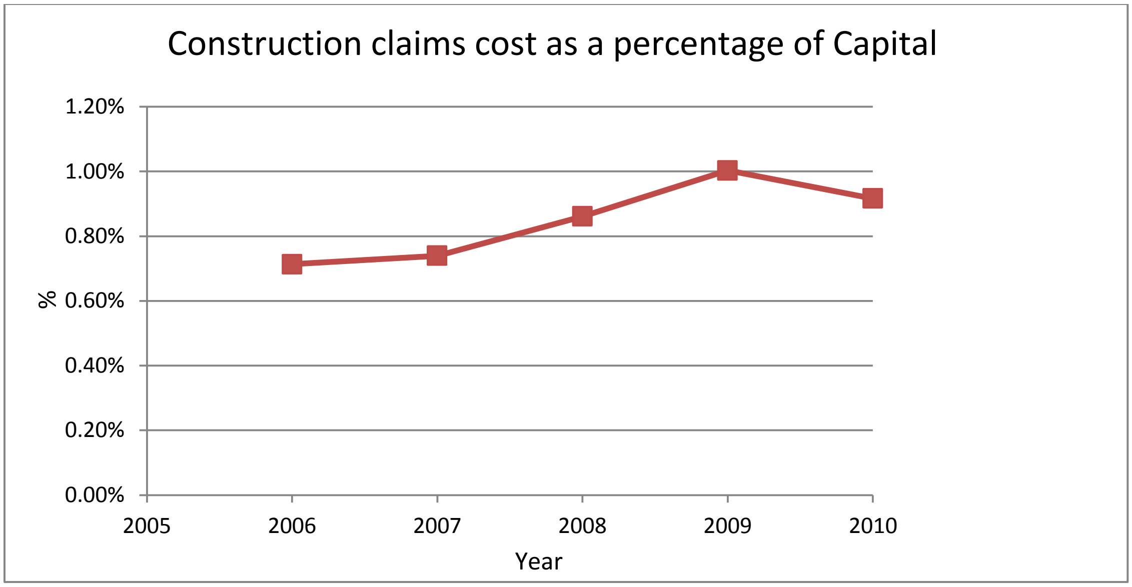


Figure 1.3. Amount paid due to construction claims as a percentage of the capital investment in BC's CI, 2006 - 2009.

In the USA, the Bureau of Labor Statistics (BLS) shows that construction workers incurred the most fatalities across all industries between 2009 and 2010 (BLS 2010a, c), accounting for 19% of fatalities (816 out of a total of 4,340) in 2009 (BLS 2010c), and 17% of fatalities (751 out of a total of 4,547) in 2010 (BLS 2010d). The number of fatalities in the US CI experienced consecutive declines on an annual basis from a peak in 2006, declining 19% in 2008, 16% in 2009, and 10% in 2010 (BLS 2010a, c). It is noteworthy however that certain trades, such as electricians, carpenters and plumbers, experienced an increased number of fatalities in the same time period (BLS 2010a). The overall decline in fatalities is thought to be directly related to the economic crisis taking place at the time, and to a reduction in the number of working hours within the construction industry (BLS 2010a,c).

Table 1.4 provides a breakdown of fatality causes by CI subsector within the US for 2010.

Table 1.4. US construction sector fatalities, 2010.

US Construction subsector	Falls	Struck/ Hit by object	Highway accidents	Homicides
Construction of Buildings	50%	9%	7%	2%
Heavy and Civil Engineering Construction	9%	10%	16%	
Specialty Trade Contractors	37%	8%	11%	1%

Source: BLS 2010d

1.1.1 Safety indicators

Monitoring of a company's safety is based on the recorded incident ratio (RIR) calculation. To calculate this indicator, the total number of incidents occurring within a company in one year is multiplied by a constant factor of 200,000, being the number of working hours of 100 workers, working 40 hours per week for a total of 50 working weeks per year (BLS 2010g). The product is then divided by the total number of hours worked by all the company employees in that same year. The number of incidents is taken from the company's OSHA forms (in the USA), or WCB forms (in Canada), which are required whenever an incident occurs.

Incidents where the affected worker is required to stay away from the company (e.g., at home), or is relocated or transferred to another department within the company, are considered serious incidents, and are used to calculate the days away, relocated, or transferred (DART) ratio (BLS 2010g). The calculation of the DART ratio uses the same formula used for calculating the RIR. The only difference is in the type of incidents considered for its calculation (BLS 2010g). In BC, the serious injury rate (SIR) is determined to account for this type of incidents. The name lost time case ratio (LTCR) will be used from now on to refer to the ratio that considers serious incidents.

Previous research has attempted to identify the hazards and risks involved in the CI, and to provide H&S stakeholders with information needed to undertake preventive actions. H&S regulatory bodies provide information relating to the causes of most accidents and fatalities in the construction process. They also assist with developing relevant H&S training material for the CI. However, in gathering the necessary data, H&S regulating bodies encounter a number of challenges: 1) information taken on paper and then typed into databases delays the process of updating H&S information and prolongs the reception of updated H&S data by H&S stakeholders; 2) H&S inspections and citations are not welcomed by construction companies due to their effect on insurance premiums; and 3) most of the minor H&S incidents in construction projects are not reported and never get to the H&S information database managed by regulatory bodies. Therefore, valuable indicators of potential risks and hazardous activities are never identified.

Recently published data in the USA suggest that construction company size have a direct relationship to the RIR. Large companies (with more than 1000 employees) have the lowest RIR. As shown in Table 1.5, as the number of employees decreases, two and threefold increments of the RIR are observed (BLS 2010e,f).

Table 1.5. Recorded incident ratio for different construction company sizes, 2009 and 2010.

Construction Company Size (employees)	Recorded Incident Ratio (RIR) (unit less)	
	2009	2010
more than 1000	1.6	1.2
250 to 999	3.2	2.6
50 to 249	4.7	4.6
11 to 49	5.1	4.6
1 to 10	3.1	3.4

Source: BLS 2010e,g.

Within BC, the WCB increased the insurance premiums required for housing construction in 2010. Residential construction is mostly carried out by small and medium size construction companies. This increase in insurance premiums appears to confirm that company size may be a factor affecting the implementation of safety standards and the generation of higher RIR. The current problem with these methodologies for calculating the various safety ratios is that they are dependent on paper based information submitted to WCB by construction companies.

Private software developers already offer solutions for managing company specific safety information, with programs such as BuildIT, Construction Safety Supervisor and Interlink Safety Management to mention a few. The challenge is in ensuring industry-wide use and implementation of such systems. As more variables are constantly added to the construction processes (e.g., environmental, social, safety), appropriate information flow and communication between the involved parties becomes essential for the successful completion of a project.

Thomas et al. (1998) concluded that effectiveness of communication generates a 41% variation in the perception of project success. Use of information and communication technologies (ICT) makes possible the desired level of information flow and communication. Adoption of ICT within the CI has been quite piecemeal and very few contractors have a comprehensive and integrated information system for their core business (Li et al. 2005). Reasons cited by researchers for this slow permeation of technology into the CI include the open work environment, the wide variety of work scope, environmental conditions (dust and moisture), and portability issues. Hewage at al. (2008) stated that very few field tests have been conducted to evaluate the capabilities of new technologies in real construction environments.

Research in areas such as occupational risk assessment, risk management, and real-time H&S monitoring, is necessary to improve H&S at construction sites. Such research can help to encourage the use of H&S oriented ICT among construction companies of all sizes. Real-time information is essential to guide informed decision-making. State-of-the-art communication technologies and risk management and communication practices can be integrated scientifically to provide an innovative and robust information system to enhance H&S in the BC CI.

1.1.2 Real-time information and communication, and wireless communication

The benefits of real-time information and ICT in construction projects have been studied by various researchers in the past. Cheung et al. (2004a) developed a web-based communication framework to keep track of eight key performance areas of a construction project, with H&S as one of these areas. They used internet connectivity to allow different stakeholders to input data to a central database, where a computing system organized and filtered the data to produce reports (Cheung et al. 2004a). Their project performance monitoring system, as they named it, used internet connectivity from the construction site to allow the different stakeholders to input data to a database. The computing system then organized and filtered the information to produce reports available after introducing a user key to log in. Nuntasunti and Bernold (2006) developed and tested an internet wireless site, where indoor and outdoor web cameras located in different areas of a construction project, were used to broadcast live video, providing valuable real-time information for decision making to the managerial team. A signal repeater received video from three web cameras located at the construction site, one camera transmitted the signal through a wired connection, while another used a wireless connection from two static positions. The third camera was a network camera transmitting video from its own signal repeater. The data from all cameras was then transmitted to another antenna, located 440m away, using a long range antenna, an antenna capable of transmitting video through large distances. Transfer rates were in the order of 30 frames per second, considered an appropriate transfer rate for today's video standards (for certain activities such as activity progress monitoring, 10 frames per second is considered acceptable). Nuntasunti and Bernold (2006) recommended the use of directional antennas to reduce interference from other wireless networks present around the construction site. They also found that insulation materials used in internal walls attenuated the reception of the wireless signal to the wireless camera, demanding the installation of a second repeater. Wireless signal strength and link quality were used as the parameters to build an attenuation map for the construction project.

With the use of repeaters, the coverage area was extended to almost everywhere in the project area. By implementing their system, Nuntasunti and Bernold (2006) estimated savings of $17,896 over a 12 month period, reducing a 66% of the required physical on-site meetings held by the managerial team with the project's architect and subcontractors. El-Saboni et al. (2007) found positive effects resulting from the use of electronic communication in a construction project’s schedule. Transparency and information availability were the key elements for this positive effect. Navon and Sacks (2007) tested radio frequency identification devices (RFID), video, camera, audio, and barcode technologies in a construction project. Sawyer (2008) referred to the use of RFID in a construction project and the resulting improvement in productivity due to a reduction in the time taken to find construction components. Jang & Skibniewski (2009) tested an innovative tracking system using a combination of ultra sound and radio frequency technologies. Though the technology still needs to be improved and manufactured at an industrial level, this is another example of the improvements the CI could gradually apply to its complex projects. Motamedi and Hammad (2009) proposed the use of RFID tags on construction components as early as the design phase. The manufacturer generates the tag during the manufacturing of the component. The component is then traceable throughout procurement, installation, and life span within the project. The component's tag is scanned during each phase of the project and updates its status in the building information model (BIM) used to control the construction process.

1.1.3 Real-time information and communication systems for construction safety

As discussed above, web-based solutions, visualization techniques, wireless communication and tracking technologies have been previously tested in construction environments. The implementation of these technologies and frameworks to provide a safer work environment has also been researched and tested.

Bernold et al. (1997) proposed and tested an intelligent crane monitoring system, that used sensors located in different parts of a truck crane to generate information to be analyzed by supervisors and to track the performance of a specific crew. Bernold et al. (1997) intelligent crane safety monitoring system used multiple sensors located on the crane to transmit and receive real-time information to their internet wireless site. Cheung et al. (2004b) developed a web-based communication framework, the construction safety & health monitoring system to manage H&S issues in construction projects. It allowed different stakeholders of a project to input and download information wherever internet access was available. Their framework reduced the gap between different sources of information and improved H&S. With the framework proposed by Cheung et al. (2004b), the gap between the generation of the information and its final use for safety management and prevention decisions is considerably reduced. Nuntasunti and Bernold (2006) suggested the use of the internet wireless site for safety management through the use of sensors and devices located on construction equipment. They proposed the use of RFID and live video to identify potential safety hazards in the project, and to provide material for training, instruction, and planning of specific activities prior to mobilization to the construction site. El-Saboni et al. (2009) tested an electronic communication system in a construction project in the United Arab Emirates. They recommended the inclusion of H&S tracking records in future information technology solutions, to achieve higher levels of safety. Based on a study of migrant construction workers in the United Kingdom, Bust et al. (2008) concluded that immigrant workers have different levels of understanding in the reasoning and practices of H&S at the workplace. Bust et al. (2008) identified different audio-visual forms to effectively communicate messages and policies to construction professionals from different backgrounds and with different education levels.

Hewage and Ruwanpura (2009) tested an audio-visual technology called the information booth (IB), in a Calgary based construction project. They reported remarkable improvements in productivity (15%), efficiency (9%), and worker satisfaction in safety information (12%). Use of hard hat identification tags containing emergency information of construction workers has been enforced by the Nova Scotia Construction Safety Association (NSCSA, 2010). Wu et al. (2010) proposed a real-time tracking system to monitor near-miss accidents. Their system used ultrasonic signals for indoor and outdoor location tracking, sensors for environment surveillance (light, noise, temperature and humidity), RFID to record safety data of construction workers, equipment, and materials. The system proposed by Wu et al. (2010) used an RFID sensor network for wireless communication among the different components, such as mobile RFID tags, ultrasound transceivers, and other end-devices with sensors. Rwamamara et al. (2010) conducted a study of three Swedish construction projects where the companies used visualization techniques and 3D and 4D CAD modeling from the early stages of the project. Rwamamara et al. (2010) concluded that the use of such technology in the early stages of the project provided the design and development team with the opportunity to identify potential risks during the construction phase. They also concluded that early detection gave room to design changes that ended up reducing the probability of H&S issues arising during the construction process. Canberra Systems developed a real-time monitoring system called the camberra unattended spectrometric aerosol monitor (CUSAM). CUSAM is an online system that measures radiation levels in environment. CUSAM is mostly used by countries that require monitoring of radioactivity levels in the environment. It sends real-time information from a monitoring unit on site, into a communication control centre via network or modem. Camberra Systems also developed a portable device with an integrated GPS to pinpoint the location of the measuring unit using geographic information systems. The signal from the portable device is transmitted via radio frequency to a control unit on site, and from there to a computer for further analysis. Camberra Systems' monitoring system demonstrates that technology is already available to implement a similar concept in construction projects, allowing the possibility to measure exposure levels of hazardous chemicals and dust particles (e.g., concentration of crystalline silica in the dust inhaled by construction workers).

1.1.4 Construction safety instruction and training

Continuous H&S training is essential to reduce the amount of accidents and incidents in construction projects. Technology's role within this safety training need have been researched and observed in the past. Nuntasunti and Bernold (2006) were able to capture a video of a situation occurring on a construction site, which was then managed by the project manager. Nuntasunti and Bernold (2006) suggested the use of this video recording for safety training and accident prevention, and even for the investigation of accidents when they occur.

Bust et al. (2008) recommended the use of audio-visual methods as crucial to accomplish meaningful and relevant ways of communicating H&S information to construction workers from different cultures and contexts. This can be achieved if construction workers gain understanding of experimental knowledge and cultural narratives (Bust et al. 2008). Bust et al. (2008) concluded that digital technology provides the opportunity to capture images of the site and transform them into different types of media to communicate the necessary messages more relevantly. Hewage et al. (2008) concluded that the implementation of ICT in the construction process would not present additional training issues within the CI, as construction workers are generally knowledgeable about computer devices, and many other electronic devices on the market. Based on a survey of an Alberta construction project, Hewage et al. (2008) also identified that construction workers were not satisfied with the poor use of technology in their projects. Hewage & Ruwanpura (2009) suggested the use of the IB for workers to be able to access safety training material. This safety training material would have been uploaded into the IB by the project's Safety Officer (Hewage & Ruwanpura 2009).

The incorporation of knowledge from other fields of science is considered to be essential to generate a bigger impact from H&S training sessions. Robin et al. (2001) used video streaming to provide training and education to social workers as part of a pilot project at the University of Minnesota. Attendees to this training programme commented on the benefits of the live stream training session. Many mentioned that being able to see cases from other states was a helpful aspect of the training. Bust et al. (2008) concluded that due to the fact that construction workers come from different cultures and backgrounds, they all have different understandings of the meaning of H&S in the workplace. Therefore, it is important to identify the proper audio visual forms to communicate H&S messages and policies (Bust et al. 2008). Bust et al. (2008) mentioned the importance of taking into account the ongoing research in fields like applied visual anthropology to evaluate the methods being used in the construction industry to provide instruction about H&S in the workplace. Applied visual anthropologists confront the issue of how to increase mutual understanding when communicating the experiences of one group of people to another group of people (Bust et al. 2008). Kaewmoracharoen (2009) concluded that a cognitive way to improve effectiveness in the work zone is by enhancing planning through visualization techniques. Eary (2008) developed a video based training called the video- based integrated system for training applications. The system was used to provide training to Scottish police officers involved in crowd management. Eary (2008) described paper based training as lacking realism and not preparing the police officers adequately for real-life dangerous events.

1.1.5 Safety monitoring and management with commercial software

The need to improve H&S in the CI has motivated the development of safety oriented software of different scopes. Following is a description of the main commercial solutions offered to manage H&S in construction projects. As will be explained more fully in following chapters, the system proposed in this thesis incorporates data input through manual and automatic processes. It also considers real-time monitoring (through video, gas sensors, RFID and barcodes) and real-time calculation of safety indicators for the benefit of the entire CI. The internet search for commercial software was intended to determine if the commercial software available in the market for the CI today contains any of these elements.

Construction Safety Supervisor

This is a web-based software. Data input is carried out through the use of drop down menus, reducing the amount of text needed to be typed by each user. The website for the software mentions that it has the capability of automating the inspection process. The software offers the possibility of being able to fill out OSHA compliance forms. It has eleven modules: incidents, vehicles, units, employees, prevention, planning, risk management, statistics, reports, project and administration. The software is advertised as having a strong database, allowing multiple users from multiple projects. A construction safety dashboard shows that the system calculates the project's RIR and compares it with the goal RIR, and the industry RIR. The software also records the number of lost time incidents. The cost of a license is between $450 and $650 per year.

BuildIT

This solution is advertised as scheduling, documentation and communication management software (emails, texts messages, files, etc.). The company’s website states that the software improves safety on site based on the fact that having every document and communication within the project properly organized; all details of the project will then be covered. The cost of the software starts with a $300 first time payment. A monthly plan is available at $85 per month. A one year plan is available for $850, and a two year plan is available for $1,700. All prices are for one user only.

ZeraWare

The software includes modules for incident report, accident investigation, safety inspections, OSHA injury record keeping, and manage safety training. It allows the possibility of tracking accident patterns, trends and problems. It unifies and standardizes safety procedures at multiple locations for a single company. Calculation of the OSHA DART ratio is one of the options available with the incident report module. The accident investigation module offers an optional root cause analysis, to determine the causes of an accident. Safety inspections can be customized for the company's needs. Automatic updating of mandatory OSHA safety forms and employee training tracking can also be accomplished with this software. Text-based training guides for 50 safety topics are additionally available for purchase at $330.

Safety Manager

This system has a total of 23 safety modules, including incident and accident report, RIR calculator, chemical exposure, confined space permits, and training modules. It has a built in calendar with reminders of upcoming or needed training sessions. It handles information from material safety data sheets, respirator tracking and follow up, safety expenditures, and it provides information about personal protection equipment required for each activity. The software is not designed specifically for the CI. It does not have web-based access, or at least this is not advertised as being the case. The user needs to have Microsoft Access installed in order to run the software and access the various types of information contained within it. The cost licensing this system is $398.

Vela Systems

This is a web-based application with a construction safety module. It provides access to OSHA documents, carries out safety inspections and runs reports to identify which sub-contractor has the highest number of incidents on a weekly basis (not based on safety parameters but rather on a list of events). It also offers synchronization at later times, which allows the software to be used on a tablet PC without access to the internet. The system focuses on safety walks or safety inspections. The system is promoted to be used at a corporate level to standardize safety information and processes. The software filters the information to allow for identification of safety deficiencies by safety area, and narrow down to identify who is contributing the most to the total violations. The system uses violations as the safety parameter factor to account the violations. It emphasizes the importance of using a tablet that recognizes hand writing, since construction workers are used to hand written notes on site. Vela Systems store the information on their own servers and storage, the user pays for both the system and for information storage.

Safeguard

This solution includes real-time reporting, root cause analysis, task management module, audit module (with detailed evidence, and historical records for claims defense), accident and incident management module, risk assessment module, chemical control module and hazards module. The hazards module offers the possibility of reporting a hazard directly into the system, or sending a text message to the system. This triggers a process where the reported hazard is communicated to the people in charge of managing hazards, and creates tasks for following it up. At the end of the process, it reports back to the initial sender about the status of the hazard that was reported. It also includes asset management, including historical inspection details for equipment and personal protection equipment, and alerts to notify when the next scheduled inspection is. Assets can be managed by location or division, and they can be moved from one location to another. The system updates the information. Additional modules included are a permit to work module, training and competency management module, and a surveys and assessment module. A library section with links to websites with safety resources, files, guides, and training materials is available. The service provider configures the software to the user's needs, therefore, adding or renaming activities as needed.

Based on the information obtained from their website, this application is used mostly in Europe by major corporations (Chevron, Experian, Crossrail, Actavis, British Sugar, WSP, Babcock, Chevron, Qinetiq, Oxford Instruments, Natural History Museum, ABB). Based on the nature of these companies, it may be concluded that this is an application mostly used by industrial manufacturers. No construction company users are advertised on the company website. However, the website mentions that the company has clients in the CI.

Accupoint Software

This solution includes capabilities for quality, environmental, and safety management. In total the system offers 60 interrelated modules (12 specifically for safety), among which are risk assessment, hazards identification, injury management, safety inspection management, safe work instructions, response planning, incident management, contingency planning, material safety data sheets management, emergency contacts, maintenance management and visitor management. The company website mentions that the system offers the possibility of analyzing H&S metrics, however, no details were available on the web regarding the type of safety metrics calculated by the system. An email requesting information in this regards was sent through their web application, but no response was received at the time of final editing of this thesis. The cost of its license starts at $1,700 per quarter, which allows five users to use the system. A ten user license is available at $2,500 per quarter. An enterprise license for more than ten users is also available.

In summary, ICT for the CI and for H&S purposes have been developed and researched in various fronts, but mutual collaboration and information sharing among all construction companies has not been enforced yet. Generation of H&S performance indicators for construction types, and the possibility to filter industry-wide information to determine root causes have not been implemented. The following chapter describes the proposed system envisioned to become the starting point for a safer CI.

1.2 Research Project Overview

This research project is concerned with the improvement of H&S provision within the CI, through the use of information and communication technology.

The central research question of this research project is as follows:

Is it possible to improve safety by providing real-time information of safety indicators (RIR and LTCR) to H&S stakeholders during a project's construction phase?

The main objective of the research is to improve H&S of construction workers in BC (and Canada) with the use of computer-based ICT. The technological framework proposed in this research is able to monitor, report, and instruct construction professionals (both workers and managers) on H&S concerns and risks regarding construction activities, tasks and trades, in specific project areas and different project types. The system integrates H&S data, captured through electronic devices located in multiple construction projects, for further processing. The processed data will help to:

a) Provide real-time information for informed-decision making;

b) Prevent incidents, accidents, and fatalities, through site-specific real-time H&S indicators and information available during decision making processes;

c) Highlight H&S hazards related to construction zones, activities, trades, and construction types;

d) Recommend best practices and guidelines for construction professionals;

e) Generate a web-based, industry-wide, real-time H&S database; and

f) Assist construction companies to use the latest industry-wide information for H&S risk assessment.

The following are the specific sub-objectives of the research project:

- Identify current H&S communication practices, information access, and training methodologies used in the CI.
- Identify the trends of injuries and fatalities in the BC (and North America) CI for the past 10 years, and their associated cost.
- Obtain feedback from construction professionals in international and local construction projects on the current status of H&S information systems and technologies.
- Propose an integrated technological framework and a real-time monitoring system for general contractors and construction companies, to minimize H&S hazards.
- Program and develop a preliminary version of the proposed system.
- Test the incident, accident and safety observation data input templates, and the project report page of the proposed system, as well as validate the needs and functions of the system.

1.2.1 Methodology

1.2.2 Literature Review

The start point for the research was a literature review of existing research, using Compendex Engineering Village, Web of Science, and ASCE Research Library digital databases. These were checked for research oriented towards:

- improving construction safety through the use of information technologies;
- web-based applications for the construction industry;

- H&S oriented web-based applications;
- information and communication technologies for construction industry and construction projects; and communication techniques and information sharing.

The outcomes of the literature review are summarised and discussed in the first part of this introduction chapter.

1.2.3 Identification of available electronic equipment for field data transfer

The next phase of the research was a review of existing technologies and equipment for real-time information transmission and information gathering. This review was primarily carried out using the internet, and included collecting information about portable electronic devices (PED), ruggedized portable computers, and portable projectors available on the market today. Analytic hierarchy process (AHP), a structured technique for organizing and assisting in complex decisions, was used to evaluate the information gathered in order to determine the most suitable technology to use with the proposed system. This part of the research process is described in section 2.2.

1.2.4 Designing the information and communication system

This phase of the research was concerned with producing all the required material and logical steps needed for a computer programming expert to develop the preliminary version of the proposed system. Diagrams and general conceptualizations were drafted and provided to a computer programmer for code writing. The researcher acted as the project manager for this programming phase. This involved holding weekly meetings to monitor the progress of the code writing and to check the functionality of the system and its interfaces. Further meetings were organized with UBC Okanagan's IT department to obtain advice regarding interactions between sub components of the proposed system and to facilitate testing of the system once programmed.

Figure 1.4 provides a breakdown of the action areas developed throughout the research project: programming, PED selection, testing, industry feedback, and investment analysis. A description of each action area is included in the following sections.

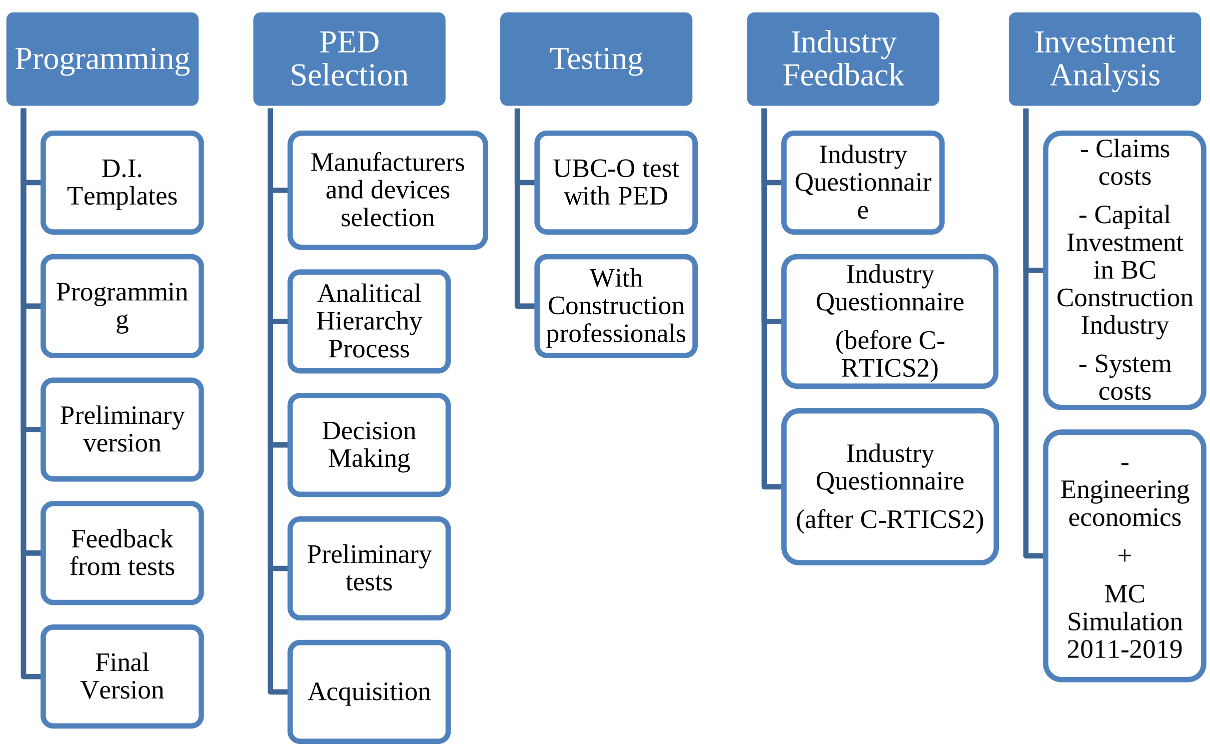


Figure 1.4. Research project action areas.

1.2.5 Programming

The framework and general conception of the proposed system was established at this point. Data input forms were developed and handed over to the programmer for coding of each template. Programming and coding of the system resulted in a preliminary version for testing purposes. Tests were conducted by the researcher and undergraduate students in the form of browsing programmed sections to identify functionality and ease of use. Feedback was provided to the programmer for corrections to be made and to produce a working version of the system.

1.2.6 PED selection

An extensive internet search for manufacturers of PEDs was carried out. Devices were selected and technical information was gathered to perform an AHP. Results of the AHP were used to help in determining the electronic device to be used for the testing phase of the project.

1.2.7 Testing

An undergraduate student from the School of Engineering at UBC was assigned with the task of accessing the system from random locations within the UBC campus, using the selected PED. The objective was to test wireless connectivity and accessibility of the system using the acquired portable device. The student was required to submit information into the system through the various data input pages. A test logbook was used to note comments regarding the performance of the system. The test logbook was reviewed and commented on by the researcher before handing it over to the programmer. The programmer was asked to make the necessary changes to correct issues related to functionality, ease of use, user interaction, navigation and data acquisition. The researcher held regular meetings with the student and the programmer to discuss programming progress and to determine actions plans.

1.2.8 Industry feedback

A questionnaire survey was developed and sent through direct emails, targeted database emails, and online forums. FIATECH, a construction industry technology focused organization, assisted by submitting the questionnaire survey to their database. Personalized emails were sent to construction professionals who had been identified as having varied experience in different types of construction projects in Canada, USA, and Costa Rica. Linked-in online forum was used to request construction professionals to fill out the questionnaire survey.

Industry feedback was again obtained once the proposed system had been developed into an operational version. A one hour session was held with potential users with different job functions and experience in construction projects. The survey sample included graduate students at UBC with previous experience in the construction industry, construction managers, structural designers, project owners, and project managers. The session started with a questionnaire. Once the questionnaire was answered, a presentation about the proposed system was delivered allowing interaction and open questions. After the presentation, participants were asked to submit a fictitious incident report through the system, and to obtain a summary report from the system. As a final step, the interviewees were asked to answer a second questionnaire survey assuming a full implementation of the proposed system in their construction projects.

2 Chapter: Construction Real-time Information and Communication System for Safety

On the basis of the literature review findings, this chapter addresses the real-time information and communication system developed during the research project. The technological framework, named the construction real-time information and communication system for safety (C-RTICS^2), was built on principles and concepts from previous research, and considering some of the features provided by commercial software as described previously. However, this research project incorporated the following additional elements to promote a wide-spread use of the system and to generate a significant impact on H&S in the CI:

a) Free access to C-RTICS^2 by all construction companies interested on using the system in construction operations: The main motivation behind this principle was to eliminate possible financial barriers to medium and small size companies from implementing the proposed system in their construction projects. It is well known that cost is one of the most controlled variables in construction projects. Therefore, providing a free of charge system can motivate companies of all sizes to implement it to improve safety in their projects.

b) Unified database for all the CI: None of the current information and communication solutions being offered for the CI incorporate safety data submitted by multiple construction projects and companies. They are applications for companies to use on their projects only. C-RTICS^2 will allow the generation of a real-time safety database for the mutual use of the entire CI with a strict confidentiality protocol.

c) Neutral system administrator: As the previous principle implies the use of the same system by different companies, protection and security of sensitive information must be guaranteed. It is considered that neither private companies nor regulating bodies should influence on the potential wide spread use of C-RTICS^2. Therefore, at the initial stages of the project, UBC (Okanagan campus) is proposed to provide a neutral ground for all the information to be stored in the common database. The level of accessibility to information will depend on the user and the access authority level. C-RITICS^2 uses a proposed user-cluster concept to ensure privacy and confidentiality. The user-cluster concept is further explained in section 2.1.3.

d) RIR and LTCR as the principal safety output indicators for project and project type: To provide a unified language for industry-wide generated information, the RIR per project (RIR_{PP}) and the LTCR per project ($LTCR_{PP}$) are proposed. These safety indicators are generated by algorithms built into the coding of the system. Furthermore, these safety indicators from multiple projects constitute the input to generate a RIR and LTCR for specific project types, as follows: commercial (RIR_C and $LTCR_C$), industrial (RIR_I and $LTCR_I$), residential (RIR_R and $LTCR_R$), and transportation (RIR_T and $LTCR_T$).

e) All H&S stakeholders in the CI must have access to the system: Users from private companies (private users), regulating bodies, and the general public (public users) should have access to the system to obtain general statistical information. General statistical information is neither company nor project specific. As mentioned previously, the user-cluster concept was developed as a mean to provide access to various H&S stakeholders while providing strict security and confidentiality protocols. This founding principle provides the ground for potential new research and training specifically related to H&S in the CI, as industry-wide information will be available for public and private researchers.

2.1 Structure and interfaces of C-RTICS^2

As shown in Figure 2.1, C-RTICS^2 is based on three main components: data input component; data processing and communication component; and data output component. A key characteristic of C-RTICS^2 is its ability to process information submitted by multiple construction projects and multiple companies in a centralized database. As shown in Figure 2.1, internet wireless networks in construction projects are proposed to serve as the internet connection required to access the proposed system. Information from multiple projects (e.g., projects B, C, D, and E submitting information to a centralized database), can be submitted and saved on a centralized database for further analysis.

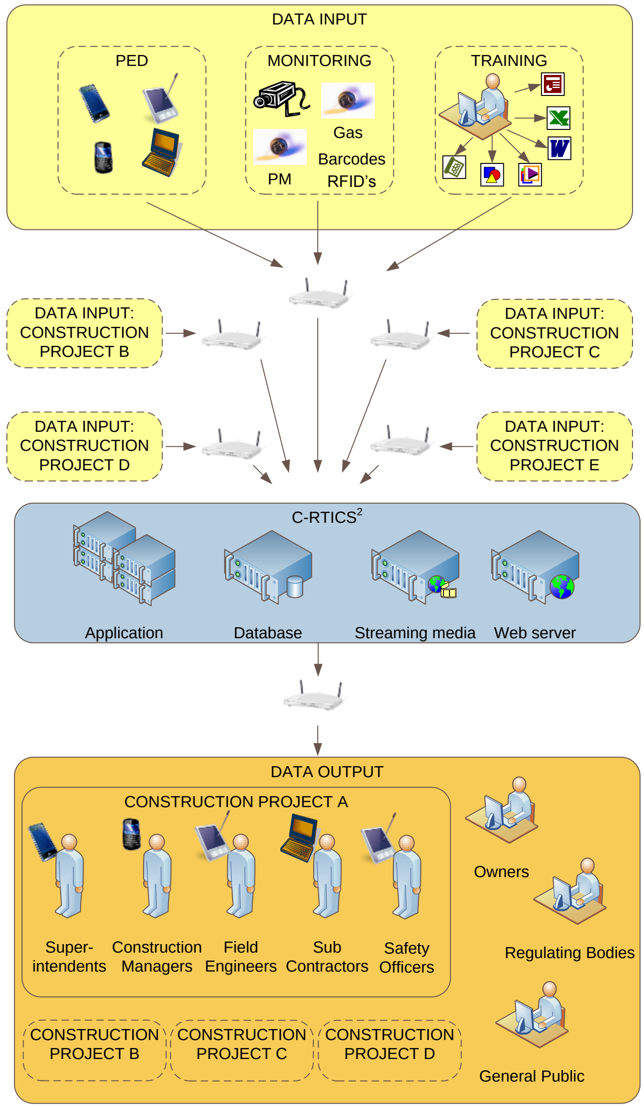


Figure 2.1. Construction real-time information and communication system for safety.

2.1.1 Data input component

The data input component focused on submission of information from three modules: the portable electronic device (PED) module; the monitoring module; and the training module.

2.1.1.1 PED module

This module uses wireless electronic devices to submit and retrieve information to and from the system. These devices can be in the form of a laptop, a PDA, a smart phone, a ruggedized portable computer, an iPad, or any other PED with access to Wi-Fi internet networks. As shown in Figure 2.2, six data input templates were developed and included for this module to submit information from the projects to the centralized database. These templates were named the safety observation report, the incident report, the accident report, the personnel report, the equipment report, and the training report. Once a report has been submitted from a project, the system uses database association processes to organize the information for future data output requests.

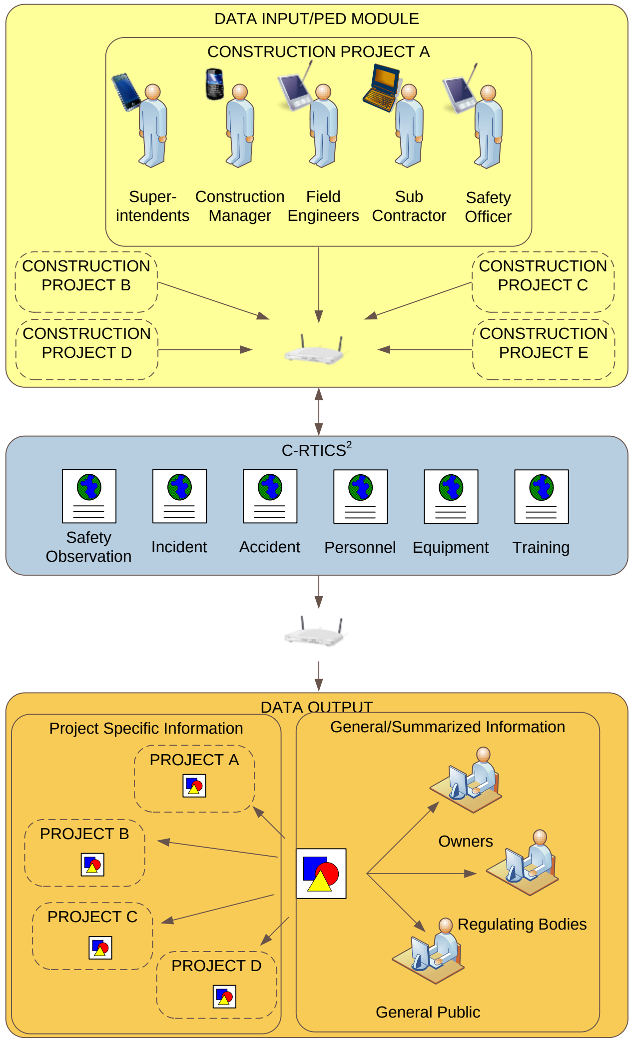


Figure 2.2. Portable electronic device (PED) module.

2.1.1.2 Monitoring module

As shown in Figure 2.3, this module incorporates wireless high resolution web cameras, gas and particulate matter wireless sensors, and barcodes and RFID. The objective of this module is to provide real-time information regarding the concentration of hazardous gases within the construction project. Hazardous particulate matter containing micro and nano particles (which could be inhaled by construction workers) can also be monitored with this module. Barcodes and RFID tags placed in heavy equipment, power tools, and hard hats, will ease the process of safety inspections. Each equipment can have its own profile created into the system. Scanning a given barcode or RFID tag will retrieve all historical safety information about that specific equipment.

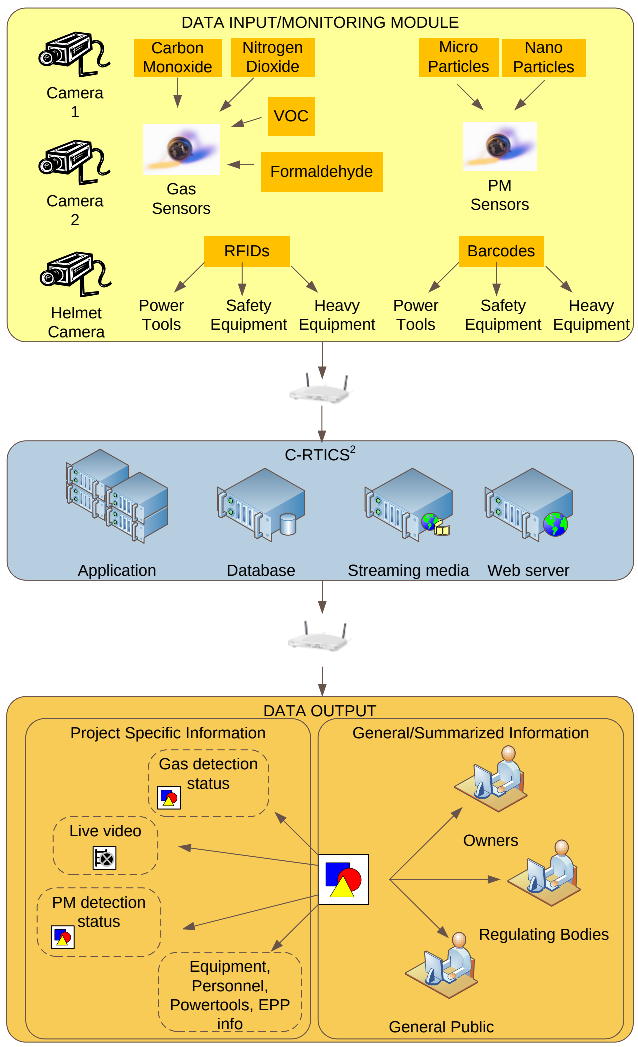


Figure 2.3. Monitoring module.

2.1.1.3 Training module

The training module allows safety officers and construction managers to upload relevant training documentation to the system. The information is then retrieved from the project to provide specific training sessions to construction workers. A novel feature of C-RTICS^2 is its ability to deliver "on-the-spot" training to construction workers. As shown in Figure 2.4, the use of a PED along with a portable projector provide safety officers and construction managers with the possibility of projecting relevant information on any surface within the construction project. This eliminates lost time due to mobilization of construction crews from their current location (e.g., where they are performing their tasks) to the safety training office as it is accustomed. File formats of different types (text documents, videos, presentations, spreadsheets, charts) can be uploaded into the centralized database and accessed as required. Tracking of training sessions can also be accomplished, as it is further explained in section 2.1.8.

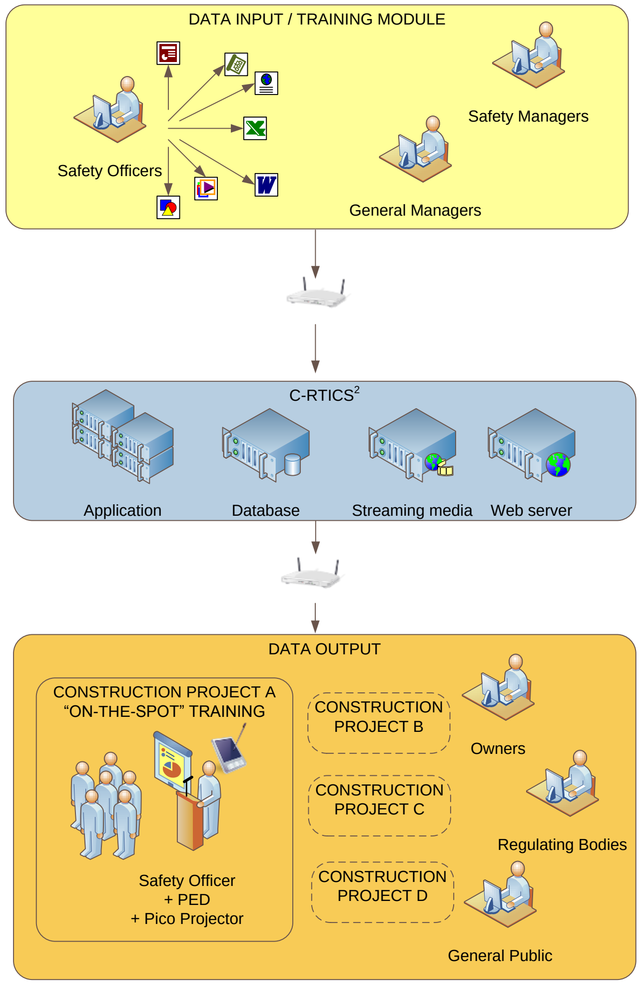


Figure 2.4. Training module.

2.1.2 Data processing and communication component

The data processing and communication component is responsible of managing and filtering information displayed to each user based on the user-cluster he or she belongs to. It also calculates the correspondent safety indicator per project and per project type (e.g., RIR_{PP} or RIR_{C} explained previously) on a real-time basis. The real-time calculation of RIR_{PP} and

$LTCR_{PP}$ is accomplished by using the information retrieved from all the incident, accident, and personnel reports submitted for a specific project. An algorithm in the system generates the required safety indicator. By managing access to information based on user-clusters, the system allows access to project specific information only to authorized users from each construction company. Figure 2.5 shows a screenshot of the flowchart used to generate the code for the calculation of the RIR_{PP}.

The RIR and LTCR for project types (commercial, residential, industrial, or transportation projects) are calculated using incident, accident, and personnel reports for each project type. The correspondent RIR_C, $LTCR_C$, RIR_R, $LTCR_R$, RIR_I, $LTCR_{I,}$ RIR_T, and $LTCR_T$, are then obtained.

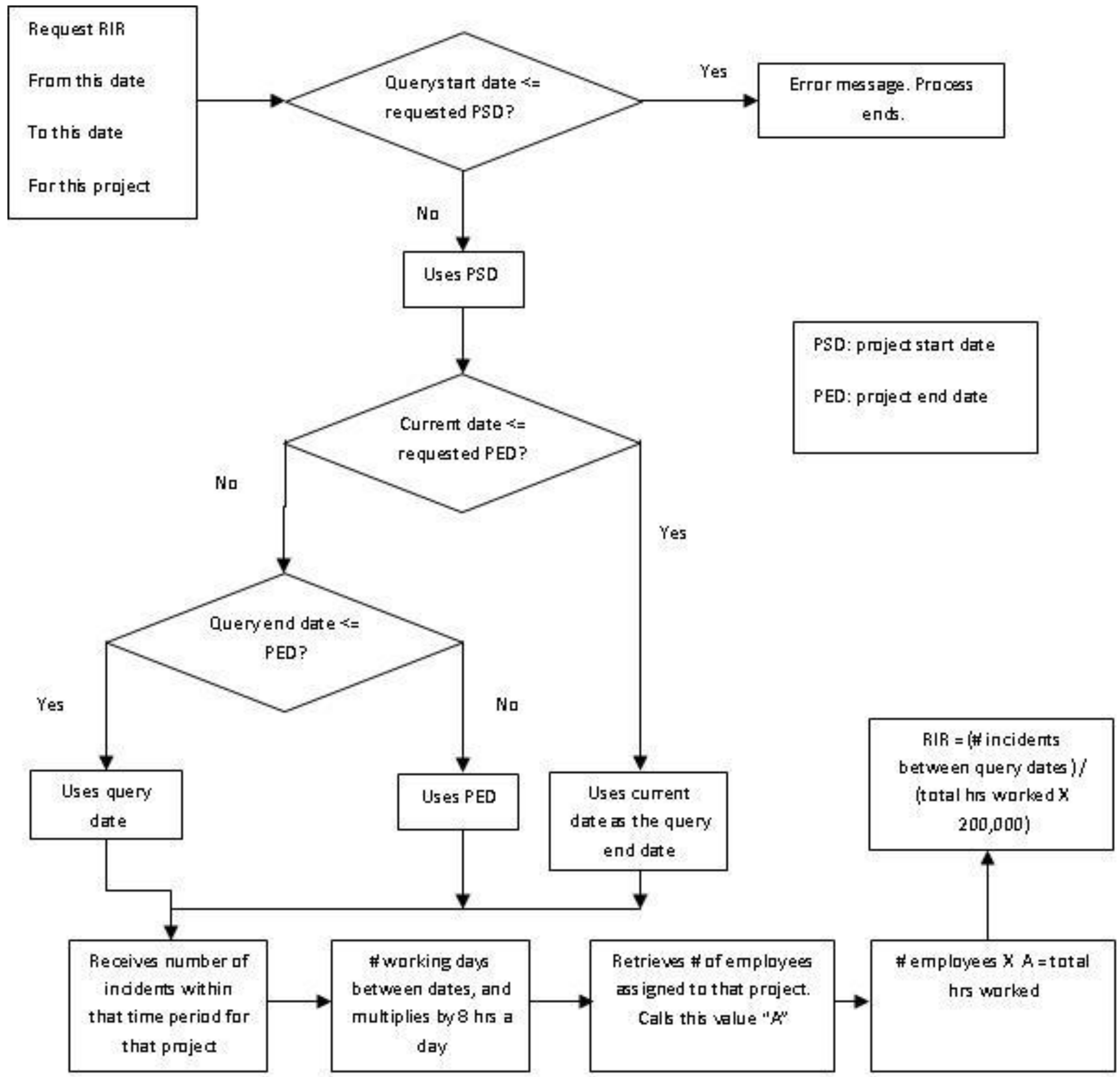


Figure 2.5. Flowchart for calculation of the RIR_{PP}.

In addition, combination of the monitoring and PED modules of the data input component constitute the communication component of the proposed system. The data processing and communication component manages live video streamed from the high-resolution web cameras located in the construction project. The voice over internet protocol (VoIP) technology allows the PED to transmit audio communication in real-time basis. This capability provides a strong tool for solving technical and work related problems without the need of expert's physical presence in the work site. As shown in Figure 2.6, a monitoring page allows work site managers to contact experts around the world and for these experts to obtain live video and audio from the project. Real-time audio-visual communication and collaboration between interdisciplinary teams across multiple locations can be accomplished through the use of C-RTICS^2.

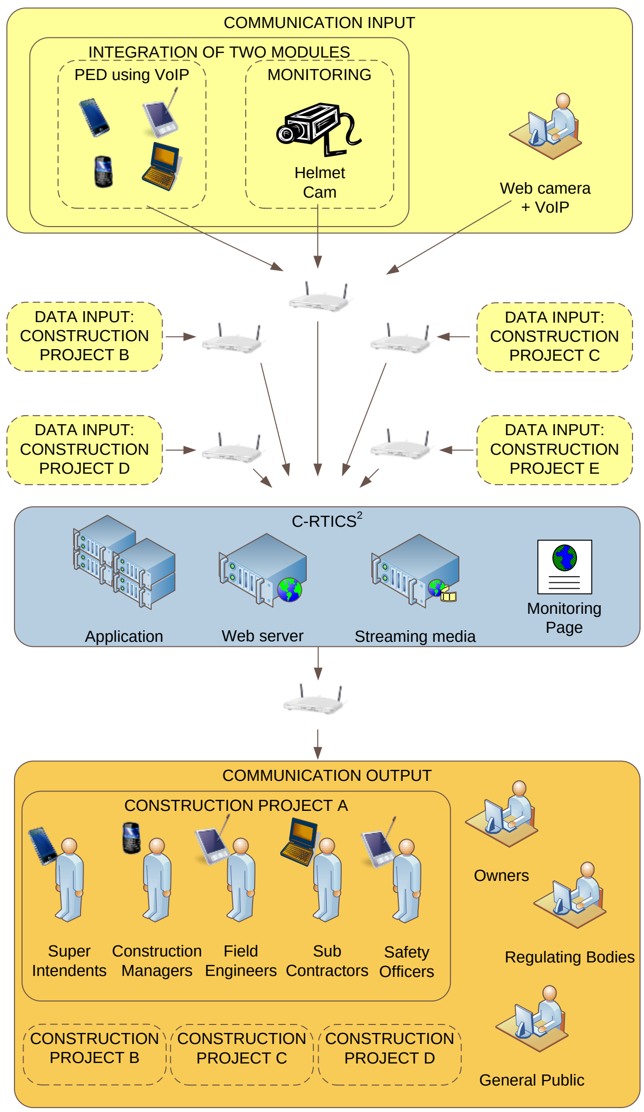


Figure 2.6. Communication component.

2.1.3 Data output component

The data output component of C-RTICS[2] provides the opportunity for H&S stakeholders to access information related to project types, or related to a project they are directly involved in. As observed from Figure 2.2 through Figure 2.6, information can be obtained for a specific project or for general project types. With proper authorization, access to a company's specific project information will be granted. If the user is not authorized to access detailed information for any project, access is granted to general statistical information related to project types (e.g., RIR_C or $LTCR_I$) only.

Figure 2.7 shows the user-cluster concept implemented to filter the flow of information throughout the system. Information without restriction flows from one stakeholder to another as long as they are part of the same user-cluster. Users pertaining to project A are the only ones with access to specific information about project A. It is considered that the user-cluster of project A is made out by the middle management in the project (i.e. construction manager, safety officer, superintendent, field engineers, and sub-contractors). The owner of project A represents a single project owner with access to information to the owned project only. Figure 2.7 also provides an example of an owner of multiple projects (bottom left hand side of figure). This owner has access to specific information of the owned projects (e.g., projects B and D). The dashed bidirectional arrow linking projects B and D indicates the possibility for the owner to authorize members of both projects (projects B and D) to access detailed information of both projects. This provides the opportunity for the project management teams to share information related to H&S of their projects, and contribute to the mutual development of preventive actions to avoid incidents and accidents in both projects.

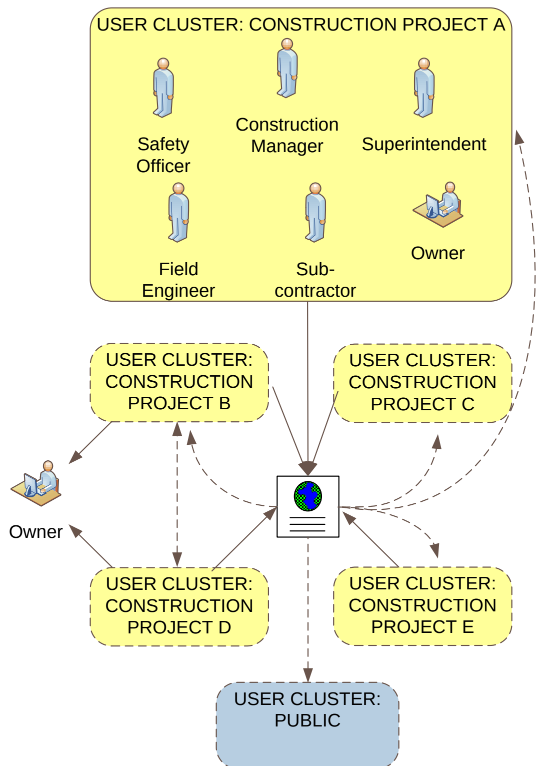


Figure 2.7. User-cluster concept.

The public user-cluster shown in Figure 2.7 represents public users who are interested about a particular project type. These users can range from general public, regulating bodies, government institutions, academic institutions, or other professionals in the CI interested in H&S statistical data. As shown by the dashed unidirectional arrow, public users are able to access the system and obtain information related to general statistics per construction type only (i.e.: RIR_C, $LTCR_C$ described in previous sections). Access to detailed project information (i.e.: RIR_{PP}) is not granted to public users.

The arched unidirectional dashed arrows shown in Figure 2.7 represent the possibility of users assigned to an specific project (i.e.: project A) to obtain information related to general statistics for construction types (i.e.: RIR_R and $LTCR_R$).

Beyond the user-cluster concept, it was considered that user's role within a project must also be considered to authorize access to the system's data input templates and reports. Table 2.1 shows the user-types defined for this purpose and the system access rights for each one.

Table 2.1. Access to the system according to user type.

	Data Input								
			Reports						
User	New Project	New User	Inc	Acc	Safe Obv	Person	Equip	Train Sess	UNTM
Admin	x	x							
CM			x	x	x		x	x	x
SO			x	x	x	x	x	x	x
Sup			x	x	x			x	
FE			x	x	x			x	
SC			x	x	x				
Owner					x				
Public User									

Notes: Admin.: Administrator; CM: Construction Manager; SO: Safety Officer; Sup: Superintendent; FE: Field Engineer; SC: Sub Contractor; Inc.: Incident; Acc.: Accident; Safe Obv.: Safety Observation; Pers.: Personnel; Equip.: Equipment; TrainSess.: Training Sessions; UNTM: Upload New Training Material; RIR_{PP}: Recorded Incident Ratio per project; $LTCR_{PP}$: Lost Time Case Ratio per project; ~: for user types assigned to the same user cluster.

Table 2.1. continued.

Data Output													
Project Specific Information~								Project Type Information					
RIR_{PP}	$LTCR_{PP}$	Inc	Acc	Safe Obv	Pers	Equip	Train Sess	RIR	LTCR	Inc	Acc	Safe Obv	Equip
								x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x		x	x	x	x	x	x	x	x
x	x	x	x	x		x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x
								x	x	x	x	x	x

As observed in Table 2.1, eight user-types were considered: administrator; construction manager (CM); safety officer (SO), superintendent (Sup.); field engineer (FE), subcontractor (SC), owner, and public user.

The administrator is in charge of creating new projects into the system. An UBC researcher with proper knowledge of the system and the research project is proposed to undertake the administrator's role during the first stages of the project. Creation of user-clusters, new users and assignment of these new users to a specific user-cluster is also the responsibility of the administrator. The administrator does not have access neither to data input templates nor to project specific RIR and LTCR. However, the administrator can have access to general statistics for construction types (i.e.: RIRR and LTCRR) based on his condition of public user.

The CM has access to all sections but the personnel report template. This task is deferred to the SO as current H&S regulation requires new workers in a construction project to go through basic H&S training before working in the project.

The SO has access to all sections of the system, as it is considered the key stakeholder of it.

The Sup. has access to the incident, accident, safety observation, and training reports of the data input component. The Sup. also has access to all data output sections of the system.

The FE has the same access to the system as the Sup., but does not have access to the personnel section of the data output component. This means that a FE can’t retrieve reports pertaining to specific construction workers. This is intended to protect worker’s sensitive personal information. Access to this type of information is provided to higher hierarchy levels only (e.g., CM, SO, and Sup.).

The SC has the same access level provided to FE but without access to the training report section of the data input component. The intention behind this restriction is to require the presence of a member of the project’s managerial team (e.g., CM, SO, Sup., or FE) during a training session. Assuring the quality and quantity of training delivered to workers is considered an important aspect to improve H&S in the projects.

The owner has access to all the data output sections of the system, but only to the safety observation report of the data input section of the system. The reason behind this restriction is that given an incident or accident, the presence of a member of the managerial team of the project is required to gather the appropriate information and submit the report to the database. Proper technical understanding of a H&S event is crucial before filling out and submitting a report into the system.

Finally, the public user has access to general statistical information only.

2.1.4 Data input templates

As mentioned in previous sections and shown in Figure 2.2, C-RTICS2 gathers information from six different data input templates: **s**afety observation, incident, accident, personnel, equipment, and training reports. The following sections describe each one of these data input templates.

2.1.5 Incident, accident, and safety observation reports

The incident report gathers information of an incident where no workers were injured, and without lost productive time. The accident report gathers information of an incident with injured workers and lost productive time. The safety observation report gathers information related to worker's behaviour, attitude, or practices which can lead to a potential hazard, an incident, or an accident throughout the development of the project. This approach on safety observations provide valuable information to undertake preventive actions and avoid an incident or accident from happening in the future. Figure 2.8 show the data fields included in each of these report templates.

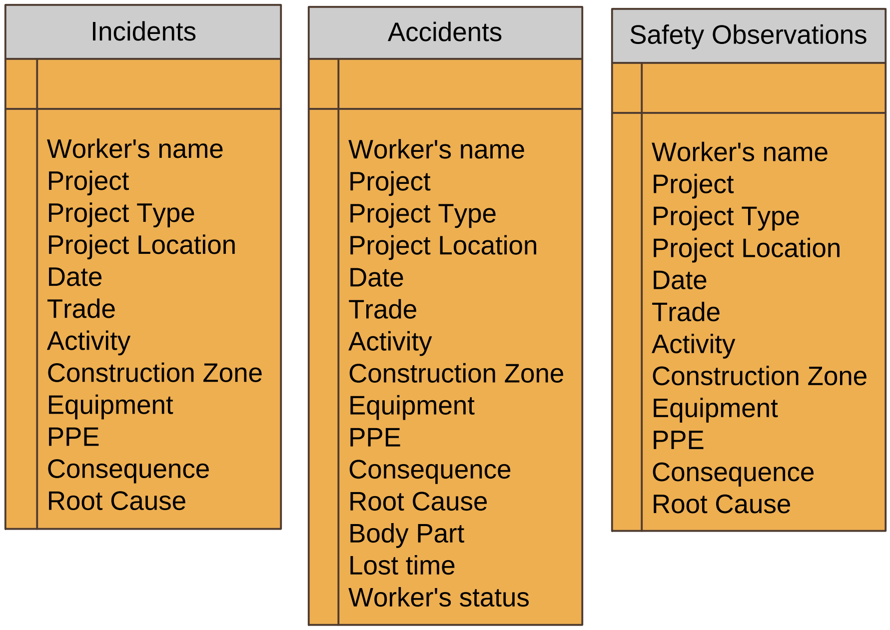


Figure 2.8. Incident, accident, and safety observation reports data fields.

The three reports share the first twelve data fields, considered important to provide the database with appropriate information to generate reports upon user request. These are:

- Worker's name: the name of the worker involved in the incident or accident is selected from a drop down menu displayed when the user clicks on the field. The drop down menu is automatically generated by the system based on the personnel reports submitted to the system.
- Project: project where the event occurred. Selected from a drop down menu.
- Project type: Type of construction project (commercial, industrial, residential or transportation as described in previous sections).
- Project location: geographical location of the project where the event occurred.
- Date: date of the event to be reported.

- Trade: trade or trades involved in the event to be reported.
- Activity: construction activity executed when the event occurred.
- Construction zone: location -within the project- where the incident or accident occurred.
- Equipment: construction equipment used at the time of the event. Manual and power tools, as well as heavy equipment can be selected.
- Personal protection equipment: personal protection equipment used by the worker involved in the event to be reported.
- Consequence: consequence of the event to the workers involved.
- Root cause: main cause contributing to the event to be reported.

The accident report includes three additional data fields, as follows:

- Body part: body part injured, affected, or potentially affected at the time of the event.
- Lost time: total productive time (in minutes) lost as a consequence of the event (incident or accident).
- Worker’s status: condition of the affected worker.

Preliminary options or selections for each data field were included in the system. However, determination of the definitive options or selections is left for a later stage of the proposed system.

2.1.6 Personnel report

The primary focus of this report is to gather information about the total working hours in a given project. This is essential for the calculation of the RIR_{PP} and $LTCR_{PP}$, as the safety indicators are based on the total worked hours on the project. It is proposed that as a worker enters a project for the first time, a personnel report must be submitted into the system. This task is initially assigned to the SO (as current H&S regulations require a construction site orientation training to be delivered to every new worker prior of any work assignments). On the personnel report, the worker will be assigned to a project. Figure 2.9 show the database fields gathered by the personnel report.

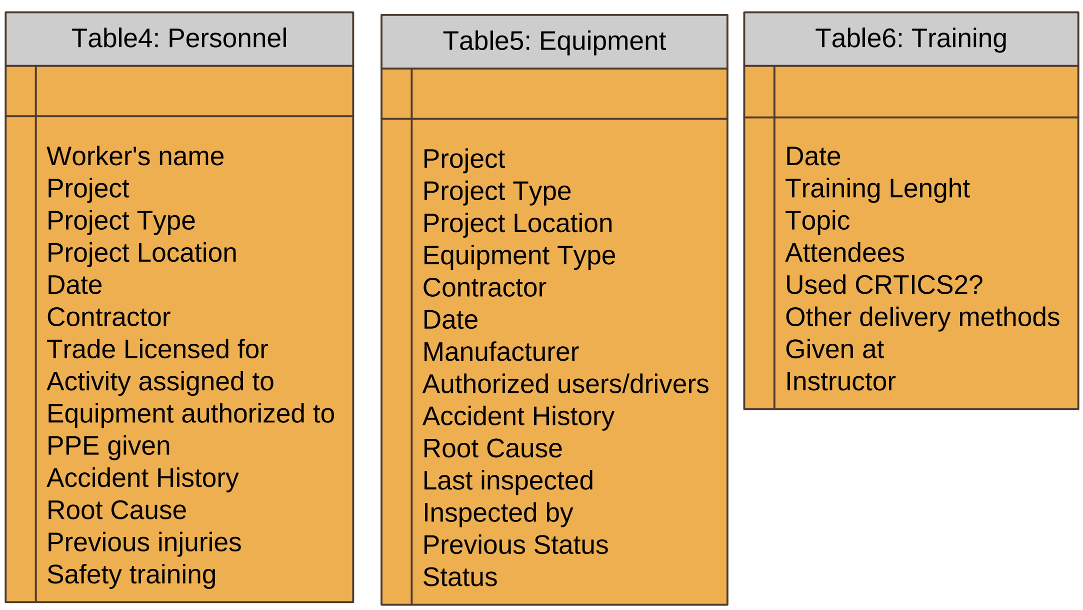


Figure 2.9. Personnel, equipment, and training reports data fields.

A description of each of the fields contained in the personnel report is provided next:

- Worker's name: name of construction worker entering the project.
- Project: project the worker is assigned to.
- Project type: construction project type (e.g., commercial, industrial, residential or transportation).
- Project location: geographical location of the project the worker has been assigned to.
- Date: date the construction worker is assigned to the project.
- Contractor: name of the sub-contractor the worker works for.
- Trade licensed for: trade the worker is licensed for.
- Activity assigned to: activity assigned to the construction worker at the time of entering the project.
- Equipment authorized to: equipment the worker is authorized to use or operate. Manual and power tools, as well as heavy equipment can be selected.
- PPE given: personal protection equipment provided to the worker when entering the project.
- Accident history: accidents the worker has been involved in the past.
- Root cause: main cause contributing for past accidents to occur.
- Previous injuries: injuries (treated or active) the worker has at the time of entering the project.

Safety training: official and certified safety training received by the worker at other construction projects.

2.1.7 Equipment report

It is suggested for all new equipment entering the project to be recorded into the proposed system. This is accomplished by filling up and submitting an equipment report. Figure 2.9 show the fields contained in this report. The equipment report gathers information that can be used for future equipment inspections. This report can be used to track heavy equipment only, or expand its use to other types of equipment including manual and power tools, and safety equipment. The implementation of RFID and barcodes (elements proposed for the monitoring module of the data input component of the system), provide the possibility to retrieve previously entered information regarding that specific piece of equipment.

A description of each of the fields contained in the equipment report is provided next:

- Project: project the equipment is assigned to.
- Project type: construction project type (commercial, industrial, residential or transportation).
- Project location: geographical location of the project.
- Contractor: Sub contractor requesting authorization to use the specific equipment in the project. This contractor is considered responsible for all aspects related to that piece of equipment.
- Date: date when the equipment is entered into the project.
- Manufacturer: name of the manufacturer of the equipment.
- Authorized users or drivers: workers authorized to operate or drive the equipment.
- Accident history: accidents the equipment have been involved in the past.
- Root cause: main cause that generated those accidents to occur.

- Last inspected: last date of H&S inspection of the equipment.
- Inspected by: person who inspected the equipment.
- Previous status: status of the equipment after the last inspection. Green, yellow, and red status are proposed. A green status indicates the equipment was inspected and complied with the project's H&S standards. A yellow status indicates the equipment was inspected and allowed to continue operating in the project, but maintenance or repairs were required. A red status indicates the equipment was inspected and considered non complying with the H&S standards of the project, therefore not allowed to be used.
- Status: new status assigned to the equipment at the end of the latest inspection.

Two purposes are pursued by submitting equipment reports. The first one is to generate a new entry into the database when a new equipment enters the project (an equipment never used in a project before). If this is the case, the data fields related to history of previous accidents, inspections, etc., are left blank. If the equipment is not new (e.g., a used equipment to entering the project for the first time), it is proposed that a special service contract clause be included in the contract between the contractor and the construction company. The special clause would require the contractor to disclose the H&S history of the equipment to be used in the project. If the equipment was used in another project of the same construction company, it is proposed for a equipment relocation request to be sent from one project to the other. The system would provide the possibility to export or import equipment from one project to another.

The second purpose of the equipment report is to serve as an inspection tool for SO. The SO can inspect a specific piece of equipment by accessing the equipment file in the proposed system. The accident history of the equipment, as well as information from the last H&S inspection (if any) can provide valuable information for the SO to take the necessary preventive actions to avoid incidents or accidents from happening.

2.1.8 Training report

The training report is proposed to be used after a safety instruction or training is delivered to a particular worker or group of workers. As shown in Figure 2.9, instruction time and attendees are some of the data fields included in the report. Those fields are used to gather information related to the total training hours received by a specific worker. The total training hours can be used at a later stage to determine is an incident or accident is linked to a lack of safety instruction to a particular worker or group of workers.

A description of each of the data fields contained in the training report is provided next:

- Date: date the training was provided to the worker or group of workers.
- Training length: total training time (in minutes) provided to the worker or group of workers.
- Topic: H&S topic presented during the training session.
- Attendees: workers who attended the training session.
- Used CRTICS[2]?: indicate if the training was provided by accessing and downloading information from the proposed system. This is a yes or no answer.

- Other delivery methods: method used to provide information to attendees (if not C-RTICS[2]).
- Given at: location the training was delivered at. The options to select from are on-the-spot, common areas, H&S classroom, other.
- Instructor: name of the instructor delivering the H&S subject.

2.2 Selection of the portable electronic device

As described in previous sections, PEDs are an integral part of the proposed system, specifically within the PED module of the data input component. PEDs with connection to the internet (through wireless connections) provide the user the capability to access the proposed system. If not already present, wireless internet connectivity in construction projects can be easily accomplished by connecting wireless antennas to existing internet connections (wired connections) to site offices. The web-based nature of the proposed system expands the options of the PED to use for information submittal or retrieval. A robust processor and massive storage are no longer required to access and interact with the system.

An extensive internet search for available PEDs was performed as part the of the research project. Manufacturers were selected based on three main characteristics of the PED they offered: size, weight and wireless connectivity to the internet. In certain cases, several configurations where considered for the same manufacturer and model. Differences between configurations included processing speed, memory, input/output ports, etc.

The following manufacturers and models were selected:

- Motion Computing: Model F5v. Nine configurations of this device were considered for the analysis.

- Panasonic: Model CF-H1F. Three configurations of this device were considered.

- Model CF-U1. Two configurations of this device were considered for the analysis.

- OQO: Model E+2. Four configurations of this device were considered for the analysis.

- Xplore: Model iX104C4. Seven configurations of this device were considered for the analysis.

- Apple: Model iPad. Six configurations of this device were considered for the analysis.

- Hewlett Packard: Model iPaq 111 classic and iPaq 211were considered for the analysis.

- Rugged Notebooks: Model RNB T10, six configurations of model GTAC E100, four configurations of model PS535F Rugged PDA, and two configurations of model PS236 Ultrarugged HH PC were considered for the analysis.

- Trimble: Model Yuma Rugged Tablet (YMA-FYS6AS-00), seven configurations of model Nomad Rugged Handheld (EGL-FYN2gEB), and two configurations of model Recon Rugged Handheld (RE5-FY4CEX-00) were considered for the analysis.

- Nexcom: Model MRC 2100-E. Four configurations of this device were considered for the analysis.

In total, sixty devices (named the sample from now on) from ten manufacturers were considered for the analysis. A matrix including manufacturer's names and device's specifications is included in Appendix A.3.

An AHP was performed to analyze the available options and determine the best suitable PED for a construction project. Initially, twenty three decision making criteria (factors) were considered. The factors are described in the following section.

- Cost (x1): an average cost of $2,502 was obtained for the entire sample, with a minimum cost of $380 and a maximum cost of $5,783.

- Weight (x2): an average weight of 5.2 pounds was obtained for the entire sample, with a minimum weight of 0.25 pounds and a maximum weight of 5.2 pounds.

- Screen size (x3): the minimum screen size for the entire sample was 3.5 inches. The maximum screen sized was 10.4 inches.

- Memory (x4): memory ranged from 64 Mega Bytes (MB) to 64 Giga Bytes (GB).

- Processor speed and type (x5): sixteen processor types and speeds were included in the sample, as can be observed Appendix A.3.

- RFID reader (x6): device capability to scan RFID tags.

- Bar code reader (x7): device capability to scan bar codes (2D and/or 3D).

- Support (x8): customer service support provided after purchasing of the equipment.

- Ruggedized (x9): device internal and external construction to stand rough conditions of construction projects. The following standards were found among the sample:

    - IP67, IP 65, and IP54: Ingress protection. Protection from rain and weather conditions that could damage the electronic device. IP67 provides the highest protection.

    - MIL-STD-461E, MIL-STD-810F and MIL-STD-810G: Military standards for roughness of an electronic device and protection against impact if dropped.

    - Otterbox defender series case: protection case manufactured for the Apple Ipad.

- Digital Camera (x10): options available within the sample included cameras of 1.3 Mega Pixles (MP), 2 MP and 3 MP, located on the rear of front of the PED.

- Bluetooth (x11): bluetooth connectivity.

- I/O Ports (x12): input and/ or output ports. Ports to connect the device to another electronic device to import/ export information.

- Operating System (x13): Operating system installed in the PED.

- Energy Efficiency (x14): energy efficiency standard assigned to the PED.

- Handwriting recognition (x15): capability of the device to recognize handwriting typed directly on the PED screen.

- Battery life (x16): hours of operation from the battery provided with the device.

- Wi-Fi connectivity (x17): capability to connect to wireless internet networks.

- Screen type/technology (x18): type of screen.

- Web Camera (x19): camera to transmit video thru the internet.

- Mobile Internet Connectivity (x20): capability to connect to the internet thru cellular telephone networks.

- Hard Drive (x21): storage capacity of the capacity of the device.

- Temperature of operation (x22): operating temperatures recommended for the device.

- Warranty (x23): years of warranty provided by the manufacturer/ retailer.

The value between parentheses (e.g., x23) represents the factor number, used from now on to refer to each factor.

Figure 2.10 shows a schematic of the twenty three decision making criteria and the manufacturers considered for the AHP.

A pair-wise comparison matrix was developed for the 23 factors. The objective was to determine the most important criteria and set a cut off value to reduce the amount of factors before moving forward in the analysis. The pair-wise comparison matrix and the normalized matrix for the factors are included in Appendix C.1. A consistency ratio of 0.09 was obtained for this matrix (considered acceptable).

The priority vector obtained for each factor is shown in Table 2.2. The factors are organized in descending order.

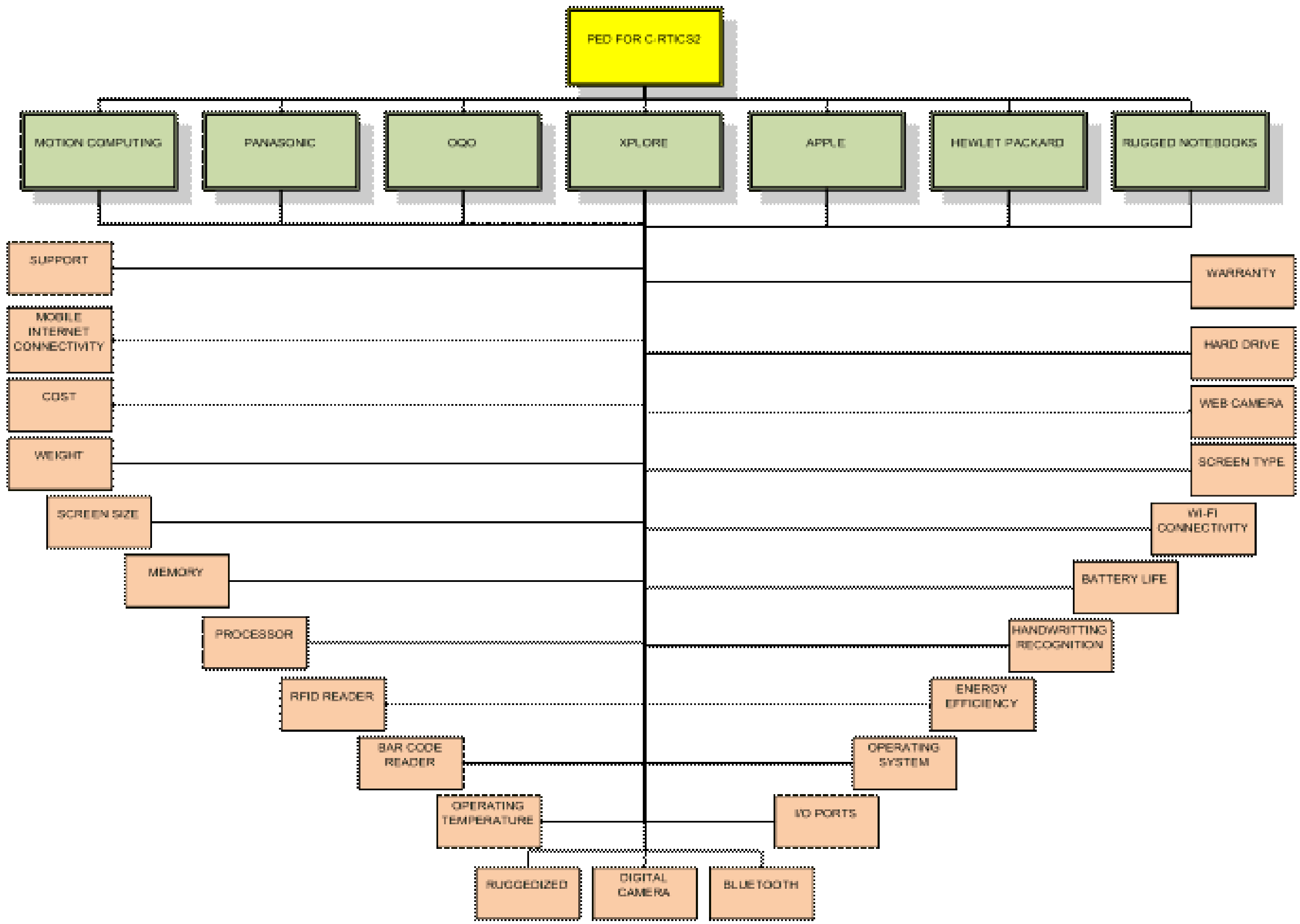


Figure 2.10. AHP decision making criteria.

Table 2.2. Priority vector obtained for the twenty three factors.

Factor	Priority vector
x1	0.135
x14	0.091
x20	0.079
x17	0.079
x22	0.063
x15	0.062
x19	0.058
x23	0.056
x16	0.056
x12	0.049
x9	0.040
x10	0.034
x8	0.030
x6	0.025
x3	0.020
x2	0.019
x11	0.016
x21	0.016
x4	0.015
x5	0.014
x18	0.013
x13	0.011
x7	0.007

It was observed that removing the lowest scored factors (e.g., factors x7, x13, x18, x5, x4, x21, x11, and x2) in certain cases would have eliminated the only differentiating factor between models from the same manufacturer. Therefore, the original twenty three factors were kept and a second level of analysis was performed. This second level consisted of analyzing each manufacturer and its corresponding models independently. At the end of the analysis of each manufacturer, the 1st ranked model was moved to a final round of analysis. A final analysis was applied to the finalists from all manufacturers. At the end of the analysis, a ranking was obtained for each device as it will be shown further ahead. Figure 2.11 depicts the stages of the AHP applied to the sample.

The following sections detail the factors used to analyze the models from each manufacturer, as well as the final decision matrix.

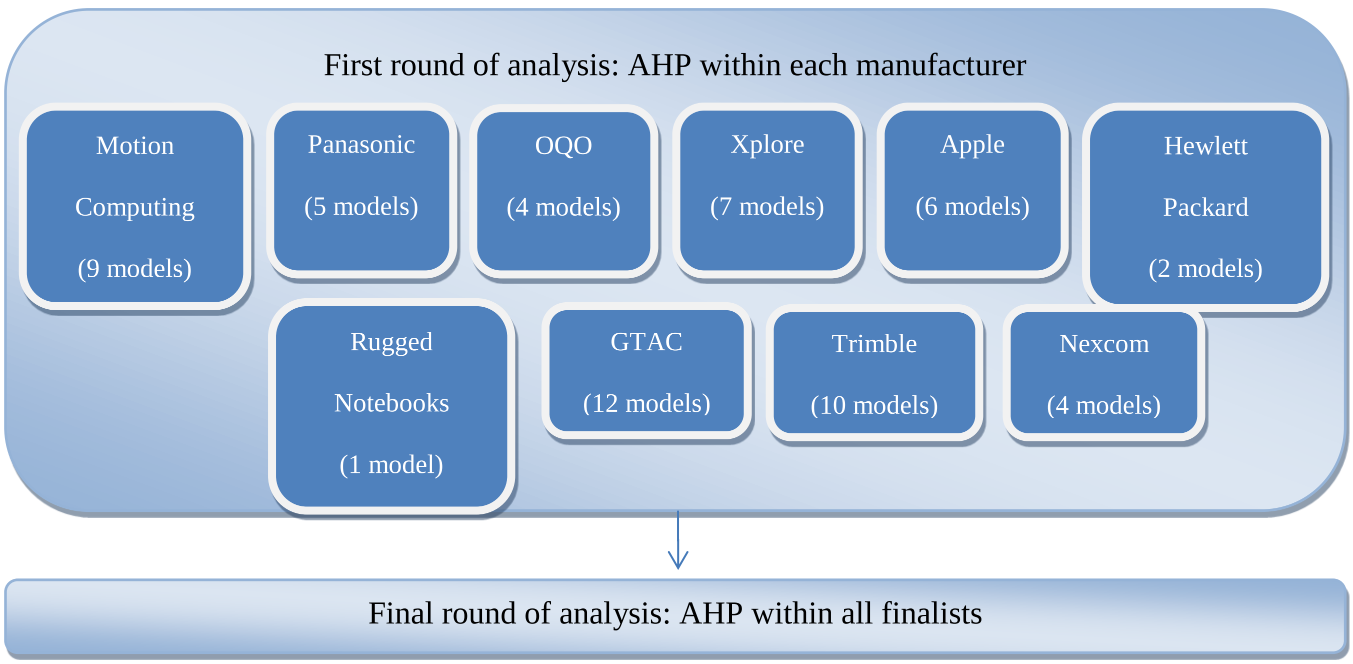


Figure 2.11 Methodology used for AHP

2.2.1 Motion computing

For this brand, factors x1, x4, x5, x6, x7, x10, x19, and x20 were used. The remaining factors were excluded from the analysis as all models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C1 to Appendix C9.

Figure 2.12 shows the final decision matrix obtained for the Motion Computing models. Model A9 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 17.1 %. A Mode ranking was estimated also. The intention was to provide an additional argument to assign the number one ranking to a model. This is particularly important if no significant difference is obtained for the V(Ai) of two models.

pj	13.58%	1.52%	1.47%	2.57%	0.75%	3.40%	5.87%	7.97%	DMUU			
normalized	36.57%	4.10%	3.96%	6.92%	2.02%	9.17%	15.80%	21.45%				
	x1	**x4**	**x5**	**x6**	**x7**	**x10**	**x19**	**x20**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	28%	1%	8%	2%	2%	2%	2%	4%	11.9%	3	28%	1
A2	18%	6%	8%	2%	2%	2%	2%	4%	8.5%	5	18%	2
A3	11%	4%	8%	2%	2%	16%	16%	4%	9.6%	5	11%	4
A4	7%	4%	8%	22%	22%	16%	16%	4%	9.8%	4	7%	6
A5	14%	15%	8%	2%	2%	2%	2%	4%	7.6%	7	14%	3
A6	9%	17%	8%	2%	2%	16%	16%	4%	9.4%	6	9%	5
A7	6%	17%	8%	22%	22%	16%	16%	4%	9.8%	4	6%	7
A8	4%	18%	8%	22%	22%	16%	16%	36%	16.2%	2	4%	8
A9	3%	19%	38%	22%	22%	16%	16%	36%	17.1%	1	3%	9
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.12. Final decision matrix for Motion Computing.

2.2.2 Panasonic

For this brand, factors x1, x2, x3, x6, x7, and x10 were used. The remaining factors were excluded from the analysis as all models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C10to Appendix C15.

Figure 2.13 shows the final decision matrix obtained for the Panasonic models. Model A4 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 30%. The Mode ranking confirmed this model as the number one model for Panasonic.

pj	13.58%	2.00%	2.06%	2.57%	0.75%	3.40%	DMUU			
pj normalized	55.75%	8.19%	8.45%	10.55%	3.08%	13.97%				
	x1	**x2**	**x3**	**x6**	**x7**	**x10**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	16%	8%	29%	8%	5%	3%	13%	5	16%	3
A2	9%	8%	29%	8%	43%	31%	15%	4	9%	4
A3	5%	8%	29%	69%	43%	31%	19%	3	5%	5
A4	44%	38%	6%	8%	5%	3%	30%	1	44%	1
A5	26%	38%	6%	8%	5%	31%	23%	2	26%	2
	1.00	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.13. Final decision matrix for Panasonic.

2.2.3 OQO

For this brand, factors x1, x4, x5, x18, x20, and x21 were used. The remaining factors were excluded from the analysis as all models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C16 to Appendix C21.

Figure 2.14 shows the final decision matrix obtained for the OQO models. Model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 29.1%. The Mode ranking confirmed this model as the number one model for OQO.

pj	13.58%	1.52%	1.47%	1.31%	7.97%	1.61%	DMUU			
normalized	49.47%	5.54%	5.36%	4.76%	29.01%	5.86%				
	x1	**x4**	**x5**	**x18**	**x20**	**x21**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	53%	6%	6%	6%	5%	5%	29.1%	1	53.3%	1
A2	27%	31%	31%	31%	5%	13%	20.6%	4	27.3%	2
A3	13%	31%	31%	31%	45%	13%	25.0%	3	12.8%	3
A4	7%	31%	31%	31%	45%	69%	25.3%	2	6.7%	4
	1.00	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.14. Final decision matrix for OQO.

2.2.4 Xplore

For this brand, factors x1, x4, x18, x20, and x21 were used. The remaining factors were excluded from the analysis as all models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C22 to Appendix C26.

Figure 2.15 shows the final decision matrix obtained for the Xplore models. Model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 21%. The Mode ranking confirmed this model as the number one model for Xplore.

pj	13.58%	1.52%	1.31%	7.97%	1.61%	DMUU			
normalized	52.27%	5.85%	5.03%	30.66%	6.19%				
	x1	**x4**	**x18**	**x20**	**x21**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	35%	26%	2%	3%	5%	21.0%	1	34.5%	1
A2	23%	26%	4%	3%	5%	15.1%	2	23.0%	2
A3	18%	26%	19%	3%	5%	13.0%	6	17.6%	3
A4	10%	5%	19%	3%	5%	7.5%	7	9.6%	4
A5	7%	5%	19%	29%	5%	14.0%	5	6.8%	5
A6	5%	5%	19%	29%	28%	14.5%	4	5.0%	6
A7	3%	5%	19%	29%	49%	15.0%	3	3.5%	7
	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.15. Final decision matrix for Xplore.

2.2.5 Apple

For this brand, factors x1, x4, and x20 were used. The remaining factors were excluded from the analysis as all models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C27 to Appendix C28.

Figure 2.16 shows the final decision matrix obtained for the Apple models. Model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 24.5%. The Mode ranking confirmed this model as the number one model for Apple.

pj	13.58%	1.52%	7.97%	DMUU			
normalized	58.88%	6.59%	34.53%				
	x1	x4	x20	V(Ai)	Rank	Mode	Rank
A1	39%	3%	3%	24.5%	1	39.4%	1
A2	23%	9%	3%	15.5%	3	23.3%	2
A3	10%	38%	3%	9.7%	6	10.3%	4
A4	15%	3%	30%	19.6%	2	15.3%	3
A5	7%	9%	30%	15.3%	5	7.3%	5
A6	4%	38%	30%	15.4%	4	4.4%	6
	1.00	1.00	1.00	1.00			

Figure 2.16. Final decision matrix for Apple.

2.2.6 Hewlett Packard

For this brand, factors x1, x2, x3, x4, and x18 were used. The remaining factors were excluded from the analysis as all models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C29 to Appendix C33.

Figure 2.17 shows the final decision matrix obtained for the Hewlett Packard models. Model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 65.6%. The Mode ranking confirmed this model as the number one model for Hewlett Packard.

pj	13.58%	2.00%	2.06%	1.52%	1.31%	DMUU			
normalized	66.38%	9.75%	10.06%	7.43%	6.38%				
	x1	x2	x3	x4	x18	V(Ai)	Rank	Mode	Rank
A1	83%	50%	33%	17%	13%	65.6%	1	83.3%	1
A2	17%	50%	67%	83%	88%	34.4%	2	16.7%	2
	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.17. Final decision matrix for Hewlett Packard.

2.2.7 Rugged Notebooks RNB T10

This is the only model found for this manufacturer. It was directly moved to the final round of analysis.

2.2.8 GTAC E100

For this brand and model type, factors x1, x20, and x21 were used. The remaining factors were excluded from the analysis as all E100 models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C34 to Appendix C36.

Figure 2.18 shows the final decision matrix obtained for the GTAC E100 models. Model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 26.3%. The Mode ranking confirmed this model as the number one model for GTAC E100.

pj	13.58%	7.97%	1.61%	DMUU			
normalized	58.66%	34.40%	6.95%				
	x1	**x20**	**x21**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	43%	3%	3%	26.3%	1	42.6%	1
A2	25%	30%	3%	24.9%	2	24.5%	2
A3	11%	3%	12%	8.6%	6	11.3%	3
A4	5%	30%	12%	14.2%	4	5.1%	4
A5	11%	3%	35%	10.2%	5	11.3%	3
A6	5%	30%	35%	15.8%	3	5.1%	4
	1.00	1.00	1.00	1.00			

Figure 2.18. Final decision matrix for GTAC E100.

2.2.9 GTAC Rugged PDA

For this brand and model type, factors x1, x2, x4, x10, x16, x20, and x21 were used. The remaining factors were excluded from the analysis as all GTAC Rugged PDA models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C37 to Appendix C42.

Figure 2.19 shows the final decision matrix obtained for the GTAC Rugged PDA models. Model A6 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 24.7%. The Mode ranking didn't confirm this model as the number one model. However, the difference in the V(Ai) between model A6 and A1 is considered sufficient to promote model A6 to the final round of evaluation.

pj	13.58%	2.00%	1.52%	3.40%	5.64%	7.97%	1.61%	DMUU			
normalized	38.03%	5.59%	4.26%	9.53%	15.78%	22.30%	4.50%				
	x1	**x2**	**x4**	**x10**	**x16**	**x20**	**x21**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	38%	21%	7%	3%	10%	7%	7%	19.8%	2	38.2%	1
A2	20%	21%	7%	24%	10%	7%	7%	14.9%	3	20.2%	2
A3	20%	21%	36%	3%	10%	7%	7%	14.1%	4	20.2%	2
A4	13%	21%	36%	24%	10%	7%	7%	13.4%	5	13.0%	3
A5	6%	7%	7%	24%	30%	7%	36%	13.1%	6	5.7%	4
A6	3%	7%	7%	24%	30%	64%	36%	24.7%	1	2.7%	5
	1.00	1.00	1.00	1.00	21.00	1.00	17.00	1.00			

Figure 2.19. Final decision matrix for GTAC Rugged PDA.

2.2.10 Trimble

For this brand, factors x1, x2, x3, x4, x7, x10, x13, x16, x17, x18, x19, x20, and x21 were used. The remaining factors were excluded from the analysis as all Trimble models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C43 to Appendix C56.

Figure 2.20 shows the final decision matrix obtained for the Trimble models. Model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 14.8%. The Mode ranking didn’t confirm this model as the number one model. However, the difference in the V(Ai) between model A1 and A8 (ranked second based on V(Ai)) is considered sufficient to promote model A1 to the final round of evaluation.

	x1	x2	x3	x4	x7	x10	x13	x16	x17	x18	x19	x20	x21	x22	DMUU			
pj	13.58%	2.00%	2.06%	1.52%	0.75%	3.40%	1.18%	5.64%	7.91%	1.31%	5.87%	7.97%	1.61%	6.38%				
normalized	22.21%	3.26%	3.36%	2.49%	1.23%	5.57%	1.92%	9.21%	12.93%	2.14%	9.59%	13.02%	2.63%	10.43%				
	x1	**x2**	**x3**	**x4**	**x7**	**x10**	**x13**	**x16**	**x17**	**x18**	**x19**	**x20**	**x21**	**x22**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	5%	1%	36%	42%	3%	18%	44%	2%	11%	47%	50%	4%	43%	4%	14.8%	1	5.3%	10
A2	15%	6%	7%	8%	3%	2%	6%	11%	1%	7%	6%	4%	3%	13%	7.8%	10	14.5%	2
A3	12%	6%	7%	8%	3%	2%	6%	11%	11%	7%	6%	4%	6%	13%	8.5%	8	11.5%	3
A4	10%	6%	7%	8%	3%	18%	6%	11%	11%	7%	6%	4%	6%	13%	9.1%	6	10.3%	5
A5	8%	6%	7%	8%	26%	18%	6%	11%	11%	7%	6%	13%	6%	13%	10.2%	5	8.4%	7
A6	9%	6%	7%	8%	3%	2%	6%	11%	11%	7%	6%	23%	11%	13%	10.5%	4	8.8%	6
A7	8%	6%	7%	8%	3%	18%	6%	11%	11%	7%	6%	23%	11%	13%	11.2%	3	8.1%	8
A8	7%	6%	7%	8%	26%	18%	6%	11%	11%	7%	6%	23%	11%	13%	11.3%	2	6.9%	9
A9	15%	27%	7%	2%	3%	2%	6%	11%	11%	2%	6%	3%	2%	4%	8.6%	7	15.1%	1
A10	11%	27%	7%	2%	26%	2%	6%	11%	11%	2%	6%	3%	2%	4%	8.0%	9	11.0%	4
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.20. Final decision matrix for Trimble.

2.2.11 Nexcom

For this brand, factors x1, x6, x7, and x20 were used. The remaining factors were excluded from the analysis as all Nexcom models share the same specifications for those factors. Pair-wise comparison matrices for each factor are included from Appendix C57 to Appendix C60. As observed in Figure 2.21, model A1 obtained the highest value vector V(Ai) of all models from this manufacturer, with a 28.7%. The Mode ranking confirmed this model as the number one model for Nexcom.

pj	13.58%	2.57%	0.75%	7.97%	DMUU			
normalized	54.61%	10.33%	3.02%	32.03%				
	x1	**x6**	**x7**	**x20**	**V(Ai)**	**Rank**	**Mode**	**Rank**
A1	49%	5%	8%	4%	28.7%	1	49.1%	1
A2	29%	5%	8%	32%	27.0%	2	29.1%	2
A3	15%	45%	8%	32%	23.4%	3	15.1%	3
A4	7%	45%	75%	32%	20.9%	4	6.7%	4
	1.00	1.00	1.00	1.00	1.00			

Figure 2.21. Final decision matrix for Nexcom.

2.2.12 Final round of analysis

For the final round of analysis, factors x5 (Processor type), x8 (Support), x11 (Bluetooth), x12 (I/O ports), x17 (Wi-Fi connectivity), and x18 (screen type) were not included in the analysis. Factors x5 and x18 were excluded as it was difficult to assess differences between brands and technical capabilities for both processors and screens (e.g., Intel vs. Apple). Factor x8 was excluded as all models from all manufacturers had a website with contact information for support. Factors x11 and x17 were excluded as all models had Bluetooth and

Wi-Fi capability. Factor x12 was excluded as all models had at least one port to connect the portable projector proposed with the system. The pair-wise comparison matrices for each remaining factors are included from Appendix C.63 to Appendix C.78. Figure 2.22 shows the summarized values obtained for the selected models.

	x1	x2	x3	x4	x6	x7	x9	x10	x13	x14	x15	x16	x19	x20	x21	x22	x23	V(Ai)	Rank	Mode	Rank
pj	13.58%	2.00%	2.06%	1.52%	2.57%	0.75%	4.10%	3.40%	1.18%	9.14%	6.27%	5.64%	5.87%	7.97%	1.61%	6.38%	5.64%	DMUU			
normalized	17.05%	2.50%	2.58%	1.91%	3.23%	0.94%	5.14%	4.27%	1.48%	11.48%	7.87%	7.07%	7.37%	10.00%	2.02%	8.01%	7.08%				
B1	7%	3%	10%	3%	4%	4%	8%	18%	11%	2%	1%	4%	3%	4%	12%	14%	7%	6.11%	10	6.9%	4
B2	4%	4%	9%	3%	4%	4%	16%	15%	11%	17%	1%	12%	28%	4%	14%	17%	3%	10.06%	4	3.5%	9
B3	6%	11%	4%	0%	4%	4%	16%	25%	2%	2%	16%	15%	3%	33%	3%	17%	10%	11.67%	2	5.5%	5
B4	5%	4%	10%	3%	4%	4%	8%	2%	11%	2%	5%	10%	3%	4%	6%	10%	17%	6.11%	9	5.0%	6
B5	33%	47%	4%	0%	4%	4%	1%	2%	2%	2%	5%	5%	3%	4%	2%	2%	3%	9.27%	6	33.1%	1
B6	21%	4%	12%	55%	4%	4%	1%	2%	11%	17%	1%	15%	3%	4%	5%	8%	7%	10.53%	3	21.0%	2
B7	3%	2%	13%	3%	4%	4%	16%	2%	11%	2%	16%	7%	3%	4%	11%	14%	10%	6.85%	8	3.4%	10
B8	9%	12%	6%	3%	4%	4%	1%	2%	11%	2%	16%	5%	3%	4%	8%	2%	10%	6.01%	11	9.1%	3
B9	4%	5%	7%	7%	4%	4%	16%	2%	11%	20%	16%	13%	3%	4%	15%	5%	10%	8.96%	7	4.5%	7
B10	4%	4%	13%	14%	33%	33%	8%	25%	11%	17%	16%	6%	22%	33%	11%	7%	10%	14.49%	1	4.0%	8
B11	4%	4%	13%	7%	33%	33%	8%	2%	11%	16%	5%	7%	28%	4%	15%	5%	10%	9.96%	5	4.0%	8
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			

Figure 2.22. AHP final decision matrix.

Based on V(Ai)			Cost	Weight (lb)	Screen Size (in)
1	B10	Motion Computing/Model F5v	$3,155.00	3.3	10.4
2	B3	GTAC PS236 Ultrarugged HH PC	$2,278.00	1.1	3.5
3	B6	Mac/iPad	$598.00	2.7	9.7
4	B2	Trimble Yuma Rugged Tablet (YMA-FYS6AS-00)	$3,569.00	2.6	7.0
5	B11	RuggedNoteBooks/RNB T10	$3,145.00	2.7	10.4
6	B5	HP/iPaq 111 Classic	$379.94	0.3	3.5
7	B9	CF-U1	$2,798.00	2.3	5.6
8	B7	Xplore/iX104C4	$3,697.00	5.2	10.4
9	B4	GTAC E100	$2,539.00	3.1	8.4
10	B1	Nexcom MRC 2100-E	$1,825.00	3.6	8.4
11	B8	OQO/E+2	$1,378.00	1.0	5.0

Figure 2.23. Summary of final PED analysis.

Figure 2.23 provides a summary of the results obtained at the end of the analysis. Manufacturing company and model description is included, as well as the cost, weight and screen size. The intention of this summary was to provide the researcher with enough information to recommend the model to procure for field testing of the proposed system. The Apple Ipad was selected as the PED for field testing of the proposed system. This device ranked 3rd under V(Ai), and ranked 2nd under the Mode ranking, making it a cost effective device for testing purposes.

2.2.13 Limitations

As observed in Figure 2.10 and Appendix C.1, the AHP used for the selection of the PED was based on an initial pair wise comparison matrix of 23x23. Determination of weights to obtain an acceptable consistency ratio for a matrix this size was an extensive and complicated process. The researcher approached the analysis as an academic exercise, which may not be practical for real life applications as it have the risk of not dissipating the uncertainty surrounding the decision at hand. It is advised that future analysis be based on a smaller number of decision making criteria to reduce uncertainty to the overall analysis and obtain reliable results for real life application.

2.3 Programming language and database type

Microsoft's Visual Studio Express was used as the programming interface for C-RTICS[2]. This free software had all the required programming capabilities for this project. As recommended by the system programmer, it contains an ASP.net/C# development environment and the ability to view programmed web pages through the programmer’s browser instantly. It also allows to program and run the application as many times as needed while accessing the output (the final product or interface) from a web browser. Microsoft SQL Server was chosen as the database solution. It offered all required database capabilities at a cost effective price. It is considered that if the system becomes widely used, additional software and security features can be integrated to enhance the database’s performance and guarantee protection of sensitive information.

3 Chapter: Industry Feedback and System testing

3.1 Industry Feedback

A total of 119 emails were sent out to industry professionals. Twenty four responses were received from the email send-out and from questionnaires posted in online forums (e.g., Linked-In). Figures 3.1 through 3.3 show some of the demographics of the respondents.

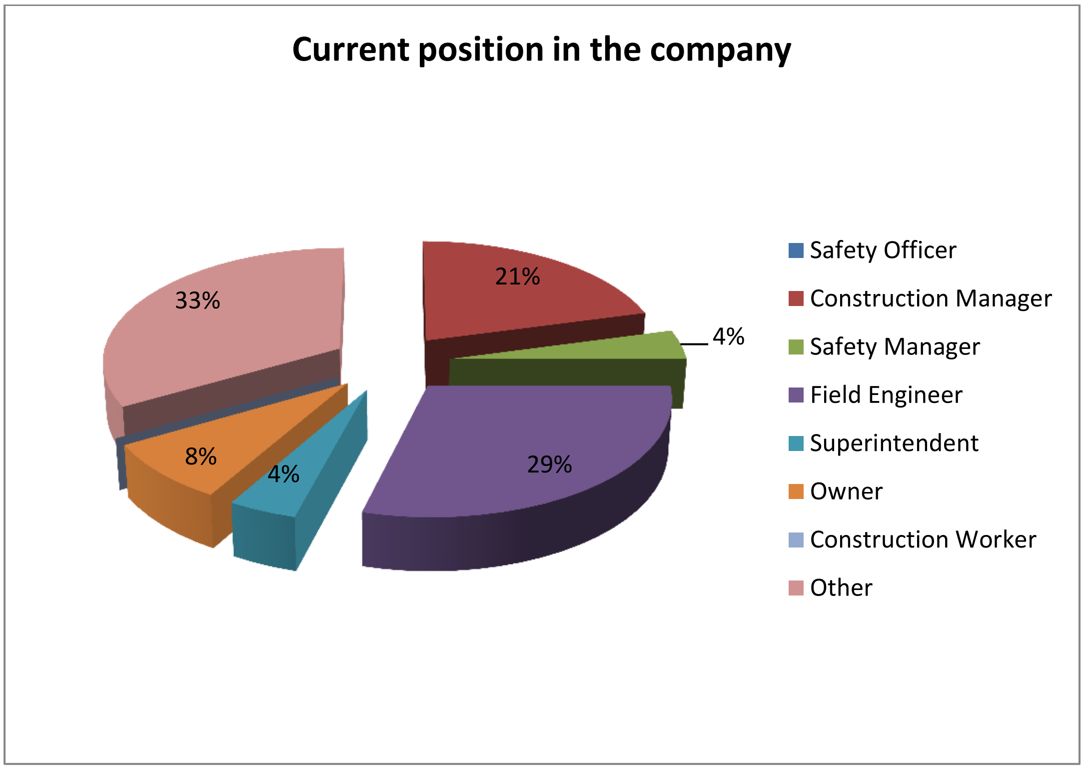


Figure 3.1. Industry questionnaire, question 1.1.

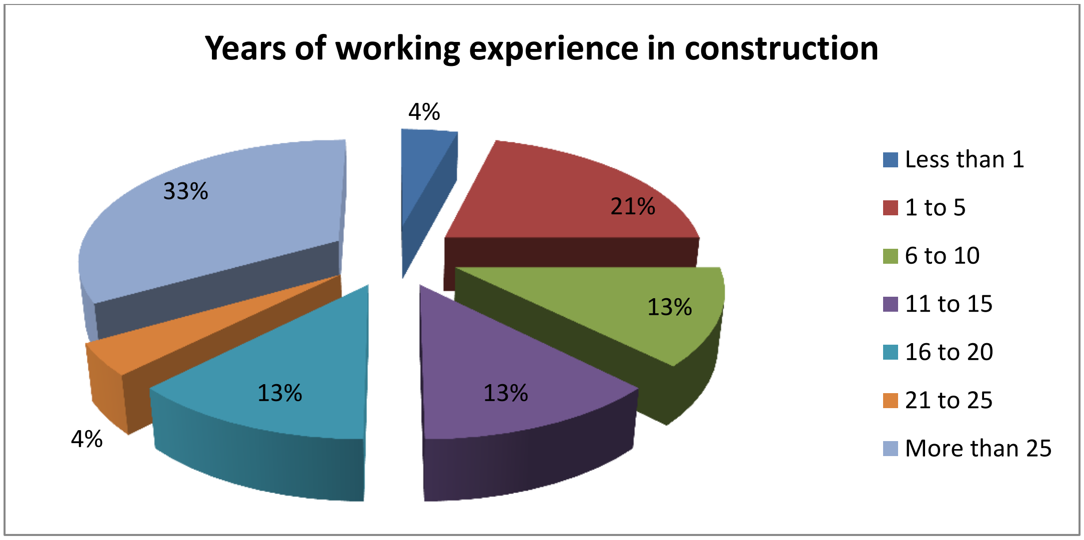


Figure 3.2. Industry questionnaire, question 1.2.

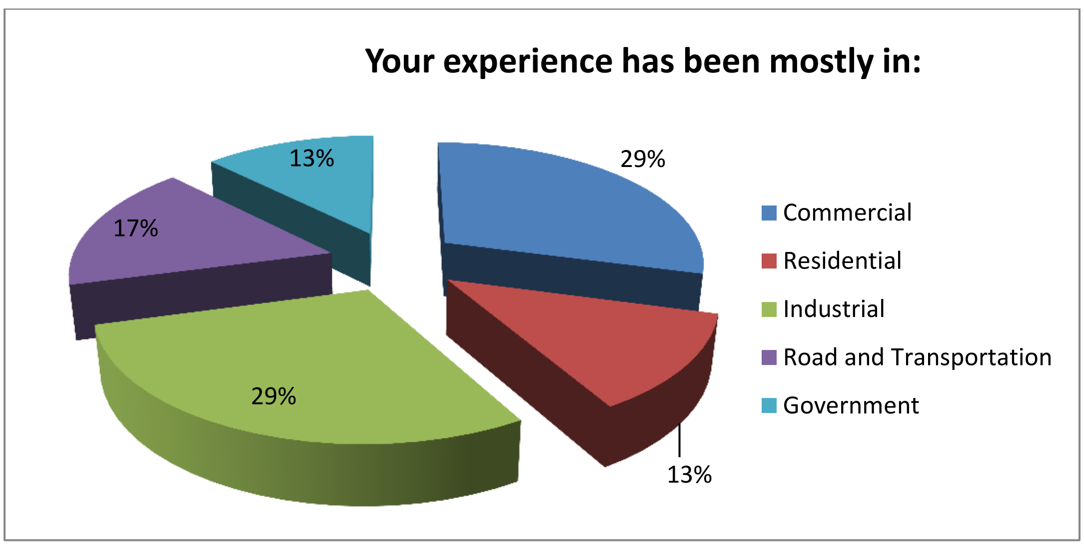


Figure 3.3. Industry questionnaire, question 1.5.

When asked for the probable cause of not implementing or using technology in the field, 41% of respondents selected the cost as the main reason, followed by 19% who selected the economic crisis as the main cause. See Figure 3.4.

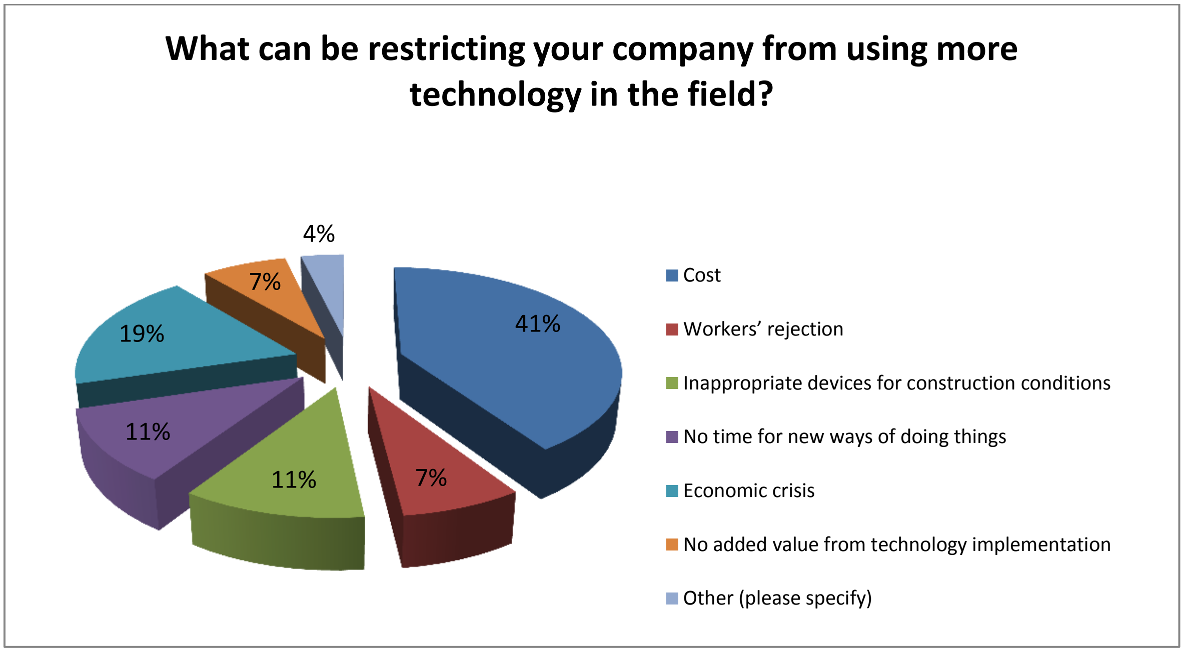


Figure 3.4. Industry questionnaire, question 2.4.

As shown in Figure 3.5, 83% of respondents agreed that having real-time project statistics would help them improve safety.

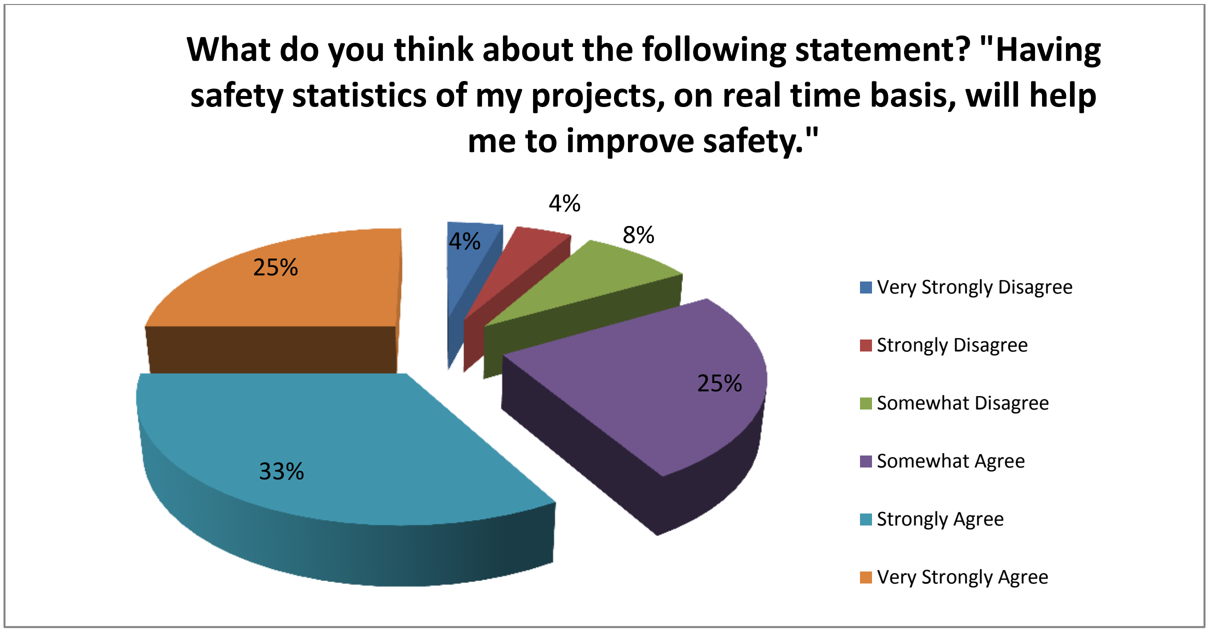


Figure 3.5. Industry questionnaire, question 3.8.

In terms of cost, 54% of respondents would implement a safety information system in their construction projects of no direct cost is attached to it, as shown in Figure 3.6.

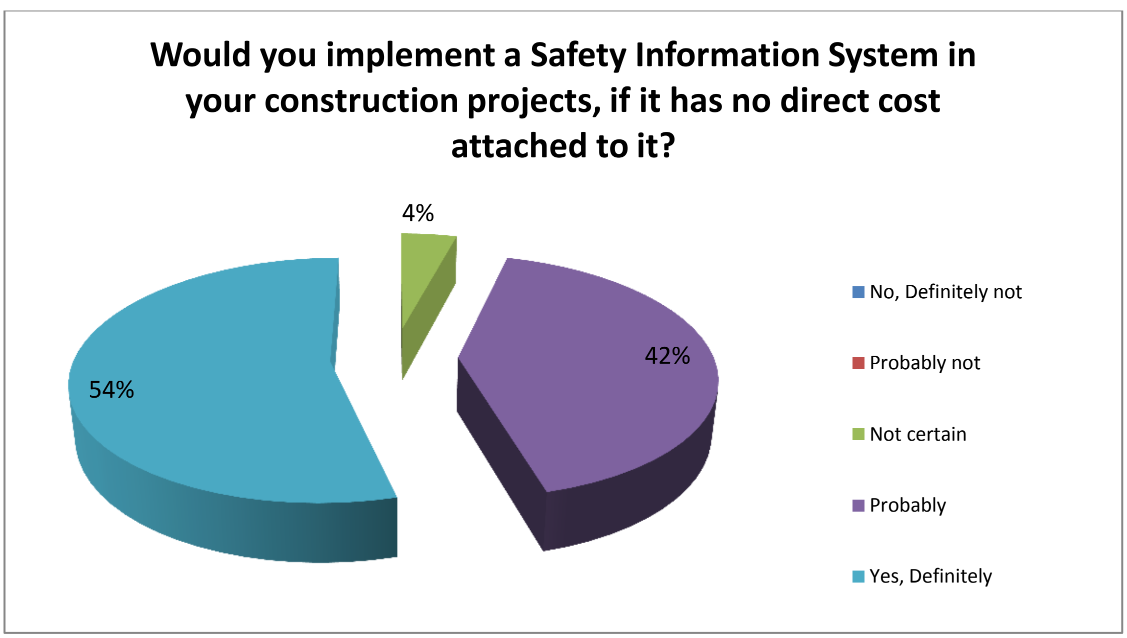


Figure 3.6. Industry questionnaire, question 3.9.

3.2 System Testing: Questionnaire 2a

As described in Chapter 2, a questionnaire was given to seven participants at the start of the system test. Participants took an average of 8 minutes to complete this first questionnaire. The results obtained for each question are included below. Researcher comments are included where considered pertinent.

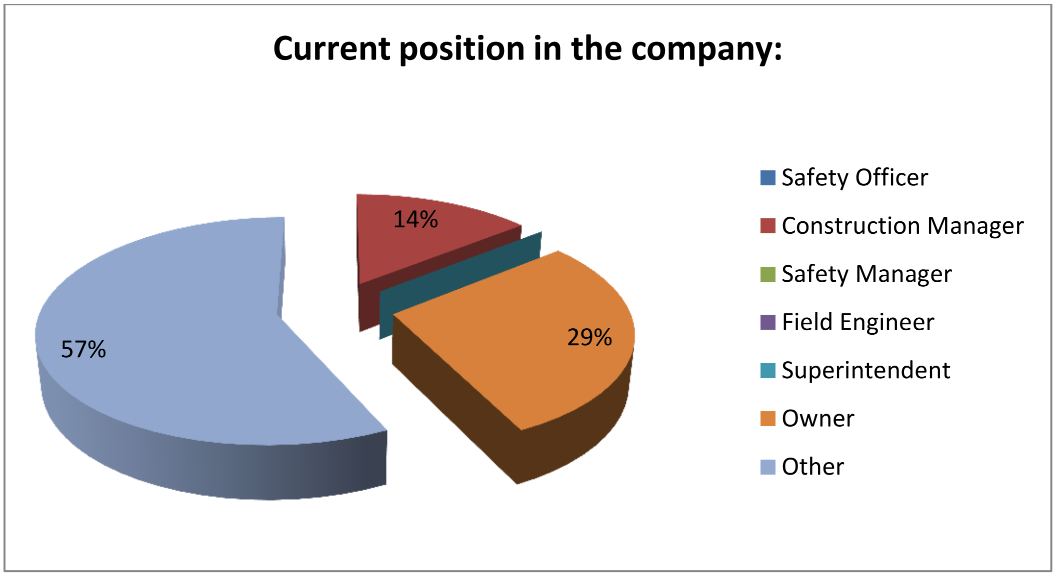


Figure 3.7. Questionnaire 2a, question 1.1.

As observed in Figure 3.7, 14% of respondents have performed the role of construction manager, 29% the role of company owner, and 57% have had roles in different areas within the construction projects.

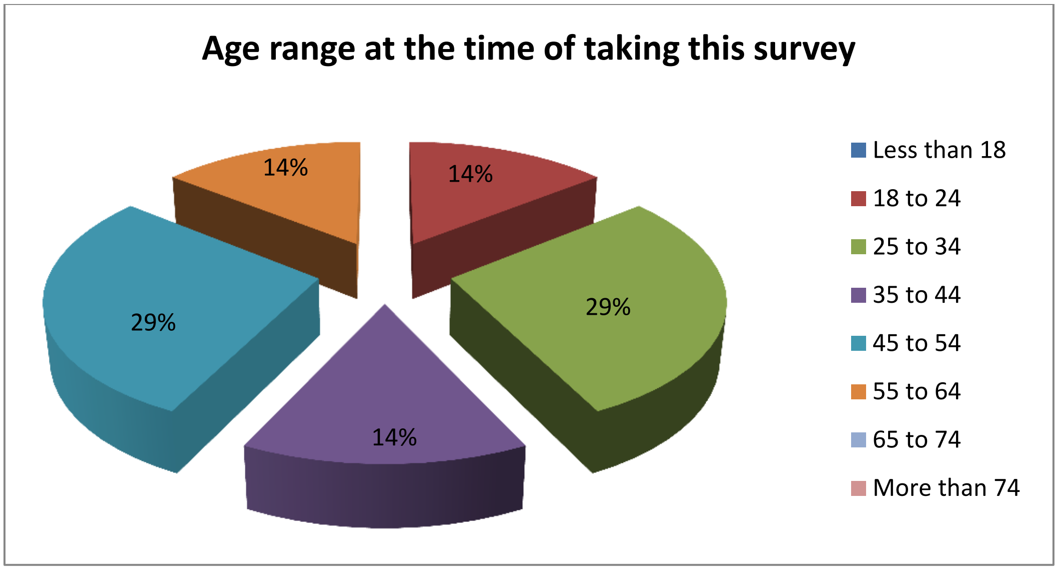


Figure 3.8. Questionnaire 2a, question 1.2.

The respondents covered a wide range of ages. The biggest representation, 29%, was for each one of the age groups of 25 to 34 and 45 to 54, as shown in Figure 3.8.

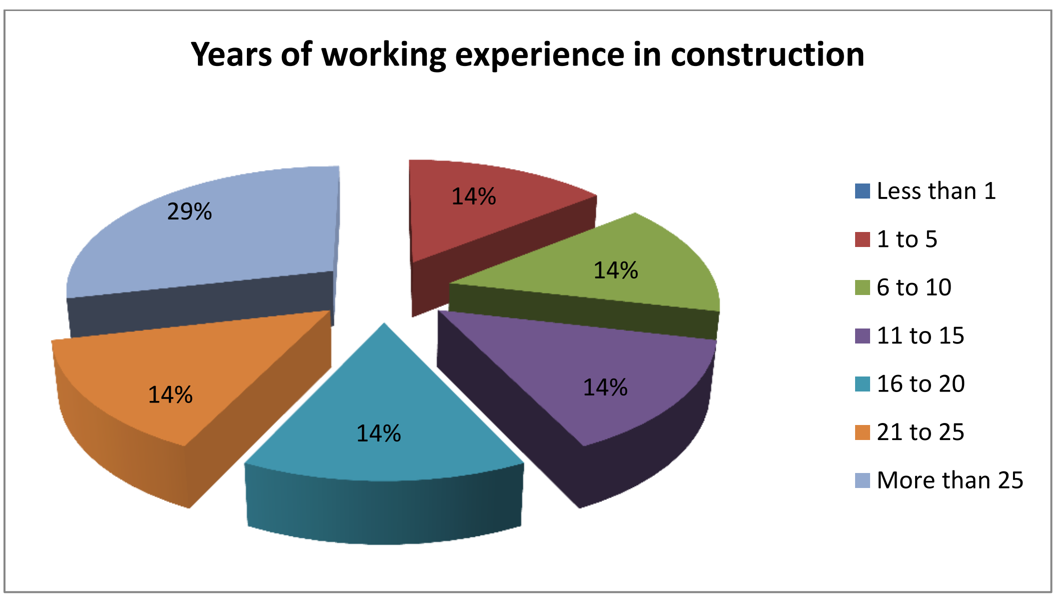


Figure 3.9. Questionnaire 2a, question 1.3.

As detailed in Figure 3.9, the highest representation was obtained from professionals with more than 25 years of experience in the construction industry. The remaining 71% was evenly distributed among the other experience groups. None of the respondents had less than 1 year of experience.

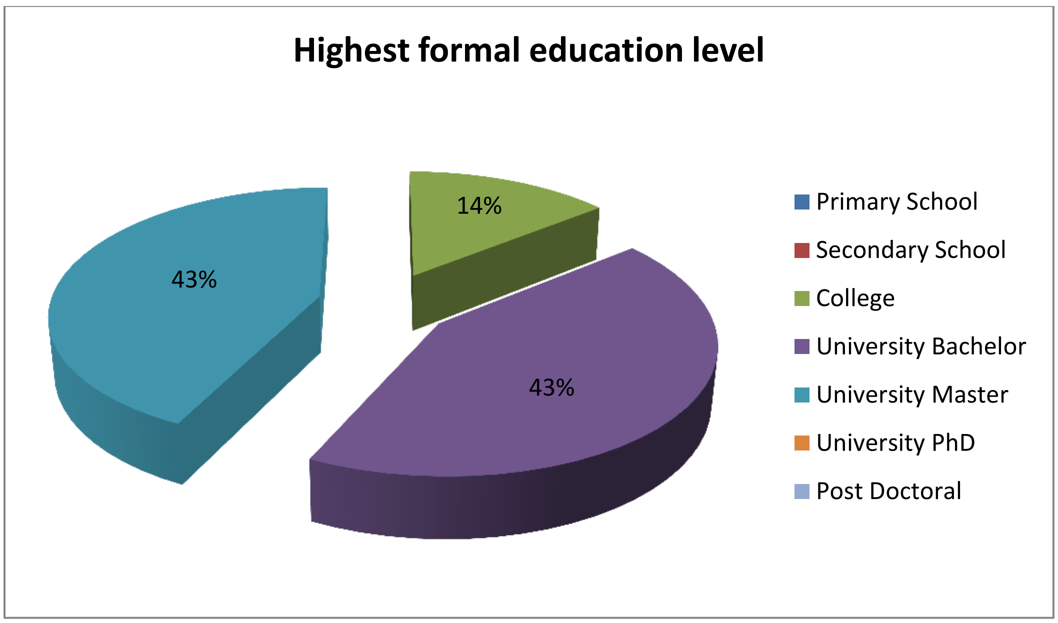


Figure 3.10. Questionnaire 2a, question 1.4.

Figure 3.10 includes information regarding the education level of the respondents. 43% of the respondents had a university bachelor's degree, 43% a university master, and 14% a college degree.

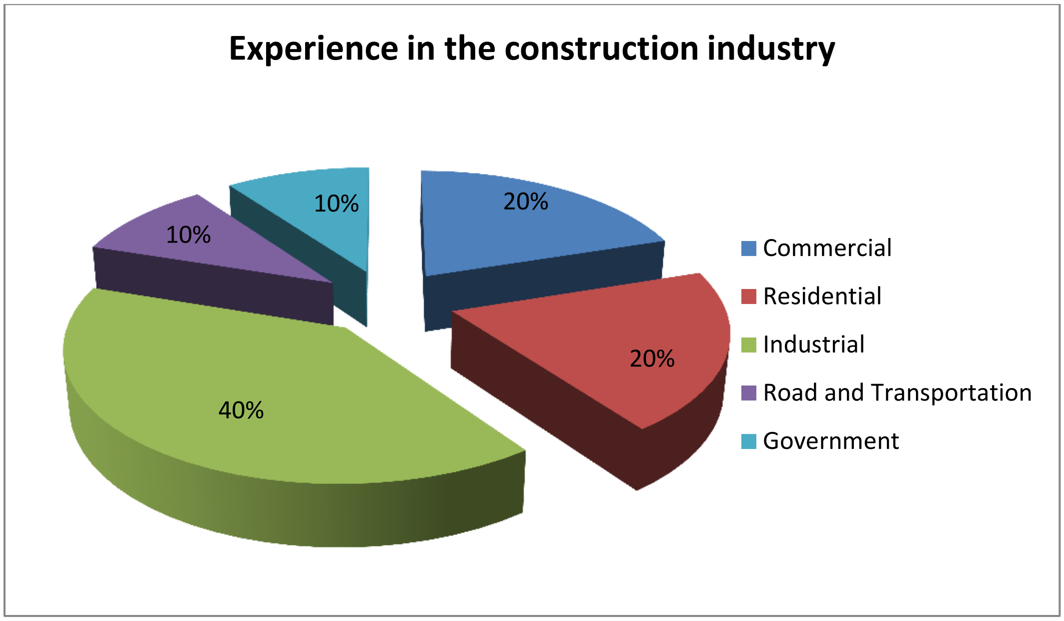


Figure 3.11. Questionnaire 2a, question 1.5.

In terms of experience in the construction industry, as shown in Figure 3.11, 40% of the respondents have had experience mostly in industrial construction projects, followed by residential and commercial projects, and government, road and Transportation projects.

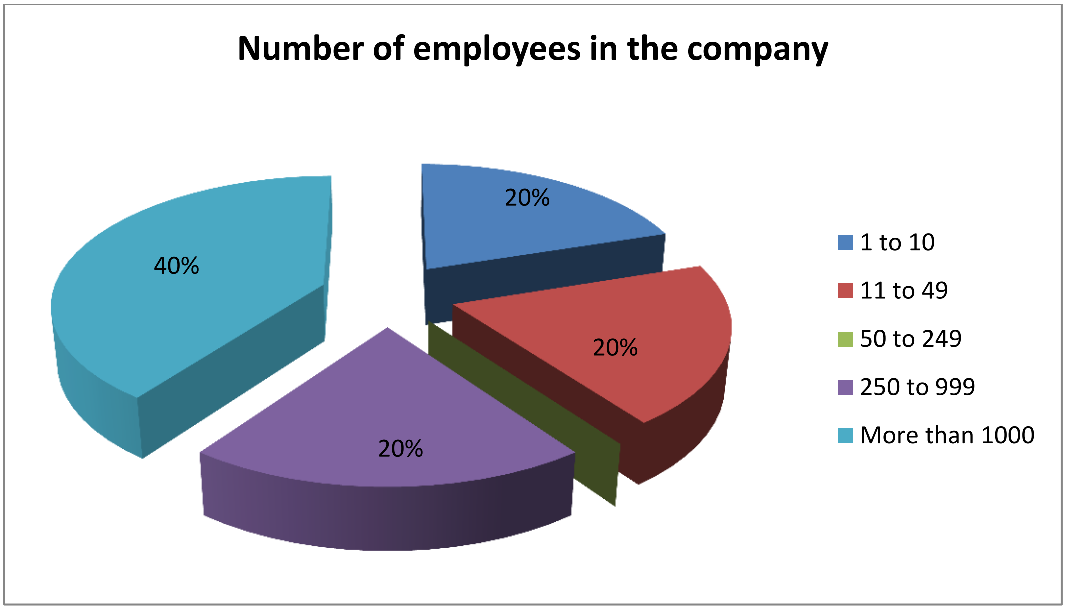


Figure 3.12. Questionnaire 2a, question 1.6.

As observed in Figure 3.12, none of the respondents were involved with companies having between 50 and 249 employees. 40% were involved with companies having more than 1000 employees, and 20% for each one of the remaining categories.

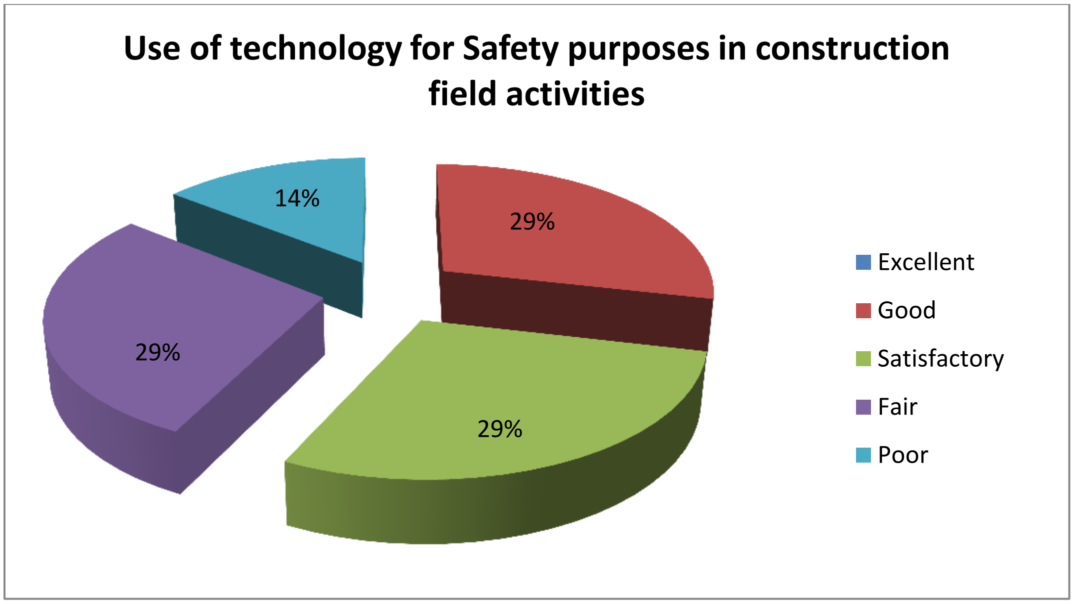


Figure 3.13. Questionnaire 2a, question 2.1.

Figure 3.13 details the respondents' criteria regarding the use of technology in construction field activities. 29% of respondents rated the use of technology for safety purposes in construction field activities as satisfactory, 29% as good, 20% as fair, and 14% as poor. None of the respondents rated the use of technology as excellent.

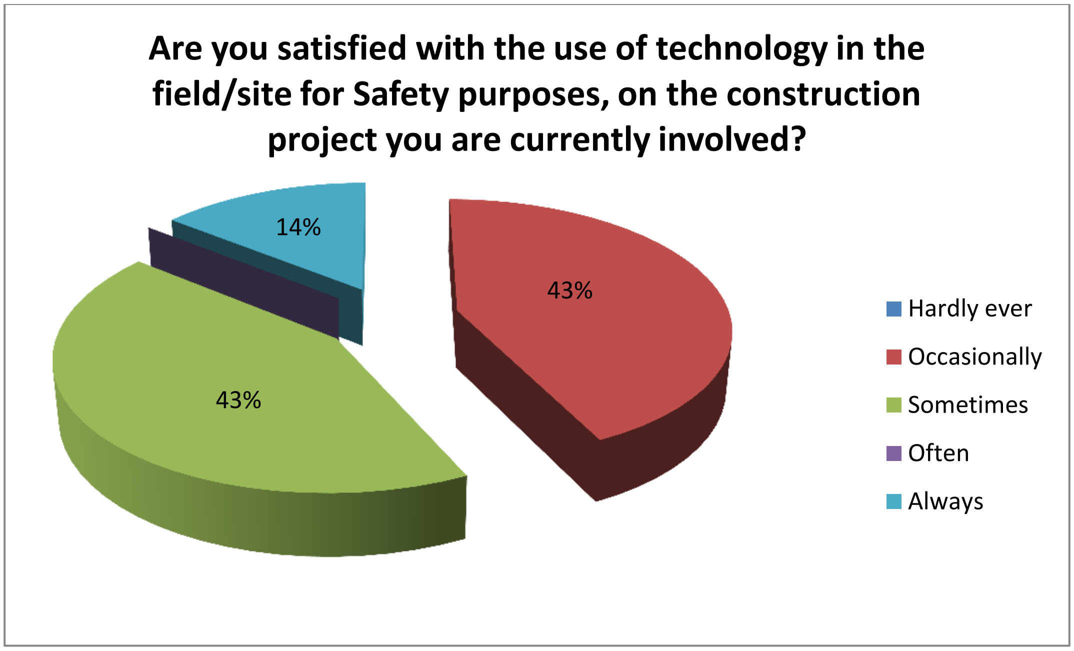


Figure 3.14. Questionnaire 2a, question 2.2.

In contrast to the previous answers, when asked if satisfied with the use of technology for safety purposes in the projects where currently involved, none of the respondents replied neither always satisfied nor often satisfied. Instead, 43% selected occasionally satisfied, 43% selected sometimes satisfied, and 14% hardly ever satisfied. See Figure 3.14.

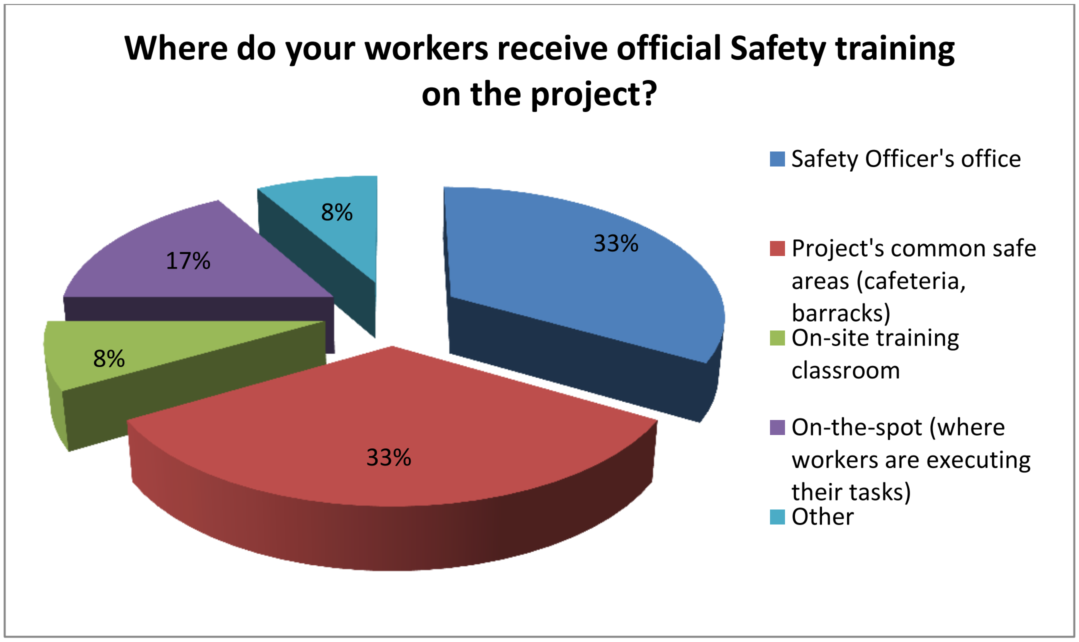


Figure 3.15. Questionnaire 2a, question 2.3.

Figure 3.15 shows the location where workers receive safety training within the construction project. The safety officer's office and the project's common areas were the areas where most respondents answered as the ones used for this purpose, followed by on-the-spot training with 17%, on-site training classroom, and other areas.

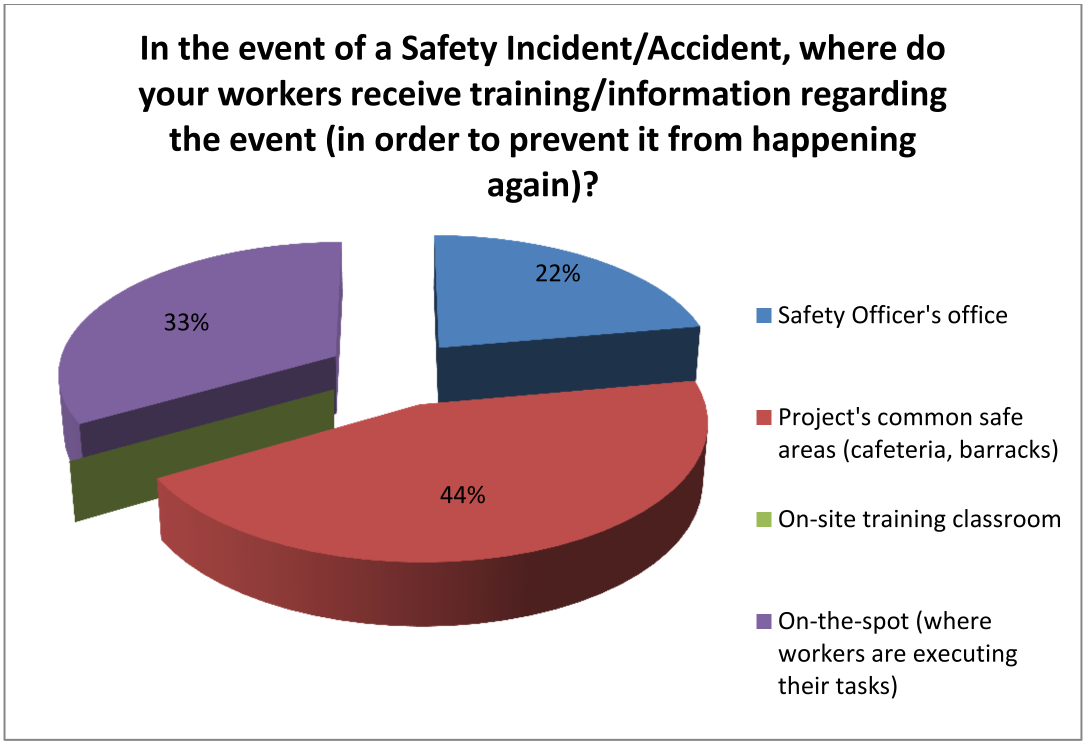


Figure 3.16. Questionnaire 2a, question 2.4.

In the event of an incident or accident, 44% of respondents selected the project's common areas as the ones used for training purposes, 33% selected on-the-spot training, and 22% selected the safety officer's office. See Figure 3.16.

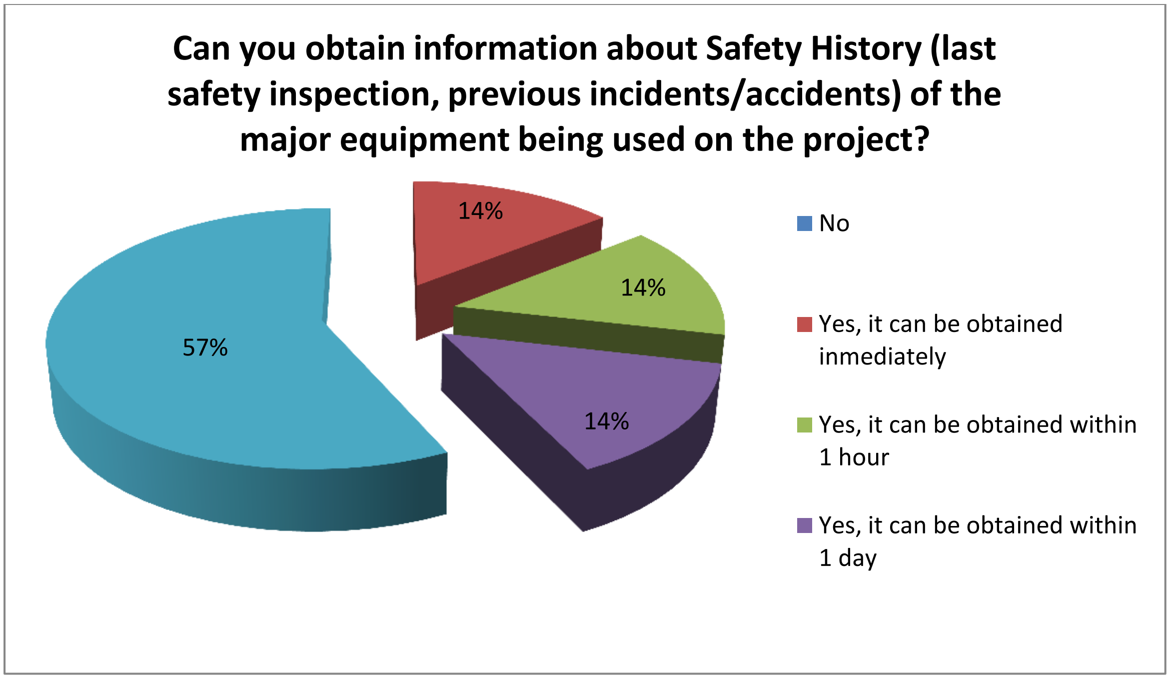


Figure 3.17. Questionnaire 2a, question 2.5.

As observed in Figure 3.17, 57% of respondents answered that it was possible for them to obtain information about safety history of the major equipment being used on the project, but at an unknown amount of time. 14% can obtain the information within 1 day, 14% within 1 hour, and 14% immediately.

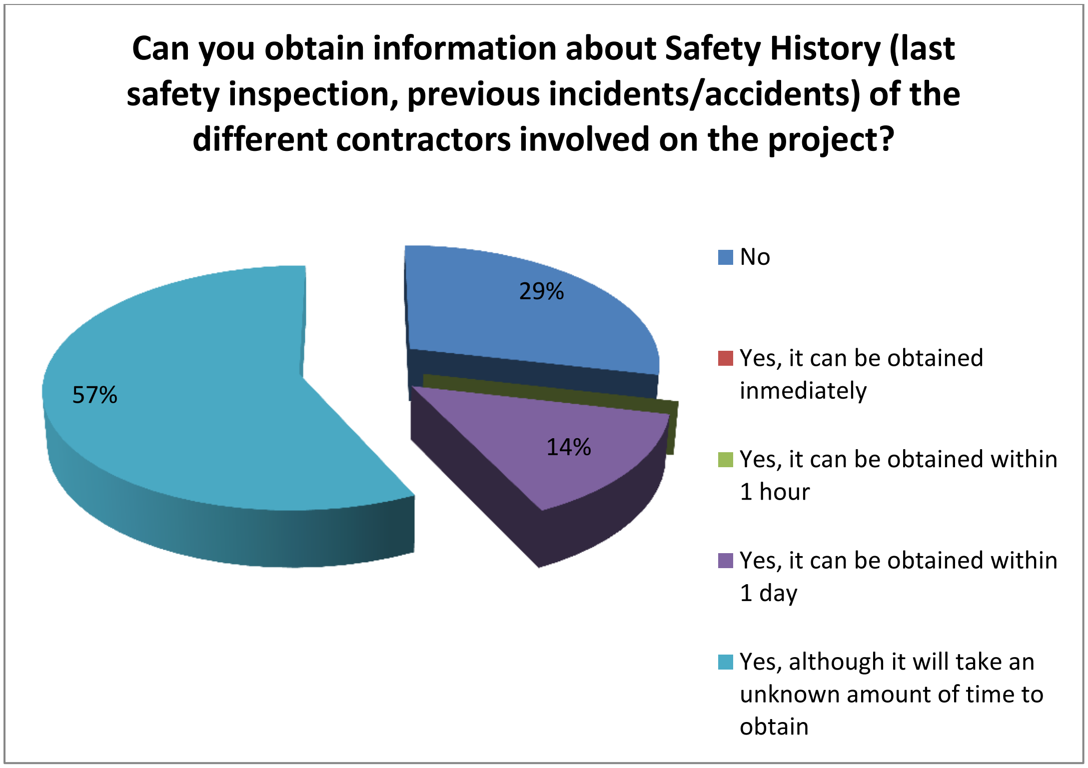


Figure 3.18. Questionnaire 2a, question 2.6.

57% of respondents answered that it was possible for them to obtain information about safety history of the different subcontractors involved on the project, but at an unknown amount of time. 14% can obtain the information within 1 day, and 29% can't obtain information at all, as shown in Figure 3.18.

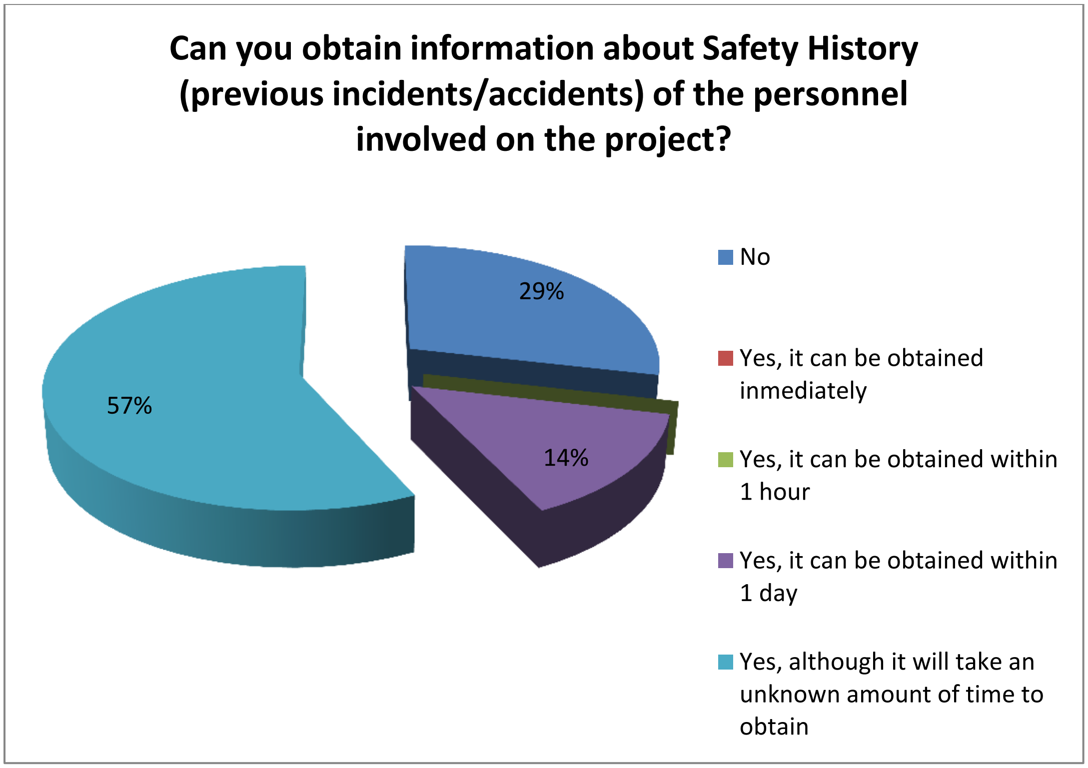


Figure 3.19. Questionnaire 2a, question 2.7.

The same trend obtained for subcontractors was obtained for personnel. As detailed in Figure 3.19, 57% of respondents answered that it was possible for them to obtain information about safety history of the personnel involved on the project, but at an unknown amount of time. 14% can obtain the information within 1 day, and 29% can't obtain information at all.

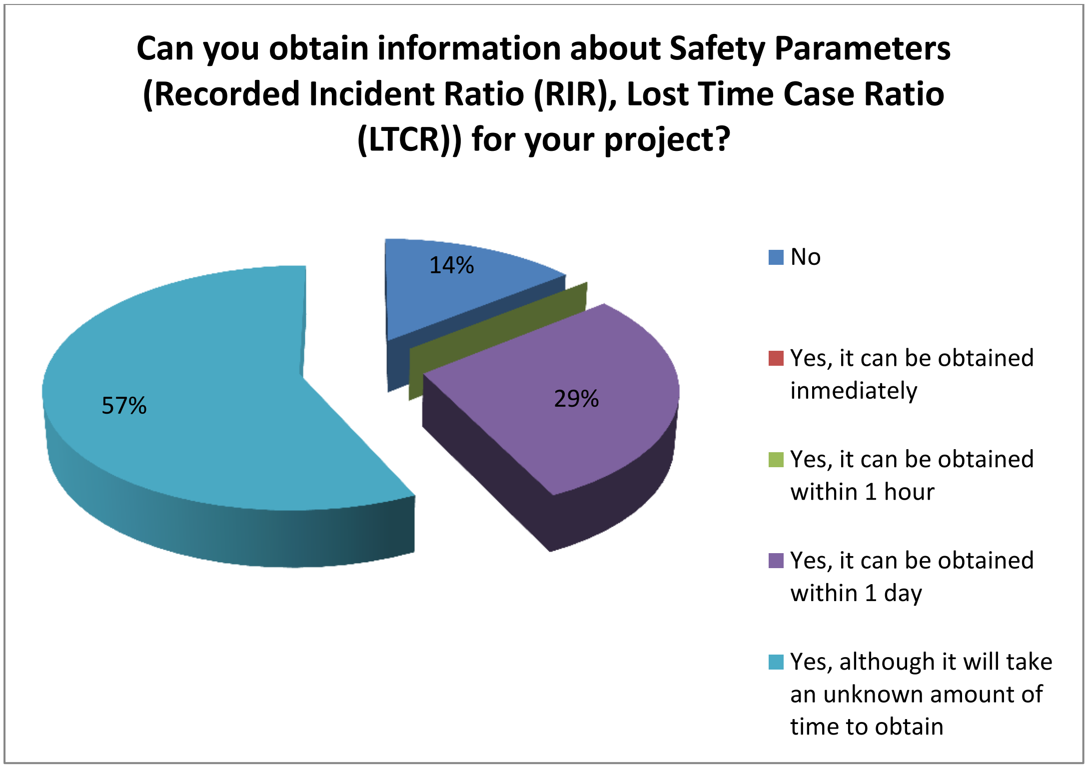


Figure 3.20. Questionnaire 2a, question 2.8.

A similar trend to that obtained for subcontractors and personnel was obtained for safety parameters. As observed in Figure 3.20, 57% of respondents answered that it was possible for them to obtain information about safety parameters of the project, but at an unknown amount of time. But in this case, 29% can obtain the information within 1 day, and 14% can't obtain information at all.

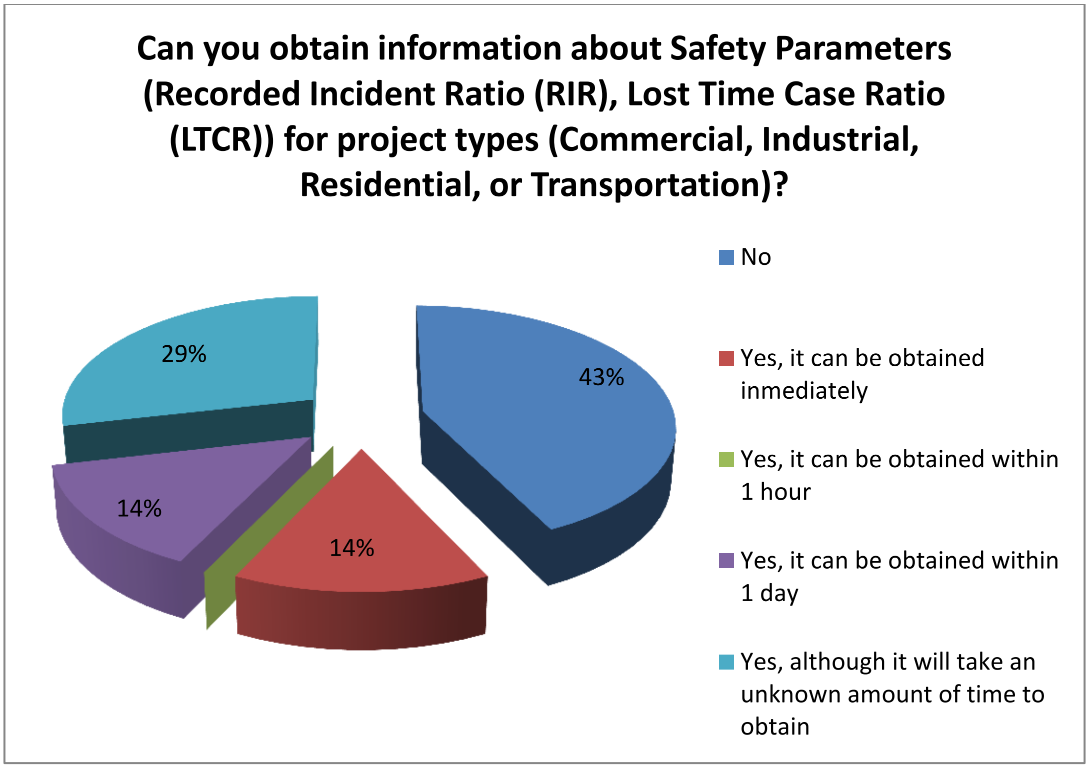


Figure 3.21. Questionnaire 2a, question 2.9.

As shown in Figure 3.21, 43% of respondents cant' obtain safety parameters for project types, 29% can obtain them but at an unknown period of time. 14% can obtain them within one day, and 14% can obtain them immediately.

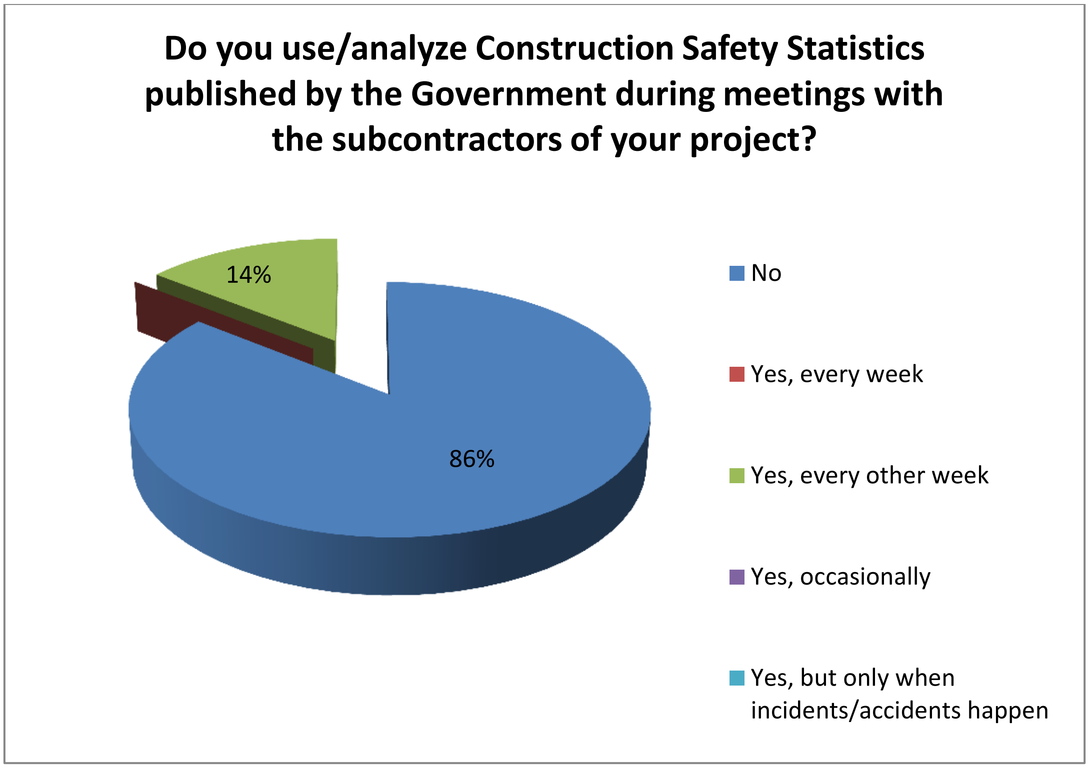


Figure 3.22. Questionnaire 2a, question 2.10.

86% of respondents do not use construction safety statistics published by the government during meetings with subcontractors, and 14% use them during meetings every other week, as observed in Figure 3.22.

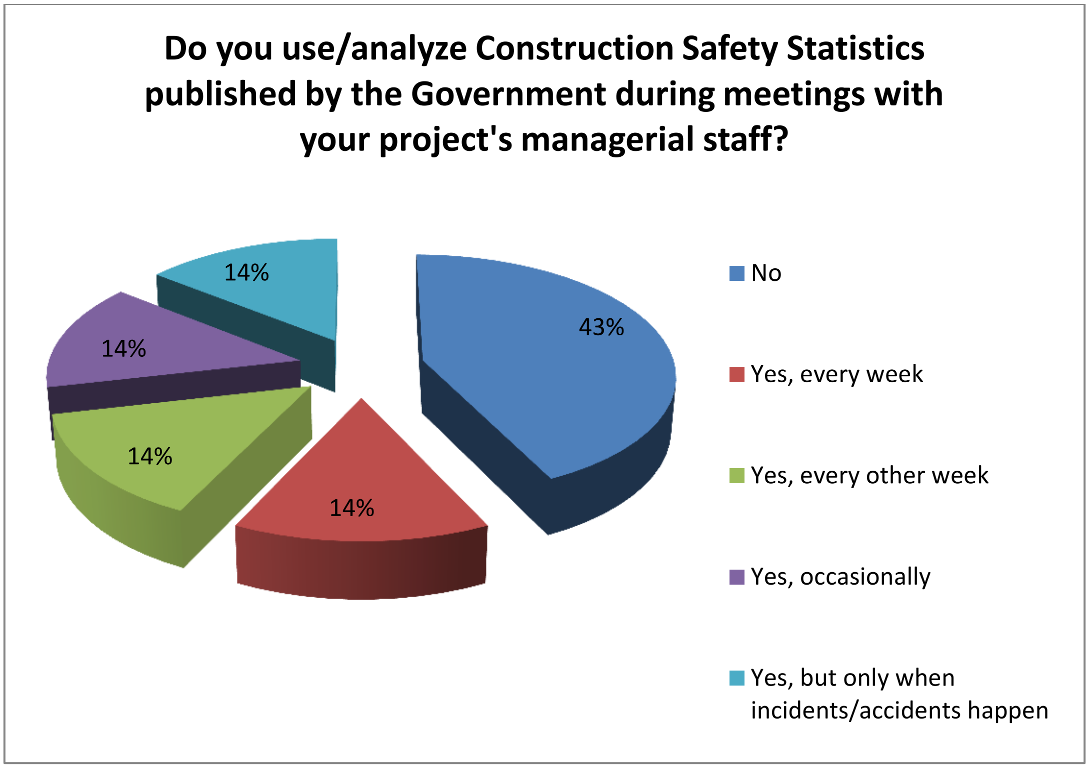


Figure 3.23. Questionnaire 2a, question 2.11.

As shown in Figure 3.23, 43% of respondents do not use construction safety statistics published by the government during meetings with the project's managerial staff. 14% use them during meetings every other week, 14% occasionally, and 14% every week.

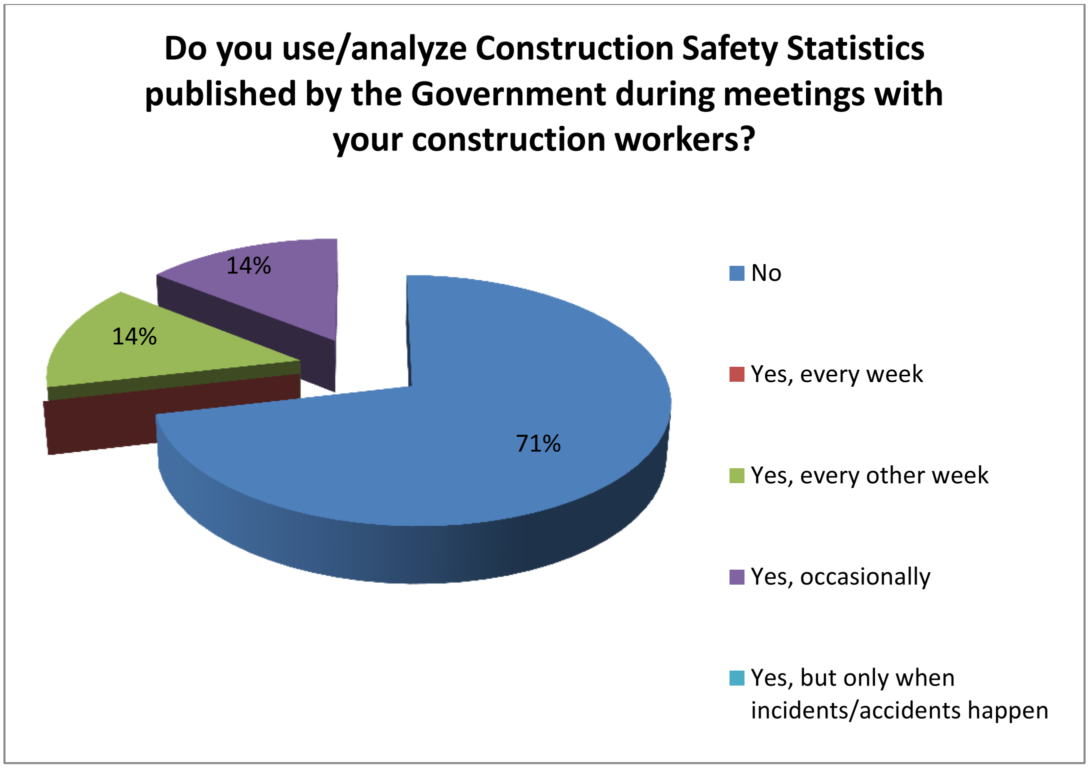


Figure 3.24. Questionnaire 2a, question 2.12.

71% of respondents do not use construction safety statistics published by the government during meetings with construction workers, 14% use them during meetings every other week, and 14% occasionally, as observed in Figure 3.24.

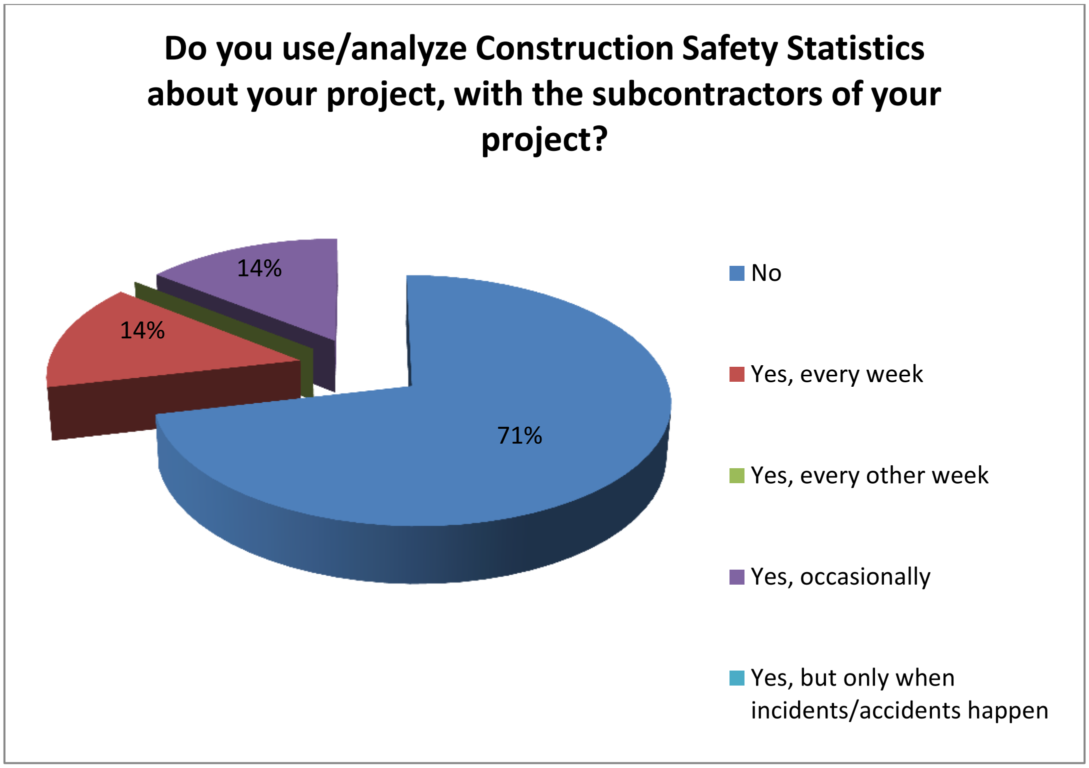


Figure 3.25. Questionnaire 2a, question 2.13.

71% of respondents do not use or analyze construction safety statistics about the project with the project's subcontractors, 14% use them during meetings every week, and 14% use them occasionally, as observed in Figure 3.25.

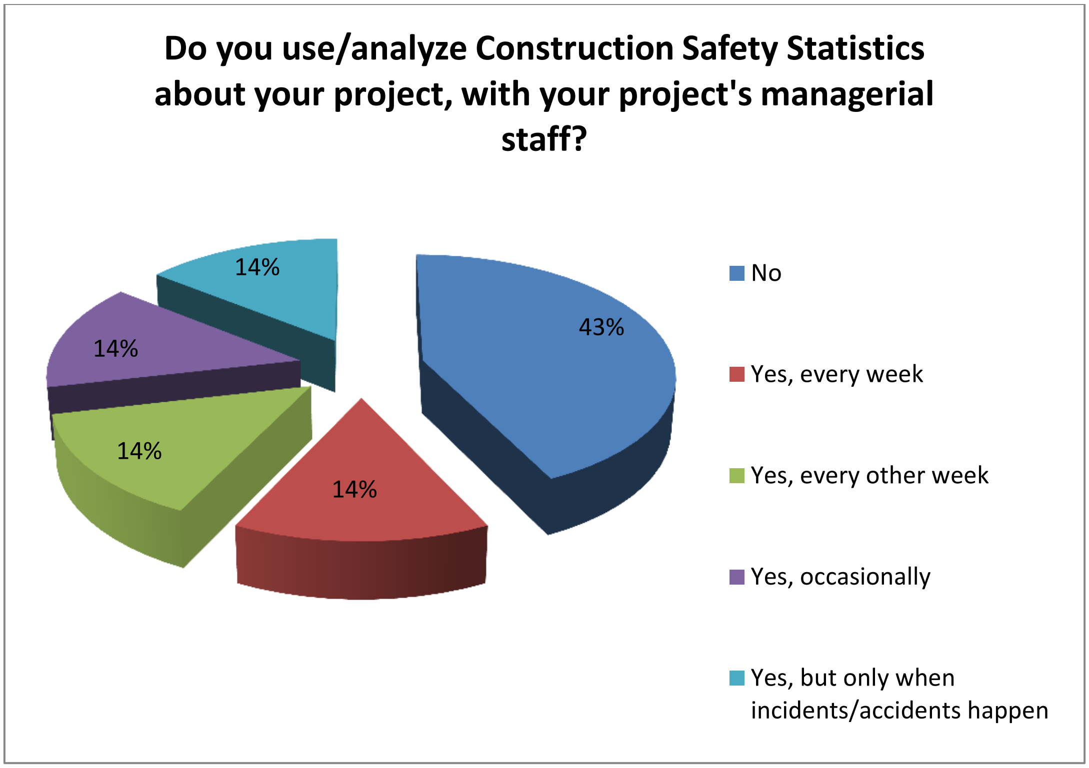


Figure 3.26. Questionnaire 2a, question 2.14.

43% of respondents do not use construction safety statistics about the project with the project's managerial staff. 14% use them during meetings held every week, 14% use them occasionally, 14% use them every other week, and 14% use them only when an incident or accident occurs. See Figure 3.26.

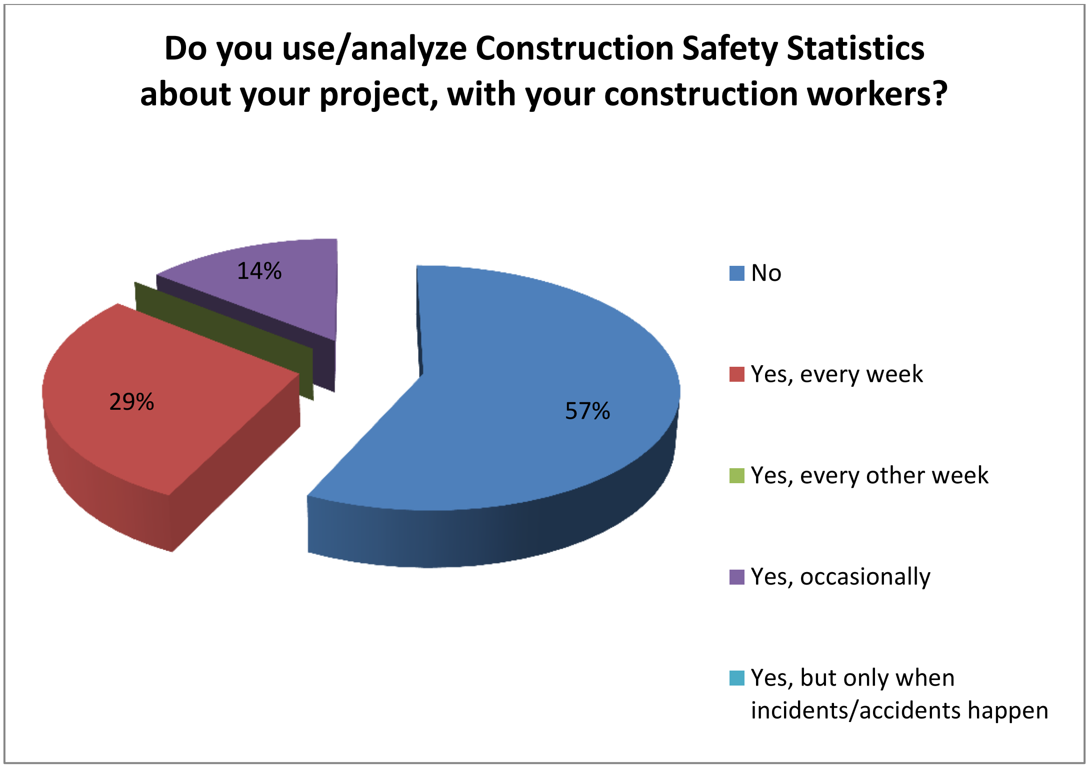


Figure 3.27. Questionnaire 2a, question 2.15.

57% of respondents do not use construction safety statistics about their project with the project's construction workers. 14% use them occasionally, and 29% use them every week, as observed in Figure 3.27.

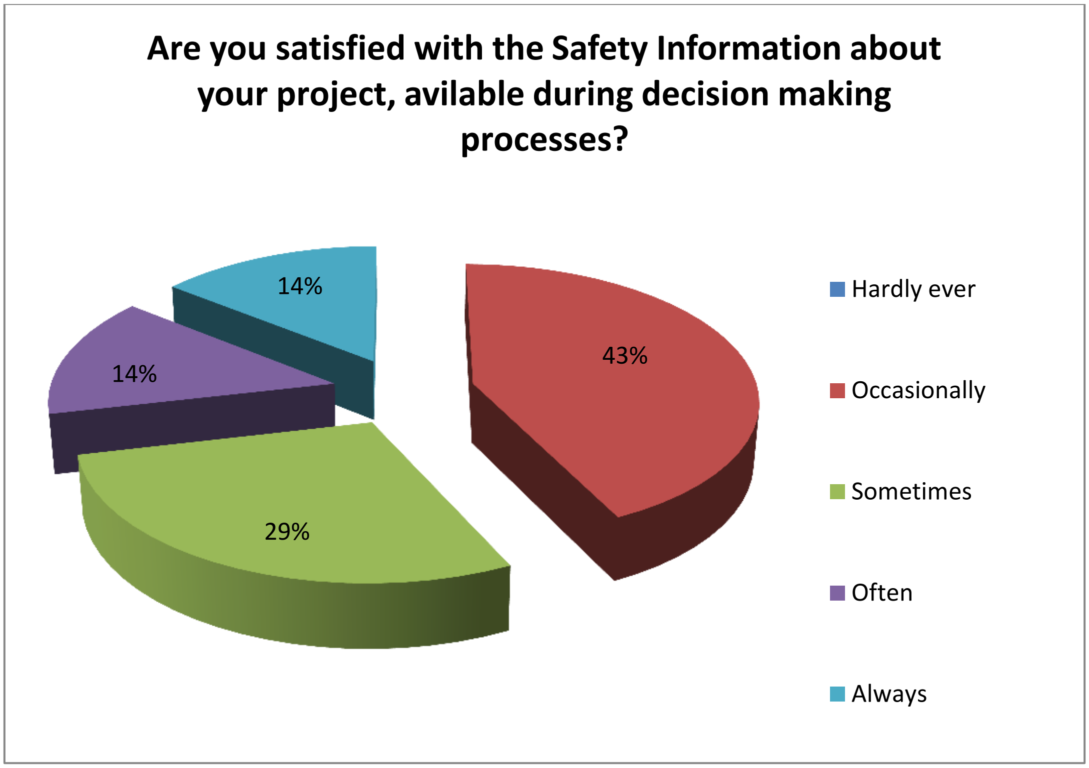


Figure 3.28. Questionnaire 2a, question 2.16.

43% of respondents are occasionally satisfied with the safety information made available during decision making processes. 29% are sometimes satisfied, 14% are often satisfied, and 14% are always satisfied. See Figure 3.28.

3.3 System testing: Powerpoint ™ presentation and software interaction

A Powerpoint ™ presentation was presented to participants after completing the first questionnaire. The presentation length ranged from 33 minutes to 1 hour and 5 minutes, with an average time of 45 minutes. Variation in presentation length was based on the amount of questions asked by participants. Participants were allowed to ask questions at any time during the presentation, as the intention of this part of the test was to provide them with a good understanding of the proposed system. A copy of the presentation delivered to the subjects is included in Appendix D .

After the presentation, participants were allowed to test the system at its current development stage. A fictitious event (e.g., an incident, accident or safety observation) was given to the subjects for them to input it into the system. Once submitted, the subjects were asked to access the data output section of the system to obtain a report. Additional questions from participants and further system interaction and testing were allowed as required.

3.4 System Testing: Questionnaire 2b

Questionnaire 2b was given to the participants after the system interaction was finished. Completing this final questionnaire took an average of 3 minutes to complete. The subjects were requested to assume a scenario where the proposed system had been already implemented and operational in a construction site. Answers and researcher comments to each question are included in the following sections.

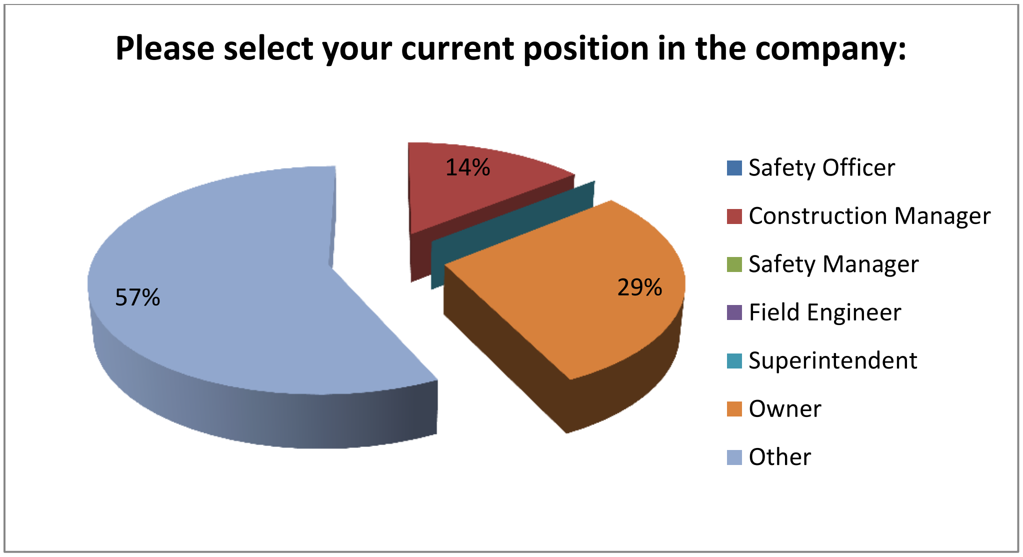


Figure 3.29. Questionnaire 2b, question 1.1.

Question 1.1 of questionnaire 2a was asked again with two purposes: 1) to verify the answers giving at the beginning of the test, and 2) to allow independent analysis of each questionnaire (and possible correlations) in future research. No difference was obtained after comparing these answers to the answers obtained for question 1.1 in questionnaire 2a. See Figures 3.7 and 3.29.

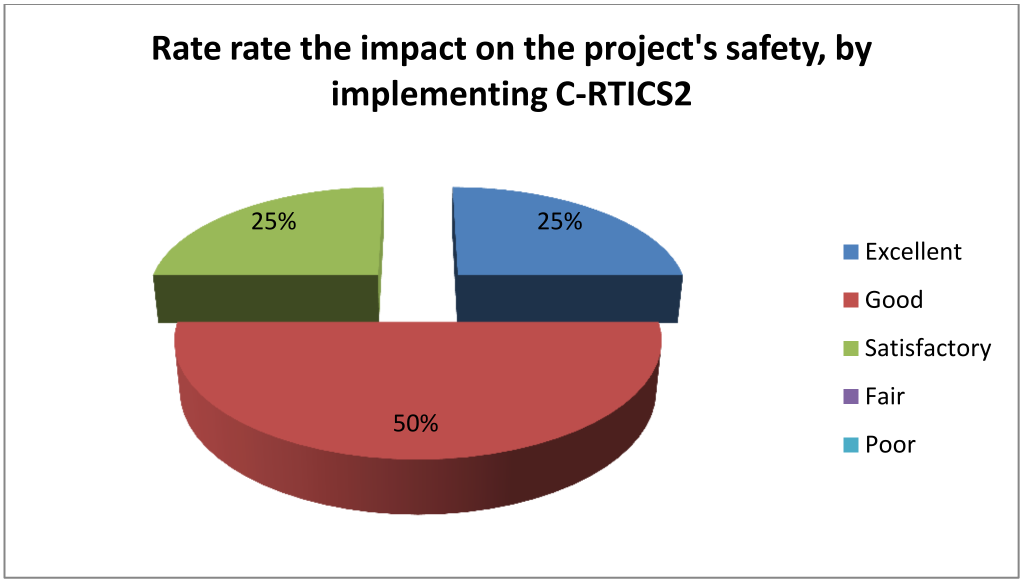


Figure 3.30. Questionnaire 2b, question 2.1.

50% of participants considered the impact of implementing C-RTICS^2 as good, 25% as satisfactory, and 25% as excellent, as shown in Figure 3.30.

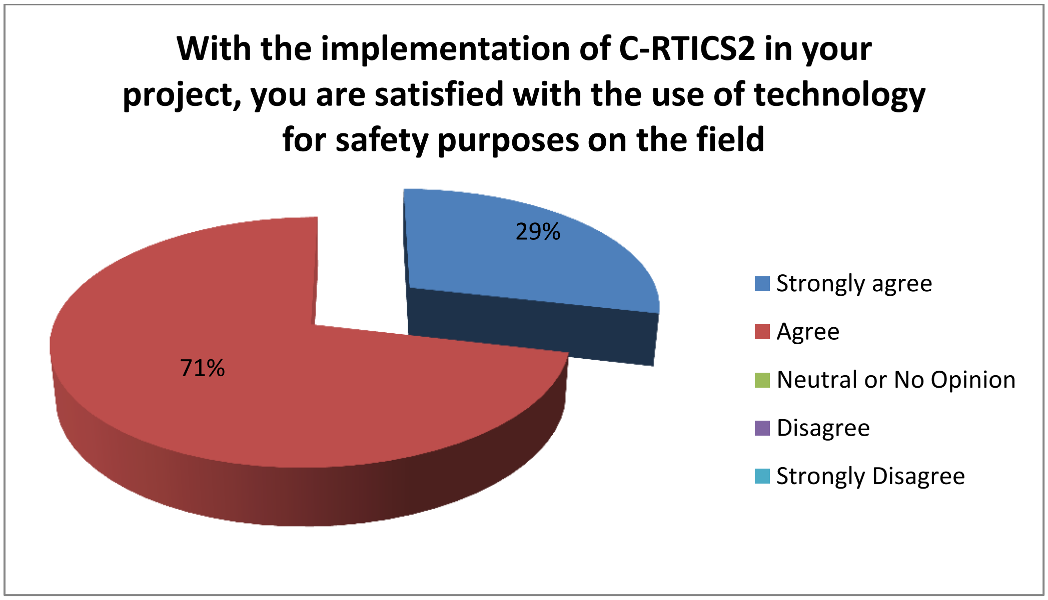


Figure 3.31. Questionnaire 2b, question 2.2.

As observed in Figure 3.31, given the stated argument, 71% of participants agreed that they would be satisfied with the use of technology for safety purposes. 23% strongly agreed to the statement.

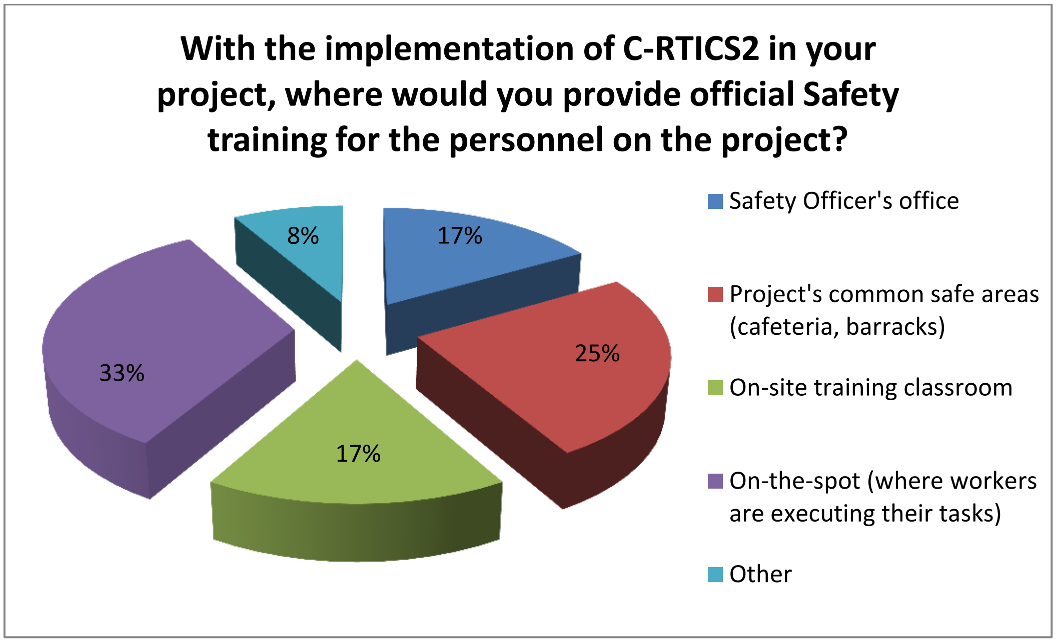


Figure 3.32. Questionnaire 2b, question 2.3.

By implementing C-RTICS^2, 33% of the participants would provide official safety training on-the-spot, 25% would provide it at the project's common areas, 17% at the on-site training classroom, 17% at the safety officer's office, and 8% in other areas, as observed in Figure 3.32.

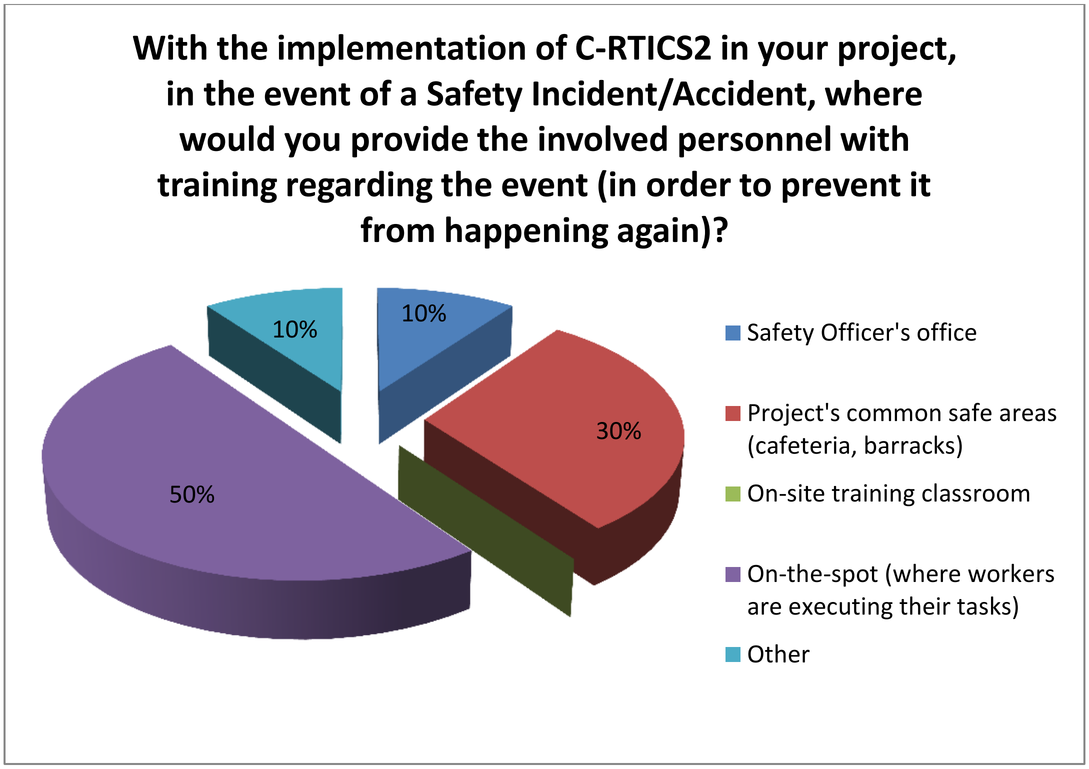


Figure 3.33. Questionnaire 2b, question 2.4.

As shown in Figure 3.33, in the event of a safety incident or accident, 50% of participants would provide on-the-spot training to the involved personnel, 30% would provide the training at the project's common areas, 10% at the safety officer's office, and 10% in other areas.

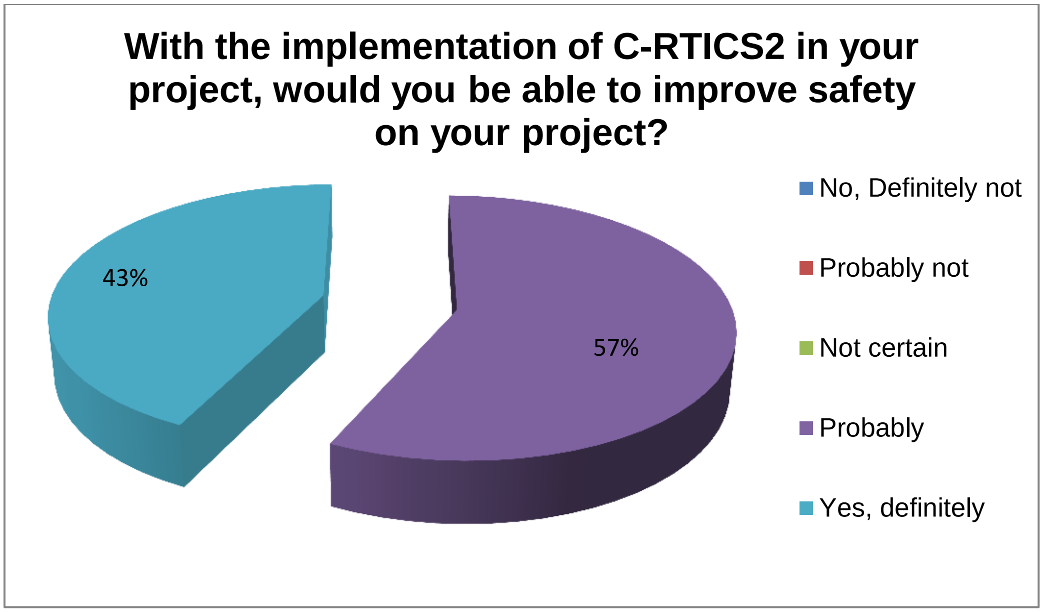


Figure 3.34. Questionnaire 2b, question 2.5.

57% of participants answered they would probably be able to improve safety in their projects by implementing C-RTICS^2, 43% answered they would definitely be able to improve safety in their project by implementing C-RTICS^2, as shown in Figure 3.34.

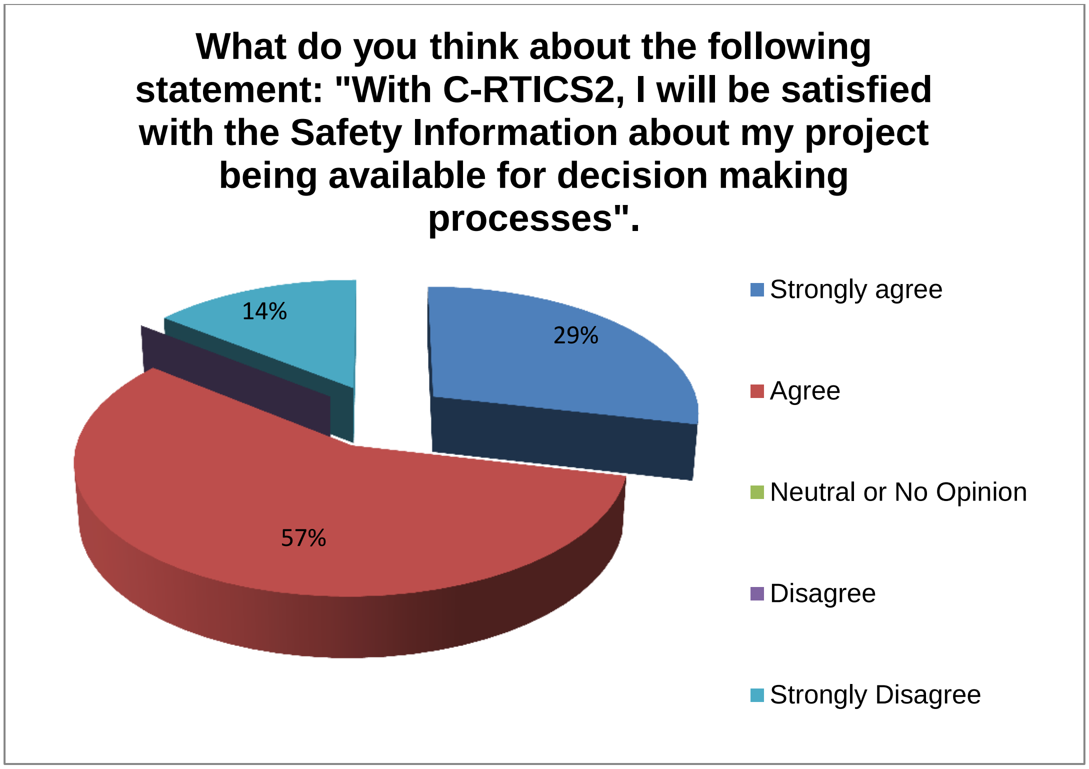


Figure 3.35. Questionnaire 2b, question 2.6.

As observed in Figure 3.35, 57% of participants agreed with the statement that they will be satisfied with the safety information about their projects available for decision making processes by using C-RTICS^2. 29% strongly agreed to that statement, and 14% strongly disagreed.

3.5 System Testing: Questionnaires analysis

As shown in Figure 3.36, on-the-spot training showed a dramatic increase and obtained the highest preference as the location where safety training would be provided after the implementation of C-RTCS^2, changing from 17% in questionnaire 2a, to a 33% in questionnaire 2b. This represents a 100% increase from a scenario under current practice, to a scenario where C-RTICS^2 had been implemented. At the same time, training at traditional locations (safety officers; office and project's common areas) decreased respectively. This result represents a confirmation of the potential benefit of the training module contained within the proposed system, and the portability of the real-time H&S information achieved by using portable projectors.

Figure 3.36. Training location before and after the implementation of C-RTICS^2.

The acceptance of the on-the-spot training future is confirmed by the responses given by the subjects in the event of an incident/ accident. As shown in Figure 3.37, on-the-spot training showed a dramatic increase and obtained the highest preference, changing from 33% in questionnaire 2a, to a 50% in questionnaire 2b. This represents a 50% increase from a scenario under current practices, to a scenario where C-RTICS^2 had been implemented. Training at traditional locations (safety officers; office and project's common areas) decreased respectively.

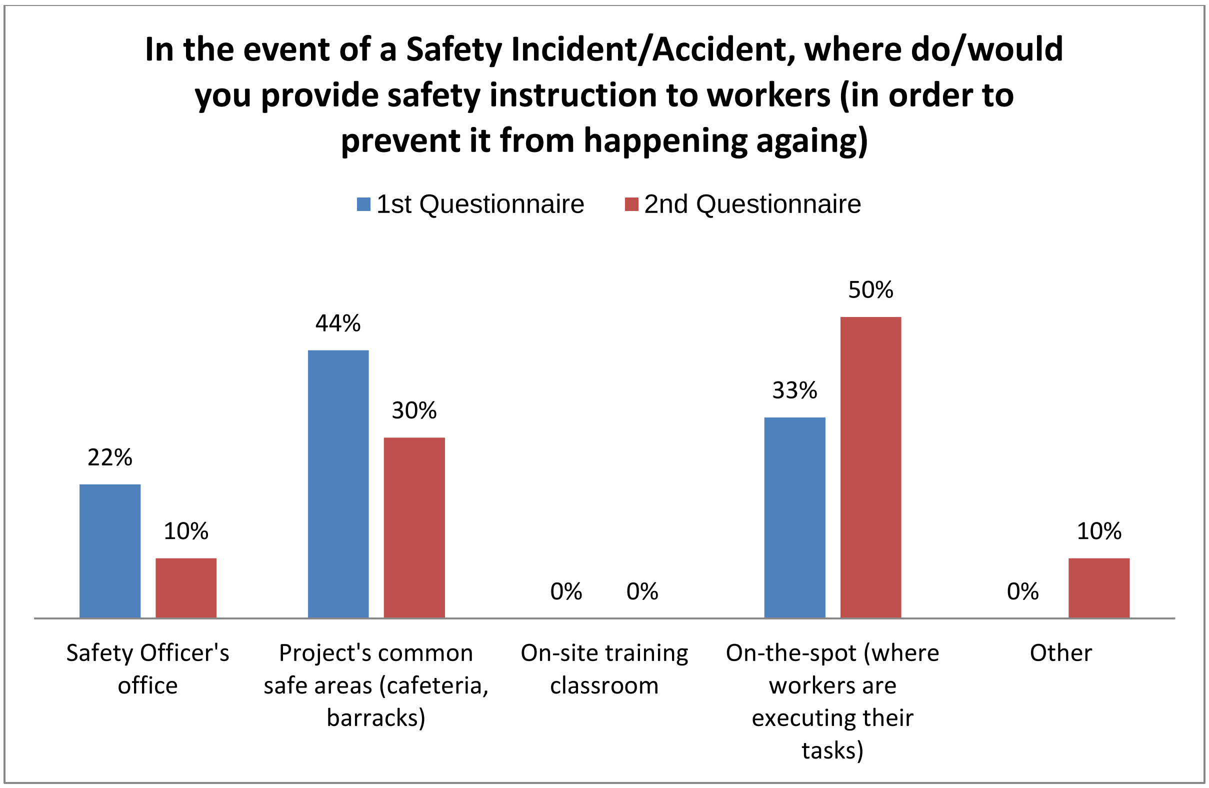


Figure 3.37. Training location after an incident/accident, before and after the implementation of C-RTICS^2.

4 Chapter: Conclusions and Future Research

Even as extensive research has been developed in the areas of construction safety and the use of technology in construction projects, the trend of injured workers and fatalities on a yearly basis have not decreased dramatically since the year 2000 in BC's CI. In general, the CI is one of the most hazardous industries among all industries. This reality applies not only to BC's CI but to the remaining provinces in Canada.

The proposed construction real-time information and communication system for safety (C-RTICS2) can provide the starting point for the CI to become a safer industry. Among the features of the proposed system, is the possibility to obtain real-time statistical information on a project by project basis and for different project types (e.g., commercial, industrial, residential and transportation). This compared to the actual scenario where safety statistics are available only on a company by company basis. 84% of respondents from a questionnaire sent out to industry professionals agreed to some level to the statement that having safety statistics about their projects would help them improve safety.

Profit based software companies have developed solutions to monitor and manage the safety component of construction companies and projects at various levels. These solutions have been in the market for many years already, but yet, BC's CI keeps injuring an average of 16,000 workers and killing an average of 33 on a yearly basis. License costs, commonly charged on an annual basis, may be restricting construction companies from actively using them to improve safety in their projects. The need for a free of charge safety management system to be massively implemented by construction companies is greater than ever.

Feedback from industry professionals confirmed that cost is one of the main elements restricting companies from using more technology in the field, followed by the economic crisis, which in turn is somehow related to the cost component. Additionally, industry professionals confirmed that removing the cost component of a given safety management system would lead them to implement the system in their projects.

Results from a one on one sessions with industry professionals indicate that implementation of the proposed system would positively impact safety in their projects. Furthermore, implementing C-RTICS^2 would have them satisfied with the use of technology for safety purposes.

Field accessibility to the system would increase on-the-spot training and instruction by 16%, while reducing instruction in traditional areas such as training classroom, project’s common areas, and safety officer’s office. In the event of a safety incident or accident in the project, on-the-spot training would increase by 17%.

C-RTICS^2 can be easily implemented in other provinces in Canada or other countries where internet access is available at construction sites (a common resource in today’s globalized markets). Translation to other languages can be done to expand its use to other countries where English is not the official language, but where the need for improvement of H&S is equally important. Furthermore, modification of the data fields contained within the coding of C-RTICS^2 can be done to fit the needs of other industries. This opens the possibility of implementing the system into the Manufacturing (M-RTICS^2), Transportation (T-RTICS^2), and Services (S-RTICS^2) industries. Positive impacts to society due to safer working environments may be possible in the short term.

4.1 Future research

Privacy and protection of information: A comment that came constantly during presentations of the proposed system at various instances (both academic and industry related), was protection of information and privacy. Therefore, one of the challenges of the proposed system is to prove that incorporation of user clusters and user types will protect sensitive information from unauthorized access. Future research can focus on this aspect of the proposed system and generate enough information to strengthen the security protocols and the security component of the system.

Field testing: The preliminary version of the proposed system still requires testing under a real construction project scenario. This type of testing is essential to obtain feedback for various aspects of the project, including system and server performance, calculation of the RIR and LTCR, and users' access to various levels of information, among many others. Generation of field data and its corresponding analysis can produce a new level of information to present to potential sponsors for the proposed system to become a reality.

Multi company and multi project testing: Further research can perform testing of the system in multiple projects, a required step before testing the system in multiple companies. Wide-spread use of the system can start only when enough field testing is conducted and enough companies have had the possibility to see the real benefit of the proposed system.

Testing of the system in real construction projects will populate the database, providing the capability to identify root causes of H&S events. This information can be analyzed with current H&S information made available by regulatory bodies. Eventually, comparison of both sources can contribute to development of best practices within construction projects to reduce the amount of incidents, accidents and fatalities occurring on a yearly basis in BC's CI.

Real-time information pertaining safety indicators (RIR and LTCR), as well as historical information of these indicators throughout the life cycle of a construction project, can provide the capability to develop prediction models for specific construction types. These prediction models can facilitate the development of preventative planning oriented to reduce incidents, accidents and fatalities in construction projects.

Monitoring module: Development and implementation of the proposed monitoring module can provide information related to dynamic flow of environmental hazards within construction projects, and the possibility to mitigate potential exposures by construction workers. Furthermore, this module can provide the grounds to research on the productivity gain or loss obtained by a better communication between the projects' stakeholders, and the impact of having real-time information for decision making processes.

Industry-wide use: Industry-wide use of the proposed system is a key element for it to be a success. Without it, the database won't contain enough information to allow identification of unsafe practices. To accomplish a wide spread use of C-RTICS^2 two approaches can be used. One approach is to generate interest among enough construction companies to participate voluntarily in the project. Future research can be oriented towards developing a cost benefit analysis from a construction company perspective, and present that analysis and its conclusions to an audience with decision making power (e.g., construction chambers or construction associations). Another approach is to enforce the implementation of the system as a requirement from H&S regulatory bodies. A preliminary investment analysis is included in 1.1.1.1.1Appendix A of this thesis. This analysis can be used as the starting point for future research oriented towards obtaining sponsorship from regulatory bodies and the possibility to enforce the use of the system in the CI.

Bibliography

Accupoint Software. < http://www.accupointsoftware.com/safety.htm > (Nov. 11, 2010).

Association of Workers Compensation Boards of Canada (AWCBC) (2012). National Work Injury, Disease and Fatality Statistics Publication. “Table 15. Number of Accepted Time-Loss Injuries, by Industry and Jurisdiction, 2008-2010”. <http://www.awcbc.org/common/assets.nwisptables/table15-lti-ind-jur.pdf> (Aug. 17, 2012).

Bank of Canada. 2010. “Canadian interest rates and monetary policy variables: 10- year look up. Prime Corporate Paper Rate, V122509 ”. <http://www.bankofcanada.ca/en/rates/interest-look.html> (Nov. 30, 2010).

BC Stats. 2011. “Hourly Wage Detailed Report for Computer Programmers and Interactive Media Developers, National Occupation Code 2174 (2011)”. <http://www.bcstats.gov.bc.ca/data/lss/labour/wage/viewdata.aspx > (Mar. 10, 2011).

Bernold L.E., Lorenc, S.J., Luces, E. 1997. “Intelligent technology for truck crane accident prevention”. Journal of Construction Engineering and Management, 123 (7), 276-284.

BuildIT. Build IT Systems. <http://www.builditsystems.com/Main/Construction_Health_Safety_Software.aspx> (Nov. 11, 2010).

Bureau of Labor Statistics (BLS) 2010a. US Department of Labor. "Census of Fatal Occupational Injuries Summary, 2009". <http://www.bls.gov/news.release/cfoi.nr0.htm> (Jul. 29, 2010).

BLS 2010b. "Table 2. Fatal occupational injuries by industry and selected event or exposure, 2009p." <http://www.bls.gov/news.release/cfoi.t02.htm> (Jul. 29, 2010).

BLS 2010c. "Census of Fatal Occupational Injuries Summary, 2010." <http://www.bls.gov/news.release/cfoi.nr0.htm> (Nov. 29, 2011).

BLS 2010d. "Table 2. Fatal occupational injuries by industry and selected event or exposure, 2010p." <http://www.bls.gov/news.release/cfoi.t02.htm> (Nov. 29, 2010).

BLS 2010e. "Table 3. Incidence rates of nonfatal occupational injuries and illnesses by major industry sector, employment size, and ownership, 2009". <http://www.bls.gov/news.release/osh.t03.htm> (Jul. 29, 2010).

BLS 2010f. "Workplace Injury and Illness Summary-2010". <http://www.bls.gov/news.release/osh.t03.htm> (Nov. 29, 2010).

BLS 2010g. "How to Compute a Firm's Incidence Rate for Safety Management". <http://www.bls.gov/iif/osheval.htm> (Jul. 29, 2010).

Bust, P. D., Gibb, A. G. F., and Pink, S. 2008. "Managing construction health and safety: Migrant workers and communicating safety messages". Journal of Safety Science, 46(4), 585-602.

Canberra Eurisys Benelux. Camberra Unattended Spectrometric Aerosol Monitor (CUSAM). <http://www.camberra.com> (Jul. 20, 2010).

Cheung, S.O., Suen, H.C.H., and Cheung, K.K.W. 2004a. “PPMS: a Web-based construction Project Performance Monitoring System”. Journal of Automation in Construction, 13, 361- 376.

Cheung, S.O., Cheung, K.K.W., and Suen, H.C.H. 2004b. “CSHM: Web-based Safety and Health Monitoring System for construction management”. Journal of Safety Research, 35(2), 159- 170.

Construction Safety Supervisor. Construction Safety Software Corporation. <http://www.csscsystems.com/products> (Nov. 10, 2010).

Construction Sector Council (CSC) 2010a. “Residential Investment by Region”. <http://www.constructionforecasts.ca/oft/table?preset=236&locale=en > (Nov. 15, 2010).

CSC 2010b. “Industrial, Commercial and Institutional Investment by Region”. <http://www.constructionforecasts.ca/oft/table?preset=237&locale=en> (Nov. 15, 2010).

Centre for the Study of Living Standards (CSLS) 2006. “Five Deaths a Day: Workplace Fatalities in Canada, 1993-2005”. < http://www.csls.ca/res_reports.asp> (Oct. 21, 2010).

Eary, J. 2008. "Networked interactive video for group training". British Journal of Educational Technology, 39(2), 365-368.

El-Saboni, M., Aouad, G., and Sabouni, A. 2009. “Electronic communication systems effects on the success of construction projects in the united Arab Emirates”. Advanced Engineering Informatics, 23 (1), 130-138.

Fraser, X.M., Jewkes, E.M., Bernhardth, I., and Tajima, M. 2009 . Global Engineering Economics: financial decision making for engineers. 4th Edition. Pearson Education Canada. Toronto Ontario.

Hewage, K. N., Ruwanpura, J. Y., and Jergeas, G. F. 2008. "IT usage in Alberta's building construction projects: Current status and challenges". Journal of Automation in Construction, 17(8), 940-947.

Hewage, K. N., and Ruwanpura, J. Y. 2009. "A novel solution for construction on-site communication - the information booth". Canadian Journal of Civil Engineering, 36(4), 659-671.

Hewlett Packard. Model iPaq 111 Classic. <http://www.shopping.hp.com/webapp/shopping/product_detail.do?storeName=storefronts&landing=handheld&category=PDA&lanAttr=Type&product_code=FA979AA%23ABA&catLevel=2 > (Nov. 10, 2010)

Hewlett Packard. Model iPaq 211. <http://www.shopping.hp.com/webapp/shopping/product_detail.do?storeName=storefronts&landing=handheld&category=PDA&lanAttr=Type&product_code=FB041AA%23ABA&catLevel=2 > (Nov. 10, 2010).

Interlink Safety Management. Accupoint Software. <http://www.accupointsoftware.com/safety.htm> (Feb, 15, 2011).

Jang, W-S., and Skibniewski, M.J. 2009. "Embedded System for Construction Asset Tracking Combining Radio and Ultrasound Signals". Journal of Computing in Civil Engineering, 24 (4), 221-229.

Kaewmoracharoen, M. 2009. "Feasibility of visualization and simulation applications to improve work zone safety and mobility". PhD thesis, Iowa State University.

Li H., Chen Z., Yong L., and Kong, S. C. W. 2005. "Application of integrated GPS and GIS technology for reducing construction waste and improving construction efficiency". Journal of Automation in Construction, 14, 323-331.

Mac iPad 2010. <http://store.apple.com/us/browse/home/shop_ipad/family/ipad?aid=AIC-WWW-NAUS-K2-BUYNOW-IPAD-TECH+SPECS&cp=BUYNOW-IPAD-TECH+SPECS > (Nov. 11, 2010).

Motamedi A, and Hammad A. 2009. "Lifecycle management of facilities components using radio frequency identification and building information model". Journal of Information Technology in Construction, 14, 238-262.

Motion Computing 2010. Model F5v. < http://www.motioncomputing.com/buy/buy_f5.asp> (Nov. 9, 2010).

Navon, R., and Sacks, R. 2007. “Assessing research issues in Automated Project Performance Control (APPC)”. Journal of Automation in Construction, 16 (4), 474-484.

Nova Scotia Construction Safety Association (NSCSA) 2010. < http://www.nscsa.org/> (Jan. 15, 2011).

Nuntasunti, S., and Bernold, L. E. 2006. “Experimental Assessment of Wireless Construction Technologies”. Journal of Construction Engineering and Management, 132(9), 1009-1018.

OQO 2010. Model 2+. < http://www.oqo.com/media/specs/2plus_specs.pdf> (Nov. 9, 2010) Panasonic Toughbook 2010. Model CF-H1F. <http://www.panasonic.com/business/ toughbook/ultra-mobile-rugged-toughbook-h1-field-tablet-pc.asp> (Nov. 9, 2010).

Panasonic Toughbook 2010. Model CF-U1. <http://www.panasonic.com/business/ toughbook/ultra-mobile-rugged-toughbook-u1-ultra.asp> (Nov. 9, 2010).

Robin, S. C., Reardon, R., and Strand, B. V. 2001. "A Video Streaming Pilot Project: Applications in Social Work Training and Education". Journal of Technology in Human Services, 18(3), 133.

Ruggedized Notebooks. Models RNB T10, GTAC E100, GTAC PS535F Rugged PDA, GTAC PS236 Ultrarugged HH PC, Trimble Yuma Rugged Tablet YMA-FYS-6AS-00, Trimble Nomad Rugged Handheld EGL-FYN2gEB, Trimble Recon Rugged Handheld (RE5-FY4CEX-00) , and Nexcom MRC 2100-E. < http://ruggednotebooks.com/fully-rugged/rnb/rnb-t10> (Nov. 11, 2010).

Rwamamara,, R., Norberg, H., Olofsson T., Lagerqvist, O. 2010. “Using visualization technologies for design and planning of a healthy construction workplace”. Journal of Construction Innovation, 10 (3), 248-266.

Safeguard. Rivo Software. <http://www.rivosoftware.com/solutions/health-safety-solutions/> (Feb. 15, 2011).

Safety Manager. SafetyInfo.com. <http://www.safetyinfo.com/safetymanager.htm> (Nov. 11, 2010).

Sawyer, T. 2008. “Modeling Supply Chains”. Engineering News Record, 260 (14).

Thomas, S. R., Tucker, R. L., and Kelly, W. R. 1998. "Critical Communications Variables". Journal of Construction Engineering and Management, 124(1), 58-66.

Vela Field Management. Vela Systems. <http://www.velasystems.com/vela-trial/?utm_campaign=newsletterfall2010&utm_source=email> (Nov.11, 2010).

WorkSafeBC. 2011. “WorkSafeBC Statistics Reports.” <http://www.worksafebc.com/ publications/reports/statistics_reports/default.asp > (Dec. 1, 2011).

Wu et al. (2010). “Towards an autonomous real-time system of near-miss accidents on construction sites”. Journal of Automation in Construction, 19, 134-141.

Xplore. 2010. Model iX104C4. <http://www.groupmobile.com/buy.asp/sku=3537/dept_id =/mf_id=19/Xplore+iX104C4++Rugged+MobileTablet+PC.htmlSafariHTML/Shell/Open /Command> (Nov.11, 2010)

Zeraware Safety Management Software. <http://www.zeraware.com/> (Nov. 11, 2010).

Appendices

Appendix A

A.1 Consent form

Consent Form

Construction Safety with Information Technologies (C-RTICS^2)

Principal Investigator:
Name: Dr. Kasun Hewage, P.Eng.
Position: Assistant Professor, School of Engineering
Phone: 250-807-8176
Fax: 250-807-9850
Email: Kasun.Hewage@ubc.ca

Co-Investigator(s):
Names: Gustavo E. Aguilar
Phone: 250 869 5378
E-mail:gustavo.aguilar@ubc.ca

Statistical data gathered on this research may be used for the research thesis of MASc degree. Total confidentiality and privacy of research participants will be protected in any publications and presentations.

Sponsor:
This research is funded by a grant from the National Sciences and Engineering Research Council of Canada (NSERC).

Purpose:
This research project aims to develop an information and communication system to be used on construction projects to improve construction safety.

You are being invited to take part in this research study to share your professional experiences related to technology use at construction sites, technology use to improve safety at construction sites, and to technology use to improve communication between the project's stakeholders.

Study Procedures:
The data will be collected through questionnaire surveys and interviews whenever required.

Questionnaire Surveys: A questionnaire will be sent to construction personnel at the project where C-RTICS^2 will be tested. Each Questionnaire will take about 15 minutes to complete. Construction managers, field engineers, superintendents, safety officers, owners, and construction workers will be requested to answer the questionnaire, before and after the implementation of C-RTICS^2. Their participation is completely voluntarily. Results of the questionnaire survey will be used to conduct data sensitivity analysis using statistical tools.

Interviews: An interview will be held in the event that the participant experiences any sort of inconveniences while trying to answer the questionnaire. In such cases, the researchers will ask the questions from the participant and will further explain its content. The researchers may contact the same professional twice for clarification purposes. Interview questions will be based on their experience levels and familiarity with information and communication technologies.

This study doesn't involve any control groups. There won't be any known adverse effects to the participants by participating in this research.

Potential Risks:
There are no known risks for the participants by providing their opinions in this research project.

Potential Benefits:
Benefits of this research to the participants and to the construction industry as whole are:

1. C-RITICS^2 will provide access to a real time statistical information related to safety in construction projects. Real time information about safety history, incidents, and accidents related to personnel, equipment, project areas, and project activities, will be available for management decision makers. This information will provide the opportunity for preventive actions to be taken, and therefore, improve construction safety.
2. Construction companies will be able to maintain communication between safety stakeholders via the proposed system. In addition, safety training material will be available to be accessed with portable electronic devices.
3. Detailed safety related statistical information will be available for different construction types (Industrial, Commercial, Residential, Transportation, and Government). Furthermore, construction companies will be able to access safety parameters from their previous construction projects to manage safety risks in existing or future projects.

Confidentiality:
All documents will be identified only by code number and kept in a locked filing cabinet in Dr. Kasun Hewage's office at the University of British Columbia at Okanagan. Subjects will not be identified by name in any reports of the completed study. All the computer files will be password protected. This will be kept until the thesis is defended, then, data will be deleted from the database. This is scheduled on July 2011.

Contact for information about the study:
If you have any questions or desire further information with respect to this study, you may contact Dr. Kasun Hewage or one of his associates at 1-250-807-8176.

Contact for concerns about the rights of research subjects:
If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 1-877-822-8598 or the UBC Okanagan Research Services Office at 250-807-8832.

Copy of the finding of this research:
If you like to receive a copy of the finding/results of the research please provide your email address below.

Consent:
Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without jeopardy to your [for example, employment, class standing, access to further services from the community centre, day care, etc.].

Your signature below indicates that you have received a copy of this consent form for your own records. Your signature indicates that you consent to participate in this study.

____
Participant’s Signature Date

____
Printed Name of the Participant

A.2 Questionnaire survey 2a

Questionnaire Date: Number:

Note: All the information kept confidential and will not disclose to your company or any other person. It will be remained with the University of British Columbia.

<u>CONSTRUCTION REAL TIME INFORMATION AND COMMUNICATION SYSTEM FOR SAFETY (C-RTICS^2); BEFORE ITS IMPLEMENTATION (PART A. WITH MANAGEMENT TEAM)</u>

1. Demographic Information (Kept confidential):

1.1 Please select your current position in the company:

a. Safety Officer ………….. b. Construction Manager …………..

c. Safety Manager ………….. d. Field Engineer …………..

e. Superintendent ………….. f. Owner ……………

g. h. Other (specify) ……………

1.2 Your age range at the time of taking this survey

a. less than 18 ………….. b. 18 to 24 …………..

c. 25 to 34 ………….. d. 35 to 44 …………..

e. 45 to 54 ………….. f. 55 to 64 ……………

g. 65 to 74 ………….. h. more than 74 ……………

1.3 Years of working experience in construction:

a. less than 1………….. b. 1 to 5 …………..

c. 6 to 10 ………….. d. 11 to 15 …………..

e. 16 to 20 ………….. f. 21 to 25 ……………

g. more than 25 …………..

1.4 Highest formal education level?

a. Primary School ………….. b. Secondary School …………..

c. College ………….. d. University Bachelor …………..

e. University Master ………….. f. University PhD ……………

g. Post Doctoral …………..

1.5 Your experience in the construction industry has been mostly in the following project type(s):

a. Commercial ………….. b. Residential …………..

c. Industrial ………….. d. Road and Transportation …………..

e. Government ………….

1.6 Number of employees in the company you are currently working with:

a. 1 to 10 ………….. b. 11 to 49 …………..

c. 50 to 249 ………….. d. 250 to 999 …………..

e. More than 1000 …………

2. Technology use in the field, for safety purposes:

2.1 Please rate the use of technology for Safety purposes in construction field activities in your project?

a. Excellent ………….
b. Good ………….
c. Satisfactory ………….
d. Fair ………….
e. Poor ……………

2.2 Are you satisfied with the use of technology in the field/site for Safety purposes, on the construction project you are currently involved?

a. Hardly ever ………….
b. Occasionally ………….
c. Sometimes ………….
d. Often ………….
e. Always ……………

2.3 Where do your workers receive official Safety training on the project?

a. Safety Officer's office ………….
b. Project's common safe areas (cafeteria, barracks) ………….
c. On-site training classroom ………….
d. On-the-spot (where workers are executing their tasks) ………….
e. Other (please specify): ________________________________

2.4 In the event of a Safety Incident/Accident, where do your workers receive training/information regarding the event (in order to prevent it from happening again)?

a. Safety Officer's office ………….
b. Project's common safe areas (cafeteria, barracks) ………….
c. On-site training classroom ………….
d. On-the-spot (where workers are executing their tasks) ………….
e. Other (please specify): ________________________________

2.5 Can you obtain information about Safety History (last safety inspection, previous incidents/accidents) of the major equipment being used on the project?

a. No ………….
b. Yes, it can be obtained immediately ………….
c. Yes, it can be obtained within 1 hour ……………
d. Yes, it can be obtained within 1 day ……………
e. Yes, although it will take an unknown amount of time to obtain

……………

2.6 Can you obtain information about Safety History (previous incidents/accidents) of the different contractors involved on the project?

a. No …………..
b. Yes, it can be obtained immediately …………..

c. Yes, it can be obtained within 1 hour ……………
d. Yes, it can be obtained within 1 day ……………
e. Yes, although it will take an unknown amount of time to obtain ……………

2.7 Can you obtain information about Safety History (previous incidents/accidents) of the personnel involved on the project?

a. No …………..
b. Yes, it can be obtained immediately …………..

c. Yes, it can be obtained within 1 hour ……………
d. Yes, it can be obtained within 1 day ……………
e. Yes, although it will take an unknown amount of time to obtain ……………

2.8 Can you obtain information about Safety parameters (Recorded Incident Ratio (RIR), Lost Time Case Ratio (LTCR)) for your project?

a. No …………..
b. Yes, it can be obtained immediately …………..

c. Yes, it can be obtained within 1 hour ……………
d. Yes, it can be obtained within 1 day ……………
e. Yes, although it will take an unknown amount of time to obtain ……………

2.9 Can you obtain information about Safety parameters (Recorded Incident Ratio (RIR), Lost Time Case Ratio (LTCR)) for project types (Commercial, Industrial, Residential, or Transportation)?

a. No …………..
b. Yes, it can be obtained immediately …………..

c. Yes, it can be obtained within 1 hour ……………

d. Yes, it can be obtained within 1 day ……………

e. Yes, although it will take an unknown amount of time to obtain ……………

2.10 Do you use/analyze Construction Safety Statistics published by the Government during meetings <u>with the subcontractors of your project?</u>

a. No …………..
b. Yes, every week …………..
c. Yes, every other week ……………
d. Yes, occasionally ……………
e. Yes, but only when incidents/accidents happen ……………

2.11 Do you use/analyze Construction Safety Statistics published by the Government during meetings <u>with your project's managerial staff</u>?

a. No …………..
b. Yes, every week …………..
c. Yes, every other week ……………
d. Yes, occasionally ……………
e. Yes, but only when incidents/accidents happen ……………

2.12 Do you use/analyze Construction Safety Statistics published by the Government during meetings <u>with your construction workers</u>?

a. No …………..
b. Yes, every week …………..
c. Yes, every other week ……………
d. Yes, occasionally ……………
e. Yes, but only when incidents/accidents happen ……………

2.13 Do you use/analyze Construction Safety Statistics <u>about your project</u>, <u>with the subcontractors</u> of your project?

a. No …………..
b. Yes, every week …………..
c. Yes, every other week ……………
d. Yes, occasionally ……………
e. Yes, but only when incidents/accidents happen ……………

2.14 Do you use/analyze Construction Safety Statistics <u>about your project</u>, <u>with your project's managerial staff?</u>

a. No …………..
b. Yes, every week …………..
c. Yes, every other week ……………
d. Yes, occasionally ……………
e. Yes, but only when incidents/accidents happen ……………

2.15 Do you use/analyze Construction Safety Statistics <u>about your project, with your construction workers?</u>

a. No …………..
b. Yes, every week …………..
c. Yes, every other week ……………
d. Yes, occasionally ……………
e. Yes, but only when incidents/accidents happen ……………

2.16 Are you satisfied with the Safety Information about your project, available during decision making processes?

a. Hardly ever …………..
b. Occasionally …………..
c. Sometimes ………….
d. Often …………..
e. Always ……………

A.3 Questionnaire survey 2b.

Questionnaire Date: Number:

Note: All the information kept confidential and will not disclose to your company or any other person. It will be remained with the University of British Columbia.

CONSTRUCTION REAL TIME INFORMATION AND COMMUNICATION SYSTEM FOR SAFETY (C-RTICS^2); AFTER ITS IMPLEMENTATION (PART B, WITH MANAGEMENT TEAM)

1. Demographic Information (Kept confidential):

1.3 Please select your current position in the company:

b. Safety Officer ………….. b. Construction Manager …………..

d. Safety Manager ………….. d. Field Engineer …………..

f. Superintendent ………….. f. Owner ……………

g. Other (specify) ……………

2. Technology use in the field, for safety purposes::

2.1 Please rate the impact on the project's safety, by implementing C-RTICS^2?

a. Excellent …………..
b. Good …………..
c. Satisfactory …………..
d. Fair …………..
e. Poor ……………

2.2 With the implementation of C-RTICS² in your project, you are satisfied with the use of technology for safety purposes on the field?

a. Strongly Agree …………..
b. Agree …………..
c. Neutral or No Opinion ………….
d. Disagree …………..
e. Strongly Disagree ……………

2.3 With the implementation of C-RTICS² in your project, where would you provide official Safety training for the personnel on the project?

a. Safety Officer's office …………..
b. Project's common safe areas (cafeteria, barracks) …………..
c. On-site training classroom …………..
d. On-the-spot (where workers are executing their tasks) …………..
e. Other (please specify): ________________________________

2.4 With the implementation of C-RTICS² in your project, in the event of a Safety Incident/Accident, where would you provide the involved personnel with training regarding the event (in order to prevent it from happening again)?

a. Safety Officer's office …………..
b. Project's common safe areas (cafeteria, barracks) …………..
c. On-site training classroom …………..
d. On-the-spot (where workers are executing their tasks) …………..
e. Other (please specify): ________________________________

2.5 With the implementation of C-RTICS² in your project, would you be able to improve safety on your project?

a. No, Definitely not …………..
b. Probably not …………..
c. Not Certain ……………
d. Probably ……………
e. Yes, Definitely ……………

2.6 What do think about the following statement: "With C-RTICS^2, I will be satisfied with the Safety Information about my project being available for decision making processes?

a. Strongly Agree …………..
b. Agree …………..
c. Neutral or No Opinion ………….
d. Disagree …………..
e. Strongly Disagree ……………

2.7 What suggestions would you provide to the research team in order for C-RTICS^2 to become implemented on Canada's Construction Industry?

____

____

____

____

A.4 UBC ethics board amendment

The University of British Columbia Okanagan
Research Services
Behavioural Research Ethics Board
3333 University Way
Kelowna, BC V1V 1V7

Phone: 250-807-8832
Fax: 250-807-8438

CERTIFICATE OF APPROVAL - MINIMAL RISK AMENDMENT

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Kasun Hewage	UBC/UBCO Applied Science/UBCO School of Engineering	H10-01000

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Okanagan

CO-INVESTIGATOR(S):
Daylath Mendis
Fabricio Bianchini
Gustavo E. Aguilar
Atul Porwal

SPONSORING AGENCIES:
Natural Sciences and Engineering Research Council of Canada (NSERC) - "Holistic approach for lifecycle waste management in construction projects"

PROJECT TITLE:
Holistic Approach for Lifecycle Waste Management in Construction Projects

Expiry Date - Approval of an amendment does not change the expiry date on the current UBC BREB approval of this study. An application for renewal is required on or before: May 13, 2011

AMENDMENT(S):

AMENDMENT APPROVAL DATE:
February 8, 2011

Document Name	Version	Date
Consent Forms:		
Consent Form - Fabricio Bianchini - Revised	N/A	February 1, 2011
Consent form - Gustavo Aguilar	N/A	January 31, 2011
Consent form - Fabricio Bianchini	N/A	January 31, 2011
Consent Form - Gustavo Aguilar - Revised	N/A	February 1, 2011
Questionnaire, Questionnaire Cover Letter, Tests:		
Questionnaire-workers-before-Gustavo Aguilar	N/A	January 31, 2011
Questionnaire-managers-after-Gustavo Aguilar	N/A	January 31, 2011
Questionnaire-managers-before-Gustavo Aguilar	N/A	January 31, 2011
Questionnaire - general - Gustavo Aguilar	N/A	January 31, 2011
Questionnaire - Fabricio Bianchini	N/A	January 31, 2011
Questionnaire-workers-after-Gustavo Aguilar	N/A	January 31, 2011
Letter of Initial Contact:		
Recruitment Letter - Gustavo Aguilar	N/A	January 31, 2011
Recruitment letter - Fabricio Bianchini	N/A	January 31, 2011

The amendment(s) and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board Okanagan and signed electronically by:

Dr. Daniel Salhani, Chair

Appendix B Portable electronic devices and its specifications

	Decision Making Criteria																						
Yellow cells indicate a change from previous row	Direct Cost	Weight (lbs)	Screen Size	Memory	Processor Speed and type	RFID reader	Bar code reader	Support	Ruggedized	Ditital Camera	Bluetooth	I/O Ports	Operating System	Energy Efficiency	Handwritting recognition	Battery life	WiFi connectivity	Screen type/technology	Web Camera	Mobile Internet Connectivity	HardDrive	Temperature operation	Warranty
Manufacturer/Model	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22	x23
	$	lb	inch	MB												Hrs							yrs
Motion Computing/Model F5v	2489	3.3	10.4	1000	e vPro i5 1	No	No	P54 / MIL-STD-810G / (		No	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / LED	No	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	2548	3.3	10.4	2000	e vPro i5 1	No	No	P54 / MIL-STD-810G / (		No	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	No	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	2646	3.3	10.4	2000	e vPro i5 1	No	No	P54 / MIL-STD-810G / (		Rear 3MP	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	Front 1.2M	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	2917	3.3	10.4	2000	e vPro i5 1.	Yes	Yes	P54 / MIL-STD-810G / (		Rear 3MP	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	Front 1.2M	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	2588	3.3	10.4	4000	e vPro i5 1	No	No	P54 / MIL-STD-810G / (		No	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	No	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	2686	3.3	10.4	4000	e vPro i5 1	No	No	P54 / MIL-STD-810G / (		Rear 3MP	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	Front 1.2M	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	2957	3.3	10.4	4000	e vPro i5 1.	Yes	Yes	P54 / MIL-STD-810G / (		Rear 3MP	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	Front 1.2M	No	160GB HD	5C to 40C	3
Motion Computing/Model F5v	3056	3.3	10.4	4000	e vPro i5 1	Yes	Yes	P54 / MIL-STD-810G / (		Rear 3MP	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	Front 1.2M	Gobi WWA	160GB HD	5C to 40C	3
Motion Computing/Model F5v	3155	3.3	10.4	4000	re vPro i7 1	Yes	Yes	P54 / MIL-STD-810G / (		Rear 3MP	h 2.1+EDR	1 USB 2.0	Win 7	Energy Star	Yes	4	802.11 N	AFFS+ / Viev	Front 1.2M	Gobi WWA	160GB HD	5C to 40C	3
Panasonic/Model CF-H1F	2849	3.4	10.4	2000	om Z540 1.	No	No	IP65 / MIL-STD-810G			Bluetooth 2.1+EDR Module		Win 7 or XP Ta	S Compliance/IS(	Yes	6	02.11 a/b/g.	XGA Dual Tou	No	ptional Gol	64 GD SSI	IL-STD-810	3
Discount	2849	3.4	10.4	2000	om Z540 1.	No	No	IP65 / MIL-STD-		No	h 2.1+EDR Module		Win 7 or XP Ta	S Compliance/IS(	Yes	6	02.11 a/b/g.	XGA Dual Tou	No	ptional Gol	64 GD SSI	IL-STD-810	3
H1 Field Base	2849	3.4	10.4	2000	om Z540 1.	No	No	IP65 / MIL-STD-		No	h 2.1+EDR Module		Win 7 or XP Ta	S Compliance/IS(	Yes	6	02.11 a/b/g.	XGA Dual Tou	No	ptional Gol	64 GD SSI	IL-STD-810	3
H1 Field Pro	3397	3.4	10.4	2000	om Z540 1.	No	Yes 1D/2D	IP65 / MIL-STD-		2MP	h 2.1+EDR Module		Win 7 or XP Ta	S Compliance/IS(	Yes	6	02.11 a/b/g.	XGA Dual Tou	No	ptional Gol	64 GD SSI	IL-STD-810	3
H1 Field Elite	3497	3.4	10.4	2000	om Z540 1.	Yes	Yes 1D/2D	IP65 / MIL-STD-		2MP	h 2.1+EDR Module		Win 7 or XP Ta	S Compliance/IS(	Yes	6	02.11 a/b/g.	XGA Dual Tou	No	ptional Gol	64 GD SSI	IL-STD-810	3
CF-U1	2798	2.3	5.6	2000	tom Z530 1	No	No	IP65 / MIL-STD-		No	h 2.1+EDR	USB and S	Win XP	S Compliance/IS(	Yes	9	02.11 a/b/g.	WSVGA Sun	No	ptional Gol	64 GD SSI	5C to 35C	3
CF-U1	3097	2.3	5.6	2000	tom Z530 1	No	No	IP65 / MIL-STD-		2MP	h 2.1+EDR	USB and S	Win XP	S Compliance/IS(	Yes	9	02.11 a/b/g.	WSVGA Sun	No	ptional Gol	64 GD SSI	5C to 35C	3
OQO/E+2	1378	1	5	1000	om Z520 1.	No	No		No	No	h 2.0+EDR.	USB/HDM	Win XP	N/A	Yes	3.5	02.11 a/b/g.	Wide VGA L(	No	No	60 GB HDI	N/A	3
OQO/E+2	1878	1	5	2000	om Z540 1.	No	No		No	No	h 2.0+EDR.	USB/HDM	Win XP	N/A	Yes	3.5	02.11 a/b/g.	Wide VGA O	No	No	120 GB HI	N/A	3
OQO/E+2	2406	1	5	2000	om Z540 1.	No	No		No	No	h 2.0+EDR.	USB/HDM	Win XP	N/A	Yes	3.5	02.11 a/b/g.	Wide VGA O	No	Gobi	120 GB HI	N/A	3

Appendix B Continued.

OQO/E+2	3485	1	5	2000	om Z540 1.	No	No	No	No	h 2.0+EDR	. USB/HDM	Win XP	N/A	Yes	3.5	)2.11 a/b/g	Wide VGA O	No	Gobi	60 GB SSI	N/A	3
Xplore/iX104C4	3697	5.2	10.4	1000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	XGA TFT	No	No	160GB HD	minus 20C	3
Xplore/iX104C4	4092	5.2	10.4	1000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	AllVue Displa	No	No	160GB HD	minus 20C	3
Xplore/iX104C4	4291	5.2	10.4	1000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	Dual Touch m	No	No	160GB HD	minus 20C	3
Xplore/iX104C4	4686	5.2	10.4	2000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	Dual Touch m	No	No	160GB HD	minus 20C	3
Xplore/iX104C4	5335	5.2	10.4	2000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	Dual Touch m	No	bile / oe EV	160GB HD	minus 20C	3
Xplore/iX104C4	5683	5.2	10.4	2000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	Dual Touch m	No	bile / oe EV	32GB SSD	minus 20C	3
Xplore/iX104C4	5783	5.2	10.4	2000	0 1.2 GHz	No	No	IP65 / MIL-STD-	No	h 2.0+EDR	2 USB	7 or XP Ta	N/A	Yes	4.5	302.11 a/g/	Dual Touch m	No	bile / oe EV	64GB SSD	minus 20C	3
Mac/iPad	598	2.7	9.7	16000	GHz Apple (	No	No	der Seires case and A	No	h 2.1+EDR	1 USB	Mac OS	Arsenic-Free dis	No	10	)2.11 a/b/g	LED-backlit g	No	No	16 GB	0C to 35C	2
Wi-Fi Model	698	2.7	9.7	32000	GHz Apple (	No	No	der Seires case and A	No	h 2.1+EDR	1 USB	Mac OS	Arsenic-Free dis	No	10	)2.11 a/b/g	LED-backlit g	No	No	32 GB SSD	0C to 35C	2
Wi-Fi Model	798	2.7	9.7	64000	GHz Apple (	No	No	der Seires case and A	No	h 2.1+EDR	1 USB	Mac OS	Arsenic-Free dis	No	10	)2.11 a/b/g	LED-backlit g	No	No	64 GB	0C to 35C	2
Wi-Fi + 3G Model	728	2.7	9.7	16000	GHz Apple (	No	No	der Seires case and A	No	h 2.1+EDR	1 USB	Mac OS	Arsenic-Free dis	No	10	)2.11 a/b/g	LED-backlit g	No	IHz) // GSM	16 GB	0C to 35C	2
Wi-Fi + 3G Model	828	2.7	9.7	32000	GHz Apple (	No	No	der Seires case and A	No	h 2.1+EDR	1 USB	Mac OS	Arsenic-Free dis	No	10	)2.11 a/b/g	LED-backlit g	No	IHz) // GSM	32 GB SSD	0C to 35C	2
Wi-Fi + 3G Model	928	2.7	9.7	64000	GHz Apple (	No	No	der Seires case and A	No	h 2.1+EDR	1 USB	Mac OS	Arsenic-Free dis	No	10	)2.11 a/b/g	LED-backlit g	No	IHz) // GSM	64 GB	0C to 35C	2
HP/iPaq 111 Classic	379.94	0.3	3.5	64	PXA310, 6	No	No	iapac Waterproof case	No	1 2.0+EDR	IO High ca	Vin Mobile	N/A	must be ins	3.5	802.11 b/g	TFT RGB col	No	No	256MB Fla	N/A	1
iPaq 211	479.94	0.4	4	128	PXA310, 6	No	No	iapac Waterproof case	No	1 2.0+EDR	1 capacity (	Vin Mobile	N/A	must be ins	3.5	802.11 b/g	VGA) touch p	No	No	256MB Fla	N/A	1
RuggedNoteBooks/RNB T10	3145	2.7	10.4	2000	e 2 Solo 1.	Yes	Yes	IP54 / MIL-STD-810		Bluetooth 2.1+EDR	Dock In Cc	Tablet or W	EPEAT Silver	must be ins	5	)2.11 a/b/g	TFT XGA LCD	2MP	ional 3G fo	64 GB SSI	5C to 35C	3
GTAC E100	2539	3.1	8.4	1000	tra Low Po	No	No	IP54 / MIL-STD-	No	1 2.0+EDR	2 USB/Sm	Vin XPTable	N/A	gitizer Displ	6.7	802.11 b/g	TFT SVGA LCD	No	No	80GB PAT	0C to 60C	5
GTAC E100	2794	3.1	8.4	1000	tra Low Po	No	No	IP54 / MIL-STD-	No	1 2.0+EDR	2 USB/Sm	Vin XPTable	N/A	gitizer Displ	6.7	802.11 b/g	TFT SVGA LCD	No	MBW	80GB PAT	0C to 60C	5
GTAC E100	3224	3.1	8.4	1000	tra Low Po	No	No	IP54 / MIL-STD-	No	1 2.0+EDR	2 USB/Sm	Vin XPTable	N/A	gitizer Displ	6.7	802.11 b/g	TFT SVGA LCD	No	No	32 GB SSI	0C to 60C	5

Appendix B Continued.

GTAC E100	3734	3.1	8.4	1000	ltra Low Po	No	No	IP54 / MIL-STD-	No	n 2.0+EDR:	2 USB/Sm	Vin XPTable	N/A	gitizer Displ	6.7	802.11 b/g	TFT SVGA LCD	No	MBW	32 GB SSI	0C to 60C	5
GTAC E100	3228	3.1	8.4	1000	ltra Low Po	No	No	IP54 / MIL-STD-	No	n 2.0+EDR:	2 USB/Sm	Vin XPTable	N/A	gitizer Displ	6.7	802.11 b/g	TFT SVGA LCD	No	No	80 GB SSI	0C to 60C	5
GTAC E100	3738	3.1	8.4	1000	ltra Low Po	No	No	IP54 / MIL-STD-	No	n 2.0+EDR:	2 USB/Sm	Vin XPTable	N/A	gitizer Displ	6.7	802.11 b/g	TFT SVGA LCD	No	MBW	80 GB SSI	0C to 60C	5
GTAC PS535F Rugged PDA	1089	0.7	3.5	128	, 533 MHz	No	No	IP65 / MIL-STD-	No	n 2.0+EDR:	1USB	Win Mobile	N/A	?	8	802.11 b/g	480x640, sunlight	No	No	2 GB Nanc	minus 20C	3
GTAC PS535F Rugged PDA	1188	0.7	3.5	128	, 533 MHz	No	No	IP65 / MIL-STD-	3 MP	n 2.0+EDR:	1USB	Win Mobile	N/A	?	8	802.11 b/g	480x640, sunlight	No	No	2 GB Nanc	minus 20C	3
GTAC PS535F Rugged PDA	1188	0.7	3.5	256	, 533 MHz	No	No	IP65 / MIL-STD-	No	n 2.0+EDR:	1USB	Win Mobile	N/A	?	8	802.11 b/g	480x640, sunlight	No	No	2 GB Nanc	minus 20C	3
GTAC PS535F Rugged PDA	1287	0.7	3.5	256	, 533 MHz	No	No	IP65 / MIL-STD-	3 MP	n 2.0+EDR:	1USB	Win Mobile	N/A	?	8	802.11 b/g	480x640, sunlight	No	No	2 GB Nanc	minus 20C	3
GTAC PS236 Ultrarugged HH PC	1679	1.1	3.5	128	PXA310, 8	No	No	IP67 / MIL-STD-	3MP	n 2.0+EDR:	USB/serial	'in Mobile6	N/A	Yes	10	802.11 b/g	480x640, sunlight	No	No	256 MB N/	minus 30C	3
GTAC PS236 Ultrarugged HH PC	2278	1.1	3.5	128	PXA310, 8	No	No	IP67 / MIL-STD-	3MP	n 2.0+EDR:	USB/serial	'in Mobile6	N/A	Yes	10	802.11 b/g	480x640, sunlight	No	.5G MBWM	256 MB N/	minus 30C	3
Trimble Yuma Rugged Tablet (YMA-FYS6AS-00)	3569	2.6	7	1000	Atom 1.6 (	No	No	67 / MIL-STD-810F / M	1.3 MP	luetooth 2.	3/9 pin seri	Win 7	nergy Star / RoH	?	8	802.11 b/g	1024x600 WSVGA	2MP Rear	No	32GB SSD	minus 30C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	1299	1.3	4	128	PXA320, 8	No	No	IP67 / MIL-STD-	No	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	No	VGA 480x64	No	No	512 MB Fl	minus 40C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	1641	1.3	4	128	PXA320, 8	No	No	IP67 / MIL-STD-	No	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	802.11 b/g	VGA 480x64	No	No	1 GB Flasl	minus 40C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	1840	1.3	4	128	PXA320, 8	No	No	IP67 / MIL-STD-	Yes	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	802.11 b/g	VGA 480x64	No	No	1 GB Flasl	minus 40C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	2235	1.3	4	128	PXA320, 8	No	Yes	IP67 / MIL-STD-	Yes	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	802.11 b/g	VGA 480x64	No	No	1 GB Flasl	minus 40C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	2135	1.3	4	128	PXA320, 8	No	No	IP67 / MIL-STD-	No	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	802.11 b/g	VGA 480x64	No	WWAN	2 GB Flasl	minus 40C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	2327	1.3	4	128	PXA320, 8	No	No	IP67 / MIL-STD-	Yes	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	802.11 b/g	VGA 480x64	No	WWAN	2 GB Flasl	minus 40C	1
Trimble Nomad Rugged Handheld (EGL-FYN2gEB)	2737	1.3	4	128	PXA320, 8	No	Yes	IP67 / MIL-STD-	Yes	luetooth 2.	option 9 pin	Vin Mobile	nergy Star / RoH	?	15	802.11 b/g	VGA 480x64	No	WWAN	2 GB Flasl	minus 40C	1
Trimble Recon Rugged Handheld (RE5-FY4CEX-00)	1248	1.1	4	64	XScale CF	No	No	IP67 / MIL-STD-	No	Bluetooth	3/9 pin seri	Vin Mobile	nergy Star / RoH	?	15	802.11	240x320 TFT	No	No	256 MB Fl	minus 30C	1
Trimble Recon Rugged Handheld (RE5-FY4CEX-00)	1717	1.1	4	64	XScale CF	No	r Barcode Scanner	IP67 / MIL-STD-	No	Bluetooth	3/9 pin seri	Vin Mobile	nergy Star / RoH	?	15	802.11	240x320 TFT	No	No	256 MB Fl	minus 30C	1
Nexcom MRC 2100-E	1825	3.6	8.4	1000	Atom 1.6 (	No	No	IP54 / MIL-STD-	2 MP	h 2.1+EDR	SB/mini US	Win XP Pro	N/A	?	3	802.11 b/g/	TFT LCD amb	No	No	8 GB SSD	minus 20C	2
Nexcom MRC 2100-E	2033	3.6	8.4	1000	Atom 1.6 (	No	No	IP54 / MIL-STD-	2 MP	h 2.1+EDR	SB/mini US	Win XP Pro	N/A	?	3	802.11 b/g/	TFT LCD amb	No	MBWM	8 GB SSD	minus 20C	2
Nexcom MRC 2100-E	2209	3.6	8.4	1000	Atom 1.6 (	Yes	No	IP54 / MIL-STD-	2 MP	h 2.1+EDR	SB/mini US	Win XP Pro	N/A	?	3	802.11 b/g/	TFT LCD amb	No	MBWM	8 GB SSD	minus 20C	2
Nexcom MRC 2100-E	2704	3.6	8.4	1000	Atom 1.6 (	Yes	Yes	IP54 / MIL-STD-	2 MP	h 2.1+EDR	SB/mini US	Win XP Pro	N/A	?	3	802.11 b/g/	TFT LCD amb	No	MBWM	8 GB SSD	minus 20C	2

Appendix C Pair-wise comparison matrices for the AHP analysis performed on the PED

C.1 Pair-wise comparison matrix and normalized matrix for the twenty three decision making criteria used in the AHP

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22	x23
x1	1.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.11	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00
x2	0.20	1.00	5.00	3.00	1.00	0.33	3.00	0.33	0.14	0.20	1.00	1.00	3.00	0.14	0.20	0.20	0.33	5.00	0.20	0.20	0.20	0.14	0.14
x3	0.20	0.20	1.00	3.00	0.33	0.33	3.00	0.33	0.14	0.33	3.00	0.33	5.00	0.20	1.00	0.20	0.20	3.00	0.33	0.20	3.00	0.20	0.20
x4	0.20	0.33	0.33	1.00	1.00	0.20	5.00	0.33	0.20	0.20	1.00	0.33	3.00	0.33	0.20	0.33	0.20	3.00	0.33	0.20	1.00	0.20	0.33
x5	0.20	1.00	3.00	1.00	1.00	0.33	3.00	0.20	0.20	0.20	1.00	0.33	0.33	0.20	0.20	0.33	0.20	3.00	0.33	0.20	1.00	0.33	0.20
x6	0.20	3.00	3.00	5.00	3.00	1.00	3.00	0.33	0.20	1.00	1.00	0.33	3.00	0.20	0.20	1.00	0.33	3.00	1.00	0.20	1.00	0.33	0.33
x7	0.20	0.33	0.33	0.20	0.33	0.33	1.00	0.33	0.20	0.33	0.20	0.20	0.33	0.14	0.20	0.20	0.20	0.33	0.20	0.20	0.20	0.20	0.20
x8	0.20	3.00	3.00	3.00	5.00	3.00	3.00	1.00	1.00	1.00	3.00	0.33	3.00	0.20	0.20	0.33	0.20	3.00	0.33	0.20	3.00	0.20	1.00
x9	0.20	7.00	7.00	5.00	5.00	5.00	5.00	1.00	1.00	1.00	3.00	0.33	5.00	0.20	0.20	0.20	0.20	1.00	0.33	0.33	3.00	1.00	1.00
x10	0.20	5.00	3.00	5.00	5.00	1.00	3.00	1.00	1.00	1.00	1.00	1.00	5.00	0.33	1.00	0.33	0.33	5.00	0.33	0.20	3.00	0.33	0.33
x11	0.20	1.00	0.33	1.00	1.00	1.00	5.00	0.33	0.33	1.00	1.00	0.33	3.00	0.33	0.33	0.20	0.33	0.33	0.33	0.20	1.00	0.33	0.33
x12	0.20	1.00	3.00	3.00	3.00	3.00	5.00	3.00	3.00	1.00	3.00	1.00	5.00	1.00	1.00	1.00	1.00	5.00	1.00	1.00	5.00	1.00	1.00
x13	0.20	0.33	0.20	0.33	3.00	0.33	3.00	0.33	0.20	0.20	0.33	0.20	1.00	0.14	0.20	0.20	0.20	3.00	0.20	0.20	0.33	0.20	0.20
x14	9.00	7.00	5.00	3.00	5.00	5.00	7.00	5.00	5.00	3.00	3.00	1.00	7.00	1.00	1.00	1.00	0.20	7.00	1.00	0.20	5.00	0.33	3.00
x15	0.20	5.00	1.00	5.00	5.00	5.00	5.00	5.00	5.00	1.00	3.00	1.00	1.00	1.00	1.00	3.00	0.33	3.00	1.00	1.00	7.00	3.00	1.00
x16	0.20	5.00	5.00	3.00	3.00	1.00	5.00	3.00	5.00	3.00	5.00	1.00	5.00	1.00	0.33	1.00	1.00	5.00	0.20	0.20	5.00	1.00	3.00
x17	0.20	3.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00	3.00	3.00	1.00	5.00	5.00	3.00	1.00	1.00	9.00	3.00	1.00	5.00	1.00	1.00
x18	0.20	0.20	0.33	0.33	0.33	0.33	3.00	0.33	1.00	0.20	3.00	0.20	0.33	0.14	0.33	0.20	0.11	1.00	0.20	0.14	3.00	0.20	0.14
x19	0.20	5.00	3.00	3.00	3.00	1.00	5.00	3.00	3.00	3.00	3.00	1.00	5.00	1.00	1.00	5.00	0.33	5.00	1.00	3.00	5.00	0.33	0.33
x20	0.20	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	5.00	5.00	1.00	5.00	5.00	1.00	5.00	1.00	7.00	0.33	1.00	5.00	1.00	1.00
x21	0.20	5.00	0.33	1.00	1.00	1.00	5.00	0.33	0.33	0.33	1.00	0.20	3.00	0.20	0.14	0.20	0.20	0.33	0.20	0.20	1.00	0.20	0.20
x22	0.20	7.00	5.00	5.00	3.00	3.00	5.00	5.00	1.00	3.00	3.00	1.00	5.00	3.00	0.33	1.00	1.00	5.00	3.00	1.00	5.00	1.00	1.00
x23	0.33	7.00	5.00	3.00	5.00	3.00	5.00	1.00	1.00	3.00	3.00	1.00	5.00	0.33	1.00	0.33	1.00	7.00	3.00	1.00	5.00	1.00	1.00
Sum	14.33	77.40	68.87	68.87	69.00	48.20	97.00	46.20	41.95	37.00	55.53	19.13	83.00	21.22	19.08	27.27	14.91	89.00	22.87	17.08	72.73	18.54	19.95

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22	x23	Sum	Priority vector
x1	0.07	0.06	0.07	0.07	0.07	0.10	0.05	0.11	0.12	0.14	0.09	0.26	0.06	0.01	0.26	0.18	0.34	0.06	0.22	0.29	0.07	0.27	0.15	3.12	13.58%
x2	0.01	0.01	0.07	0.04	0.01	0.01	0.03	0.01	0.00	0.01	0.02	0.05	0.04	0.01	0.01	0.01	0.02	0.06	0.01	0.01	0.00	0.01	0.01	0.46	2.00%
x3	0.01	0.00	0.01	0.04	0.00	0.01	0.03	0.01	0.00	0.01	0.05	0.02	0.06	0.01	0.05	0.01	0.01	0.03	0.01	0.01	0.04	0.01	0.01	0.47	2.06%
x4	0.01	0.00	0.00	0.01	0.01	0.00	0.05	0.01	0.00	0.01	0.02	0.02	0.04	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.02	0.35	1.52%
x5	0.01	0.01	0.04	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.34	1.47%
x6	0.01	0.04	0.04	0.07	0.04	0.02	0.03	0.01	0.00	0.03	0.02	0.02	0.04	0.01	0.01	0.04	0.02	0.03	0.04	0.01	0.01	0.02	0.02	0.59	2.57%
x7	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.17	0.75%
x8	0.01	0.04	0.04	0.04	0.07	0.06	0.03	0.02	0.02	0.03	0.05	0.02	0.04	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.04	0.01	0.05	0.69	3.01%
x9	0.01	0.09	0.10	0.07	0.07	0.10	0.05	0.02	0.02	0.03	0.05	0.02	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.05	0.05	0.94	4.10%
x10	0.01	0.06	0.04	0.07	0.07	0.02	0.03	0.02	0.02	0.03	0.02	0.05	0.06	0.02	0.05	0.01	0.02	0.06	0.01	0.01	0.04	0.02	0.02	0.78	3.40%
x11	0.01	0.01	0.00	0.01	0.01	0.02	0.05	0.01	0.01	0.03	0.02	0.02	0.04	0.02	0.02	0.01	0.02	0.00	0.01	0.01	0.01	0.02	0.02	0.39	1.69%
x12	0.01	0.01	0.04	0.04	0.04	0.06	0.05	0.06	0.07	0.03	0.05	0.05	0.06	0.05	0.05	0.04	0.07	0.06	0.04	0.06	0.07	0.05	0.05	1.14	4.94%
x13	0.01	0.00	0.00	0.00	0.04	0.01	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.00	0.01	0.01	0.27	1.18%
x14	0.63	0.09	0.07	0.04	0.07	0.10	0.07	0.11	0.12	0.08	0.05	0.05	0.08	0.05	0.05	0.04	0.01	0.08	0.04	0.01	0.07	0.02	0.15	2.10	9.14%
x15	0.01	0.06	0.01	0.07	0.07	0.10	0.05	0.11	0.12	0.03	0.05	0.05	0.01	0.05	0.05	0.11	0.02	0.03	0.04	0.06	0.10	0.16	0.05	1.44	6.27%
x16	0.01	0.06	0.07	0.04	0.04	0.02	0.05	0.06	0.12	0.08	0.09	0.05	0.06	0.05	0.02	0.04	0.07	0.06	0.01	0.01	0.07	0.05	0.15	1.30	5.64%
x17	0.01	0.04	0.07	0.07	0.07	0.06	0.05	0.11	0.12	0.08	0.05	0.05	0.06	0.24	0.16	0.04	0.07	0.10	0.13	0.06	0.07	0.05	0.05	1.82	7.91%
x18	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.02	0.01	0.05	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.30	1.31%
x19	0.01	0.06	0.04	0.04	0.04	0.02	0.05	0.06	0.07	0.08	0.05	0.05	0.06	0.05	0.05	0.18	0.02	0.06	0.04	0.18	0.07	0.02	0.02	1.35	5.87%
x20	0.01	0.06	0.07	0.07	0.07	0.10	0.05	0.11	0.07	0.14	0.09	0.05	0.06	0.24	0.05	0.18	0.07	0.08	0.01	0.06	0.07	0.05	0.05	1.83	7.97%
x21	0.01	0.06	0.00	0.01	0.01	0.02	0.05	0.01	0.01	0.01	0.02	0.01	0.04	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.37	1.61%
x22	0.01	0.09	0.07	0.07	0.04	0.06	0.05	0.11	0.02	0.08	0.05	0.05	0.06	0.14	0.02	0.04	0.07	0.06	0.13	0.06	0.07	0.05	0.05	1.47	6.38%
x23	0.02	0.09	0.07	0.04	0.07	0.06	0.05	0.02	0.02	0.08	0.05	0.05	0.06	0.02	0.05	0.01	0.07	0.08	0.13	0.06	0.07	0.05	0.05	1.30	5.64%
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	23.00	1.00

C.2 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	3.00	3.00	5.00	3.00	3.00	5.00	5.00	5.00
A2	0.33	1.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
A3	0.33	0.33	1.00	3.00	0.33	3.00	3.00	3.00	3.00
A4	0.20	0.33	0.33	1.00	0.33	0.33	3.00	3.00	3.00
A5	0.33	0.33	3.00	3.00	1.00	3.00	3.00	3.00	3.00
A6	0.33	0.33	0.33	3.00	0.33	1.00	3.00	3.00	3.00
A7	0.20	0.33	0.33	0.33	0.33	0.33	1.00	3.00	3.00
A8	0.20	0.33	0.33	0.33	0.33	0.33	0.33	1.00	3.00
A9	0.20	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.00
	3.13	6.33	11.67	19.00	9.00	14.33	21.67	24.33	27.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.32	0.47	0.26	0.26	0.33	0.21	0.23	0.21	0.19	2.48	27.52%	10.4
A2	0.11	0.16	0.26	0.16	0.33	0.21	0.14	0.12	0.11	1.59	17.72%	10.8
A3	0.11	0.05	0.09	0.16	0.04	0.21	0.14	0.12	0.11	1.02	11.35%	10.5
A4	0.06	0.05	0.03	0.05	0.04	0.02	0.14	0.12	0.11	0.63	7.01%	9.9
A5	0.11	0.05	0.26	0.16	0.11	0.21	0.14	0.12	0.11	1.27	14.08%	10.7
A6	0.11	0.05	0.03	0.16	0.04	0.07	0.14	0.12	0.11	0.83	9.17%	10.2
A7	0.06	0.05	0.03	0.02	0.04	0.02	0.05	0.12	0.11	0.50	5.59%	9.6
A8	0.06	0.05	0.03	0.02	0.04	0.02	0.02	0.04	0.11	0.39	4.34%	9.5
A9	0.06	0.05	0.03	0.02	0.04	0.02	0.02	0.01	0.04	0.29	3.21%	9.9
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	10.2

lambda max	10.15	n =	9
consistency index (CI)	0.14433		
consistency ratio (CR)	0.09953		OK, quite consistent

C.3 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x4 (Memory).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	0.20	0.20	0.20	0.11	0.11	0.11	0.11	0.11
A2	5.00	1.00	1.00	1.00	1.00	0.33	0.33	0.20	0.14
A3	5.00	1.00	1.00	1.00	0.20	0.20	0.20	0.20	0.20
A4	5.00	1.00	1.00	1.00	0.20	0.20	0.20	0.20	0.20
A5	9.00	1.00	5.00	5.00	1.00	1.00	1.00	1.00	1.00
A6	9.00	3.00	5.00	5.00	1.00	1.00	1.00	1.00	1.00
A7	9.00	3.00	5.00	5.00	1.00	1.00	1.00	1.00	1.00
A8	9.00	5.00	5.00	5.00	1.00	1.00	1.00	1.00	1.00
A9	9.00	7.00	5.00	5.00	1.00	1.00	1.00	1.00	1.00
	61.00	22.20	28.20	28.20	6.51	5.84	5.84	5.71	5.65

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.13	1.49%	9.2
A2	0.08	0.05	0.04	0.04	0.15	0.06	0.06	0.04	0.03	0.53	5.84%	9.3
A3	0.08	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.37	4.08%	9.4
A4	0.08	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.37	4.08%	9.4
A5	0.15	0.05	0.18	0.18	0.15	0.17	0.17	0.18	0.18	1.39	15.50%	9.3
A6	0.15	0.14	0.18	0.18	0.15	0.17	0.17	0.18	0.18	1.49	16.50%	9.5
A7	0.15	0.14	0.18	0.18	0.15	0.17	0.17	0.18	0.18	1.49	16.50%	9.5
A8	0.15	0.23	0.18	0.18	0.15	0.17	0.17	0.18	0.18	1.58	17.50%	9.6
A9	0.15	0.32	0.18	0.18	0.15	0.17	0.17	0.18	0.18	1.67	18.50%	9.7
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.4

lambda max	9.42	n =	9
consistency index (CI)	0.05286		
consistency ratio (CR)	0.03646		OK, quite consistent

C.4 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x5 (processor type and speed).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
A9	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	1.00
	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	2.60

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A2	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A3	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A4	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A6	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A7	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A8	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.69	7.69%	9.0
A9	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	3.46	38.46%	9.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.0

lambda max	9.00	n =	9
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.5 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x6 (RFID reader).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A2	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A3	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A4	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
A5	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A6	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A7	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
A8	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
A9	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
	41.00	41.00	41.00	4.56	41.00	41.00	4.56	4.56	4.56

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A4	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
A5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A6	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A7	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
A8	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
A9	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.0

lambda max	9.00	n =	9
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.6 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x7 (Barcode reader).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A2	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A3	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A4	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
A5	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A6	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
A7	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
A8	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
A9	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
	41.00	41.00	41.00	4.56	41.00	41.00	4.56	4.56	4.56

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A4	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
A5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A6	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.22	2.44%	9.0
A7	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
A8	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
A9	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	1.98	21.95%	9.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.0

lambda max	9.00	n =	9
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.7 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x10 (Digital Camera).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	0.11	0.11	1.00	0.11	0.11	0.11	0.11
A2	1.00	1.00	0.11	0.11	1.00	0.11	0.11	0.11	0.11
A3	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A4	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A5	1.00	1.00	0.11	0.11	1.00	0.11	0.11	0.11	0.11
A6	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A7	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A8	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A9	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
	57.00	57.00	6.33	6.33	57.00	6.33	6.33	6.33	6.33

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.75%	9.0
A2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.75%	9.0
A3	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A4	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.75%	9.0
A6	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A7	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A9	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.0

lambda max	9.00	n =	9	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.8 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x19 (Web Camera).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	0.11	0.11	1.00	0.11	0.11	0.11	0.11
A2	1.00	1.00	0.11	0.11	1.00	0.11	0.11	0.11	0.11
A3	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A4	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A5	1.00	1.00	0.11	0.11	1.00	0.11	0.11	0.11	0.11
A6	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A7	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A8	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
A9	9.00	9.00	1.00	1.00	9.00	1.00	1.00	1.00	1.00
	57.00	57.00	6.33	6.33	57.00	6.33	6.33	6.33	6.33

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.75%	9.0
A2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.75%	9.0
A3	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A4	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.75%	9.0
A6	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A7	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A8	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
A9	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.42	15.79%	9.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.0

lambda max	9.00	n =	9	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.9 Pair-wise comparison matrix and normalized matrix for Motion Computing models, based on factor x20 (Mobile Internet connectivity).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
A8	9.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	1.00
A9	9.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	1.00
	25.00	25.00	25.00	25.00	25.00	25.00	25.00	2.78	2.78

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Sum	Priority vector	Lambda
A1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A4	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A5	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A6	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A7	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.36	4.00%	9.0
A8	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	3.24	36.00%	9.0
A9	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	3.24	36.00%	9.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	1.00	9.0

lambda max	9.00	n =	9	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.10 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5
A1	1.00	3.00	3.00	0.33	0.33
A2	0.33	1.00	3.00	0.20	0.33
A3	0.33	0.33	1.00	0.20	0.20
A4	3.00	5.00	5.00	1.00	3.00
A5	3.00	3.00	5.00	0.33	1.00
	7.67	12.33	17.00	2.07	4.87

Normalized matrix

	A1	A2	A3	A4	A5	Sum	Priority vector	Lambda
A1	0.13	0.24	0.18	0.16	0.07	0.78	15.60%	5.3
A2	0.04	0.08	0.18	0.10	0.07	0.47	9.33%	5.1
A3	0.04	0.03	0.06	0.10	0.04	0.27	5.34%	5.2
A4	0.39	0.41	0.29	0.48	0.62	2.19	43.82%	5.5
A5	0.39	0.24	0.29	0.16	0.21	1.30	25.91%	5.5
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.3

lambda max	5.32	n =	5	
consistency index (CI)	0.08074			
consistency ratio (CR)	0.07209			OK, quite consistent

C.11 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x2 (Weight).

	A1	A2	A3	A4	A5
A1	1.00	1.00	1.00	0.20	0.20
A2	1.00	1.00	1.00	0.20	0.20
A3	1.00	1.00	1.00	0.20	0.20
A4	5.00	5.00	5.00	1.00	1.00
A5	5.00	5.00	5.00	1.00	1.00
	13.00	13.00	13.00	2.60	2.60

Normalized matrix

	A1	A2	A3	A4	A5	Sum	Priority vector	Lambda
A1	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
A2	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
A3	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
A4	0.38	0.38	0.38	0.38	0.38	1.92	38.46%	5.0
A5	0.38	0.38	0.38	0.38	0.38	1.92	38.46%	5.0
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.0

lambda max	5.00	n =	5
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.12 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x3 (Screen size).

	A1	A2	A3	A4	A5
A1	1.00	1.00	1.00	5.00	5.00
A2	1.00	1.00	1.00	5.00	5.00
A3	1.00	1.00	1.00	5.00	5.00
A4	0.20	0.20	0.20	1.00	1.00
A5	0.20	0.20	0.20	1.00	1.00
	3.40	3.40	3.40	17.00	17.00

Normalized matrix

	A1	A2	A3	A4	A5	Sum	Priority vector	Lambda
A1	0.29	0.29	0.29	0.29	0.29	1.47	29.41%	5.0
A2	0.29	0.29	0.29	0.29	0.29	1.47	29.41%	5.0
A3	0.29	0.29	0.29	0.29	0.29	1.47	29.41%	5.0
A4	0.06	0.06	0.06	0.06	0.06	0.29	5.88%	5.0
A5	0.06	0.06	0.06	0.06	0.06	0.29	5.88%	5.0
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.0

lambda max	5.00	n =	5
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.13 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x6 (RFID reader).

	A1	A2	A3	A4	A5
A1	1.00	1.00	0.11	1.00	1.00
A2	1.00	1.00	0.11	1.00	1.00
A3	9.00	9.00	1.00	9.00	9.00
A4	1.00	1.00	0.11	1.00	1.00
A5	1.00	1.00	0.11	1.00	1.00
	13.00	13.00	1.44	13.00	13.00

Normalized matrix

	A1	A2	A3	A4	A5	Sum	Priority vector	Lambda
A1	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
A2	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
A3	0.69	0.69	0.69	0.69	0.69	3.46	69.23%	5.0
A4	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
A5	0.08	0.08	0.08	0.08	0.08	0.38	7.69%	5.0
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.0

lambda max	5.00	n =	5
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.14 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x7 (Barcode reader).

	A1	A2	A3	A4	A5
A1	1.00	0.11	0.11	1.00	1.00
A2	9.00	1.00	1.00	9.00	9.00
A3	9.00	1.00	1.00	9.00	9.00
A4	1.00	0.11	0.11	1.00	1.00
A5	1.00	0.11	0.11	1.00	1.00
	21.00	2.33	2.33	21.00	21.00

Normalized matrix

	A1	A2	A3	A4	A5	Sum	Priority vector	Lambda
A1	0.05	0.05	0.05	0.05	0.05	0.24	4.76%	5.0
A2	0.43	0.43	0.43	0.43	0.43	2.14	42.86%	5.0
A3	0.43	0.43	0.43	0.43	0.43	2.14	42.86%	5.0
A4	0.05	0.05	0.05	0.05	0.05	0.24	4.76%	5.0
A5	0.05	0.05	0.05	0.05	0.05	0.24	4.76%	5.0
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.0

lambda max	5.00	n =	5
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.15 Pair-wise comparison matrix and normalized matrix for Panasonic models, based on factor x10 (Digital camera).

	A1	A2	A3	A4	A5
A1	1.00	0.11	0.11	1.00	0.11
A2	9.00	1.00	1.00	9.00	1.00
A3	9.00	1.00	1.00	9.00	1.00
A4	1.00	0.11	0.11	1.00	0.11
A5	9.00	1.00	1.00	9.00	1.00
	29.00	3.22	3.22	29.00	3.22

Normalized matrix

	A1	A2	A3	A4	A5	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.03	0.17	3.45%	5.0
A2	0.31	0.31	0.31	0.31	0.31	1.55	31.03%	5.0
A3	0.31	0.31	0.31	0.31	0.31	1.55	31.03%	5.0
A4	0.03	0.03	0.03	0.03	0.03	0.17	3.45%	5.0
A5	0.31	0.31	0.31	0.31	0.31	1.55	31.03%	5.0
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.0

lambda max	5.00	n =	5
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.16 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x1 (Cost).

	A1	A2	A3	A4
A1	1.00	3.00	5.00	5.00
A2	0.33	1.00	3.00	5.00
A3	0.20	0.33	1.00	3.00
A4	0.20	0.20	0.33	1.00
	1.73	4.53	9.33	14.00

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.58	0.66	0.54	0.36	2.13	53.29%	4.4
A2	0.19	0.22	0.32	0.36	1.09	27.29%	4.3
A3	0.12	0.07	0.11	0.21	0.51	12.76%	4.1
A4	0.12	0.04	0.04	0.07	0.27	6.67%	4.1
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.2

lambda max	4.20	n =	4	
consistency index (CI)	0.06709			
consistency ratio (CR)	0.07454			OK, quite consistent

C.17 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x4 (Memory).

	A1	A2	A3	A4
A1	1.00	0.20	0.20	0.20
A2	5.00	1.00	1.00	1.00
A3	5.00	1.00	1.00	1.00
A4	5.00	1.00	1.00	1.00
	16.00	3.20	3.20	3.20

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.06	0.06	0.06	0.06	0.25	6.25%	4.0
A2	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
A3	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
A4	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.18 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x5 (Processor type).

	A1	A2	A3	A4
A1	1.00	0.20	0.20	0.20
A2	5.00	1.00	1.00	1.00
A3	5.00	1.00	1.00	1.00
A4	5.00	1.00	1.00	1.00
	16.00	3.20	3.20	3.20

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.06	0.06	0.06	0.06	0.25	6.25%	4.0
A2	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
A3	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
A4	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.19 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x18 (Screen size).

	A1	A2	A3	A4
A1	1.00	0.20	0.20	0.20
A2	5.00	1.00	1.00	1.00
A3	5.00	1.00	1.00	1.00
A4	5.00	1.00	1.00	1.00
	16.00	3.20	3.20	3.20

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.06	0.06	0.06	0.06	0.25	6.25%	4.0
A2	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
A3	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
A4	0.31	0.31	0.31	0.31	1.25	31.25%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.20 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x20 (Mobile internet connectivity).

	A1	A2	A3	A4
A1	1.00	1.00	0.11	0.11
A2	1.00	1.00	0.11	0.11
A3	9.00	9.00	1.00	1.00
A4	9.00	9.00	1.00	1.00
	20.00	20.00	2.22	2.22

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.05	0.05	0.05	0.05	0.20	5.00%	4.0
A2	0.05	0.05	0.05	0.05	0.20	5.00%	4.0
A3	0.45	0.45	0.45	0.45	1.80	45.00%	4.0
A4	0.45	0.45	0.45	0.45	1.80	45.00%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.21 Pair-wise comparison matrix and normalized matrix for OQO models, based on factor x21 (Hard drive capacity).

	A1	A2	A3	A4
A1	1.00	0.33	0.33	0.11
A2	3.00	1.00	1.00	0.14
A3	3.00	1.00	1.00	0.14
A4	9.00	7.00	7.00	1.00
	16.00	9.33	9.33	1.40

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.06	0.04	0.04	0.08	0.21	5.34%	4.0
A2	0.19	0.11	0.11	0.10	0.50	12.60%	4.1
A3	0.19	0.11	0.11	0.10	0.50	12.60%	4.1
A4	0.56	0.75	0.75	0.72	2.78	69.46%	4.2
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.1

lambda max	4.09	n =	4
consistency index (CI)	0.03063		
consistency ratio (CR)	0.03404		OK, quite consistent

C.22 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5	A6	A7
A1	1.00	3.00	3.00	5.00	5.00	5.00	5.00
A2	0.33	1.00	3.00	3.00	5.00	5.00	5.00
A3	0.33	0.33	1.00	3.00	5.00	5.00	5.00
A4	0.20	0.33	0.33	1.00	3.00	3.00	3.00
A5	0.20	0.20	0.20	0.33	1.00	3.00	3.00
A6	0.20	0.20	0.20	0.33	0.33	1.00	3.00
A7	0.20	0.20	0.20	0.33	0.33	0.33	1.00
	2.47	5.27	7.93	13.00	19.67	22.33	25.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	Sum	Priority vector	Lambda
A1	0.41	0.57	0.38	0.38	0.25	0.22	0.20	2.42	34.51%	8.1
A2	0.14	0.19	0.38	0.23	0.25	0.22	0.20	1.61	23.03%	8.4
A3	0.14	0.06	0.13	0.23	0.25	0.22	0.20	1.23	17.62%	8.1
A4	0.08	0.06	0.04	0.08	0.15	0.13	0.12	0.67	9.57%	7.9
A5	0.08	0.04	0.03	0.03	0.05	0.13	0.12	0.48	6.79%	7.4
A6	0.08	0.04	0.03	0.03	0.02	0.04	0.12	0.35	5.02%	7.1
A7	0.08	0.04	0.03	0.03	0.02	0.01	0.04	0.24	3.45%	7.4
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00	1.00	7.8

lambda max	7.78	n =	7
consistency index (CI)	0.12968		
consistency ratio (CR)	0.09824		OK, quite consistent

C.23 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x4 (Memory).

	A1	A2	A3	A4	A5	A6	A7
A1	1.00	1.00	1.00	5.00	5.00	5.00	5.00
A2	1.00	1.00	1.00	5.00	5.00	5.00	5.00
A3	1.00	1.00	1.00	5.00	5.00	5.00	5.00
A4	0.20	0.20	0.20	1.00	1.00	1.00	1.00
A5	0.20	0.20	0.20	1.00	1.00	1.00	1.00
A6	0.20	0.20	0.20	1.00	1.00	1.00	1.00
A7	0.20	0.20	0.20	1.00	1.00	1.00	1.00
	3.80	3.80	3.80	19.00	19.00	19.00	19.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	Sum	Priority vector	Lambda
A1	0.26	0.26	0.26	0.26	0.26	0.26	0.26	1.84	26.32%	7.0
A2	0.26	0.26	0.26	0.26	0.26	0.26	0.26	1.84	26.32%	7.0
A3	0.26	0.26	0.26	0.26	0.26	0.26	0.26	1.84	26.32%	7.0
A4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.37	5.26%	7.0
A5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.37	5.26%	7.0
A6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.37	5.26%	7.0
A7	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.37	5.26%	7.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00	1.00	7.0

lambda max	7.00	n =	7
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.24 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x18 (Screen type).

	A1	A2	A3	A4	A5	A6	A7
A1	1.00	0.33	0.14	0.14	0.14	0.14	0.14
A2	3.00	1.00	0.20	0.20	0.20	0.20	0.20
A3	7.00	5.00	1.00	1.00	1.00	1.00	1.00
A4	7.00	5.00	1.00	1.00	1.00	1.00	1.00
A5	7.00	5.00	1.00	1.00	1.00	1.00	1.00
A6	7.00	5.00	1.00	1.00	1.00	1.00	1.00
A7	7.00	5.00	1.00	1.00	1.00	1.00	1.00
	39.00	26.33	5.34	5.34	5.34	5.34	5.34

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	Sum	Priority vector	Lambda
A1	0.03	0.01	0.03	0.03	0.03	0.03	0.03	0.17	2.46%	7.0
A2	0.08	0.04	0.04	0.04	0.04	0.04	0.04	0.30	4.32%	7.0
A3	0.18	0.19	0.19	0.19	0.19	0.19	0.19	1.31	18.65%	7.1
A4	0.18	0.19	0.19	0.19	0.19	0.19	0.19	1.31	18.65%	7.1
A5	0.18	0.19	0.19	0.19	0.19	0.19	0.19	1.31	18.65%	7.1
A6	0.18	0.19	0.19	0.19	0.19	0.19	0.19	1.31	18.65%	7.1
A7	0.18	0.19	0.19	0.19	0.19	0.19	0.19	1.31	18.65%	7.1
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00	1.00	7.1

lambda max	7.06	n =	7
consistency index (CI)	0.01031		
consistency ratio (CR)	0.00781		OK, quite consistent

C.25 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x20 (Mobile internet connectivity).

	A1	A2	A3	A4	A5	A6	A7
A1	1.00	1.00	1.00	1.00	0.11	0.11	0.11
A2	1.00	1.00	1.00	1.00	0.11	0.11	0.11
A3	1.00	1.00	1.00	1.00	0.11	0.11	0.11
A4	1.00	1.00	1.00	1.00	0.11	0.11	0.11
A5	9.00	9.00	9.00	9.00	1.00	1.00	1.00
A6	9.00	9.00	9.00	9.00	1.00	1.00	1.00
A7	9.00	9.00	9.00	9.00	1.00	1.00	1.00
	31.00	31.00	31.00	31.00	3.44	3.44	3.44

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.23	3.23%	7.0
A2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.23	3.23%	7.0
A3	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.23	3.23%	7.0
A4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.23	3.23%	7.0
A5	0.29	0.29	0.29	0.29	0.29	0.29	0.29	2.03	29.03%	7.0
A6	0.29	0.29	0.29	0.29	0.29	0.29	0.29	2.03	29.03%	7.0
A7	0.29	0.29	0.29	0.29	0.29	0.29	0.29	2.03	29.03%	7.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00	1.00	7.0

lambda max	7.00	n =	7
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.26 Pair-wise comparison matrix and normalized matrix for Xplore models, based on factor x21 (Hard disk drive).

	A1	A2	A3	A4	A5	A6	A7
A1	1.00	1.00	1.00	1.00	1.00	0.14	0.11
A2	1.00	1.00	1.00	1.00	1.00	0.14	0.11
A3	1.00	1.00	1.00	1.00	1.00	0.14	0.11
A4	1.00	1.00	1.00	1.00	1.00	0.14	0.11
A5	1.00	1.00	1.00	1.00	1.00	0.14	0.11
A6	7.00	7.00	7.00	7.00	7.00	1.00	0.20
A7	9.00	9.00	9.00	9.00	9.00	5.00	1.00
	21.00	21.00	21.00	21.00	21.00	6.71	1.76

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	Sum	Priority vector	Lambda
A1	0.05	0.05	0.05	0.05	0.05	0.02	0.06	0.32	4.61%	7.0
A2	0.05	0.05	0.05	0.05	0.05	0.02	0.06	0.32	4.61%	7.0
A3	0.05	0.05	0.05	0.05	0.05	0.02	0.06	0.32	4.61%	7.0
A4	0.05	0.05	0.05	0.05	0.05	0.02	0.06	0.32	4.61%	7.0
A5	0.05	0.05	0.05	0.05	0.05	0.02	0.06	0.32	4.61%	7.0
A6	0.33	0.33	0.33	0.33	0.33	0.15	0.11	1.93	27.56%	7.2
A7	0.43	0.43	0.43	0.43	0.43	0.74	0.57	3.46	49.39%	8.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00	1.00	7.2

lambda max	7.20	n =	7
consistency index (CI)	0.03394		
consistency ratio (CR)	0.02572		OK, quite consistent

C.27 Pair-wise comparison matrix and normalized matrix for Apple models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5	A6
A1	1.00	3.00	5.00	3.00	5.00	5.00
A2	0.33	1.00	3.00	3.00	3.00	5.00
A3	0.20	0.33	1.00	0.33	3.00	3.00
A4	0.33	0.33	3.00	1.00	3.00	3.00
A5	0.20	0.33	0.33	0.33	1.00	3.00
A6	0.20	0.20	0.33	0.33	0.33	1.00
	2.27	5.20	12.67	8.00	15.33	20.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.44	0.58	0.39	0.38	0.33	0.25	2.36	39.40%	6.7
A2	0.15	0.19	0.24	0.38	0.20	0.25	1.40	23.28%	6.8
A3	0.09	0.06	0.08	0.04	0.20	0.15	0.62	10.31%	6.4
A4	0.15	0.06	0.24	0.13	0.20	0.15	0.92	15.31%	6.7
A5	0.09	0.06	0.03	0.04	0.07	0.15	0.44	7.26%	6.2
A6	0.09	0.04	0.03	0.04	0.02	0.05	0.27	4.44%	6.3
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.5

lambda max	6.51	n =	6
consistency index (CI)	0.10125		
consistency ratio (CR)	0.08165		OK, quite consistent

C.28 Pair-wise comparison matrix and normalized matrix for Apple models, based on factor x4 (Memory).

	A1	A2	A3	A4	A5	A6
A1	1.00	0.20	0.11	1.00	0.20	0.11
A2	5.00	1.00	0.14	5.00	1.00	0.14
A3	9.00	7.00	1.00	9.00	7.00	1.00
A4	1.00	0.20	0.11	1.00	0.20	0.11
A5	5.00	1.00	0.14	5.00	1.00	0.14
A6	9.00	7.00	1.00	9.00	7.00	1.00
	30.00	16.40	2.51	30.00	16.40	2.51

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.03	0.01	0.04	0.03	0.01	0.04	0.18	2.99%	6.1
A2	0.17	0.06	0.06	0.17	0.06	0.06	0.57	9.49%	6.3
A3	0.30	0.43	0.40	0.30	0.43	0.40	2.25	37.52%	7.0
A4	0.03	0.01	0.04	0.03	0.01	0.04	0.18	2.99%	6.1
A5	0.17	0.06	0.06	0.17	0.06	0.06	0.57	9.49%	6.3
A6	0.30	0.43	0.40	0.30	0.43	0.40	2.25	37.52%	7.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.4

lambda max	6.44	n =	6
consistency index (CI)	0.08764		
consistency ratio (CR)	0.07067		OK, quite consistent

C.29 Pair-wise comparison matrix and normalized matrix for Apple models, based on factor x20 (Mobile internet mobility).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	1.00	0.11	0.11	0.11
A2	1.00	1.00	1.00	0.11	0.11	0.11
A3	1.00	1.00	1.00	0.11	0.11	0.11
A4	9.00	9.00	9.00	1.00	1.00	1.00
A5	9.00	9.00	9.00	1.00	1.00	1.00
A6	9.00	9.00	9.00	1.00	1.00	1.00
	30.00	30.00	30.00	3.33	3.33	3.33

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.03	0.03	0.20	3.33%	6.0
A2	0.03	0.03	0.03	0.03	0.03	0.03	0.20	3.33%	6.0
A3	0.03	0.03	0.03	0.03	0.03	0.03	0.20	3.33%	6.0
A4	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
A5	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
A6	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.30 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x1 (Cost).

	A1	A2
A1	1.00	5.00
A2	0.20	1.00
	1.20	6.00

Normalized matrix

	A1	A2	Sum	Priority vector	Lambda
A1	0.83	0.83	1.67	83.33%	2.0
A2	0.17	0.17	0.33	16.67%	2.0
Sum	1.00	1.00	2.00	1.00	2.0

lambda max	2.00	n =	2		
consistency index (CI)	0				
consistency ratio (CR)	#DIV/0!			#DIV/0!	

C.31 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x2 (Weight).

	A1	A2
A1	1.00	1.00
A2	1.00	1.00
	2.00	2.00

Normalized matrix

	A1	A2	Sum	Priority vector	Lambda
A1	0.50	0.50	1.00	50.00%	2.0
A2	0.50	0.50	1.00	50.00%	2.0
Sum	1.00	1.00	2.00	1.00	2.0

lambda max	2.00	n =	2
consistency index (CI)	0		
consistency ratio (CR)	#DIV/0!		#DIV/0!

C.32 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x3 (Screen size).

	A1	A2
A1	1.00	0.50
A2	2.00	1.00
	3.00	1.50

Normalized matrix

	A1	A2	Sum	Priority vector	Lambda
A1	0.33	0.33	0.67	33.33%	2.0
A2	0.67	0.67	1.33	66.67%	2.0
Sum	1.00	1.00	2.00	1.00	2.0

lambda max	2.00	n =	2
consistency index (CI)	0		
consistency ratio (CR)	#DIV/0!		#DIV/0!

C.33 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x4 (Memory).

	A1	A2
A1	1.00	0.20
A2	5.00	1.00
	6.00	1.20

Normalized matrix

	A1	A2	Sum	Priority vector	Lambda
A1	0.17	0.17	0.33	16.67%	2.0
A2	0.83	0.83	1.67	83.33%	2.0
Sum	1.00	1.00	2.00	1.00	2.0

lambda max	2.00	n =	2
consistency index (CI)	0		
consistency ratio (CR)	#DIV/0!		#DIV/0!

C.34 Pair-wise comparison matrix and normalized matrix for Hewlett Packard models, based on factor x18 (Screen type).

	A1	A2
A1	1.00	0.14
A2	7.00	1.00
	8.00	1.14

Normalized matrix

	A1	A2	Sum	Priority vector	Lambda
A1	0.13	0.13	0.25	12.50%	2.0
A2	0.88	0.88	1.75	87.50%	2.0
Sum	1.00	1.00	2.00	1.00	2.0

lambda max	2.00	n =	2
consistency index (CI)	0		
consistency ratio (CR)	#DIV/0!		#DIV/0!

C.35 Pair-wise comparison matrix and normalized matrix for GTAC E100 models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5	A6
A1	1.00	3.00	5.00	5.00	5.00	5.00
A2	0.33	1.00	3.00	5.00	3.00	5.00
A3	0.20	0.33	1.00	3.00	1.00	3.00
A4	0.20	0.20	0.33	1.00	0.33	1.00
A5	0.20	0.33	1.00	3.00	1.00	3.00
A6	0.20	0.20	0.33	1.00	0.33	1.00
	2.13	5.07	10.67	18.00	10.67	18.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.47	0.59	0.47	0.28	0.47	0.28	2.55	42.57%	6.6
A2	0.16	0.20	0.28	0.28	0.28	0.28	1.47	24.53%	6.4
A3	0.09	0.07	0.09	0.17	0.09	0.17	0.68	11.34%	6.2
A4	0.09	0.04	0.03	0.06	0.03	0.06	0.31	5.11%	6.1
A5	0.09	0.07	0.09	0.17	0.09	0.17	0.68	11.34%	6.2
A6	0.09	0.04	0.03	0.06	0.03	0.06	0.31	5.11%	6.1
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.3

lambda max	6.27	n =	6	
consistency index (CI)	0.05304			
consistency ratio (CR)	0.04277		OK, quite consistent	

C.36 Pair-wise comparison matrix and normalized matrix for GTAC E100 models, based on factor x20 (Mobile internet connectivity).

	A1	A2	A3	A4	A5	A6
A1	1.00	0.11	1.00	0.11	1.00	0.11
A2	9.00	1.00	9.00	1.00	9.00	1.00
A3	1.00	0.11	1.00	0.11	1.00	0.11
A4	9.00	1.00	9.00	1.00	9.00	1.00
A5	1.00	0.11	1.00	0.11	1.00	0.11
A6	9.00	1.00	9.00	1.00	9.00	1.00
	30.00	3.33	30.00	3.33	30.00	3.33

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.03	0.03	0.20	3.33%	6.0
A2	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
A3	0.03	0.03	0.03	0.03	0.03	0.03	0.20	3.33%	6.0
A4	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
A5	0.03	0.03	0.03	0.03	0.03	0.03	0.20	3.33%	6.0
A6	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.37 Pair-wise comparison matrix and normalized matrix for GTAC E100 models, based on factor x2 (Hard disk drive).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	0.14	0.14	0.11	0.11
A2	1.00	1.00	0.14	0.14	0.11	0.11
A3	7.00	7.00	1.00	1.00	0.20	0.20
A4	7.00	7.00	1.00	1.00	0.20	0.20
A5	9.00	9.00	5.00	5.00	1.00	1.00
A6	9.00	9.00	5.00	5.00	1.00	1.00
	34.00	34.00	12.29	12.29	2.62	2.62

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.03	0.03	0.01	0.01	0.04	0.04	0.17	2.78%	6.1
A2	0.03	0.03	0.01	0.01	0.04	0.04	0.17	2.78%	6.1
A3	0.21	0.21	0.08	0.08	0.08	0.08	0.73	12.12%	6.4
A4	0.21	0.21	0.08	0.08	0.08	0.08	0.73	12.12%	6.4
A5	0.26	0.26	0.41	0.41	0.38	0.38	2.11	35.10%	6.9
A6	0.26	0.26	0.41	0.41	0.38	0.38	2.11	35.10%	6.9
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.4

lambda max	6.43	n =	6
consistency index (CI)	0.08664		
consistency ratio (CR)	0.06987		OK, quite consistent

C.38 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5	A6
A1	1.00	3.00	3.00	3.00	7.00	7.00
A2	0.33	1.00	1.00	3.00	5.00	7.00
A3	0.33	1.00	1.00	3.00	5.00	7.00
A4	0.33	0.33	0.33	1.00	5.00	7.00
A5	0.14	0.20	0.20	0.20	1.00	5.00
A6	0.14	0.14	0.14	0.14	0.20	1.00
	2.29	5.68	5.68	10.34	23.20	34.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.44	0.53	0.53	0.29	0.30	0.21	2.29	38.20%	6.7
A2	0.15	0.18	0.18	0.29	0.22	0.21	1.21	20.16%	6.9
A3	0.15	0.18	0.18	0.29	0.22	0.21	1.21	20.16%	6.9
A4	0.15	0.06	0.06	0.10	0.22	0.21	0.78	13.02%	6.7
A5	0.06	0.04	0.04	0.02	0.04	0.15	0.34	5.71%	6.2
A6	0.06	0.03	0.03	0.01	0.01	0.03	0.16	2.74%	6.2
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.6

lambda max	6.62	n =	6
consistency index (CI)	0.12337		
consistency ratio (CR)	0.09949		OK, quite consistent

C.39 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x2 (Weight).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	1.00	1.00	3.00	3.00
A2	1.00	1.00	1.00	1.00	3.00	3.00
A3	1.00	1.00	1.00	1.00	3.00	3.00
A4	1.00	1.00	1.00	1.00	3.00	3.00
A5	0.33	0.33	0.33	0.33	1.00	1.00
A6	0.33	0.33	0.33	0.33	1.00	1.00
	4.67	4.67	4.67	4.67	14.00	14.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.21	0.21	0.21	0.21	0.21	0.21	1.29	21.43%	6.0
A2	0.21	0.21	0.21	0.21	0.21	0.21	1.29	21.43%	6.0
A3	0.21	0.21	0.21	0.21	0.21	0.21	1.29	21.43%	6.0
A4	0.21	0.21	0.21	0.21	0.21	0.21	1.29	21.43%	6.0
A5	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A6	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.40 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x4 (Memory).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	0.20	0.20	1.00	1.00
A2	1.00	1.00	0.20	0.20	1.00	1.00
A3	5.00	5.00	1.00	1.00	5.00	5.00
A4	5.00	5.00	1.00	1.00	5.00	5.00
A5	1.00	1.00	0.20	0.20	1.00	1.00
A6	1.00	1.00	0.20	0.20	1.00	1.00
	14.00	14.00	2.80	2.80	14.00	14.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A2	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A3	0.36	0.36	0.36	0.36	0.36	0.36	2.14	35.71%	6.0
A4	0.36	0.36	0.36	0.36	0.36	0.36	2.14	35.71%	6.0
A5	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A6	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.41 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x10 (Digital camera).

	A1	A2	A3	A4	A5	A6
A1	1.00	0.11	1.00	0.11	0.11	0.11
A2	9.00	1.00	9.00	1.00	1.00	1.00
A3	1.00	0.11	1.00	0.11	0.11	0.11
A4	9.00	1.00	9.00	1.00	1.00	1.00
A5	9.00	1.00	9.00	1.00	1.00	1.00
A6	9.00	1.00	9.00	1.00	1.00	1.00
	38.00	4.22	38.00	4.22	4.22	4.22

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.03	0.03	0.16	2.63%	6.0
A2	0.24	0.24	0.24	0.24	0.24	0.24	1.42	23.68%	6.0
A3	0.03	0.03	0.03	0.03	0.03	0.03	0.16	2.63%	6.0
A4	0.24	0.24	0.24	0.24	0.24	0.24	1.42	23.68%	6.0
A5	0.24	0.24	0.24	0.24	0.24	0.24	1.42	23.68%	6.0
A6	0.24	0.24	0.24	0.24	0.24	0.24	1.42	23.68%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.42 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x16 (Battery life).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	1.00	1.00	0.33	0.33
A2	1.00	1.00	1.00	1.00	0.33	0.33
A3	1.00	1.00	1.00	1.00	0.33	0.33
A4	1.00	1.00	1.00	1.00	0.33	0.33
A5	3.00	3.00	3.00	3.00	1.00	1.00
A6	3.00	3.00	3.00	3.00	1.00	1.00
	10.00	10.00	10.00	10.00	3.33	3.33

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.10	0.10	0.10	0.10	0.10	0.10	0.60	10.00%	6.0
A2	0.10	0.10	0.10	0.10	0.10	0.10	0.60	10.00%	6.0
A3	0.10	0.10	0.10	0.10	0.10	0.10	0.60	10.00%	6.0
A4	0.10	0.10	0.10	0.10	0.10	0.10	0.60	10.00%	6.0
A5	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
A6	0.30	0.30	0.30	0.30	0.30	0.30	1.80	30.00%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.43 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x20 (Mobile internet connectivity).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	1.00	1.00	1.00	0.11
A2	1.00	1.00	1.00	1.00	1.00	0.11
A3	1.00	1.00	1.00	1.00	1.00	0.11
A4	1.00	1.00	1.00	1.00	1.00	0.11
A5	1.00	1.00	1.00	1.00	1.00	0.11
A6	9.00	9.00	9.00	9.00	9.00	1.00
	14.00	14.00	14.00	14.00	14.00	1.56

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A2	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A3	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A4	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A5	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A6	0.64	0.64	0.64	0.64	0.64	0.64	3.86	64.29%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.44 Pair-wise comparison matrix and normalized matrix for GTAC Rugged PDA models, based on factor x21 (Hard disk drive).

	A1	A2	A3	A4	A5	A6
A1	1.00	1.00	1.00	1.00	0.20	0.20
A2	1.00	1.00	1.00	1.00	0.20	0.20
A3	1.00	1.00	1.00	1.00	0.20	0.20
A4	1.00	1.00	1.00	1.00	0.20	0.20
A5	5.00	5.00	5.00	5.00	1.00	1.00
A6	5.00	5.00	5.00	5.00	1.00	1.00
	14.00	14.00	14.00	14.00	2.80	2.80

Normalized matrix

	A1	A2	A3	A4	A5	A6	Sum	Priority vector	Lambda
A1	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A2	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A3	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A4	0.07	0.07	0.07	0.07	0.07	0.07	0.43	7.14%	6.0
A5	0.36	0.36	0.36	0.36	0.36	0.36	2.14	35.71%	6.0
A6	0.36	0.36	0.36	0.36	0.36	0.36	2.14	35.71%	6.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00	6.0

lambda max	6.00	n =	6
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.45 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x1 (Cost).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	0.36	0.46	0.52	0.63	0.60	0.65	0.77	0.35	0.48
A2	2.75	1.00	1.26	1.42	1.72	1.64	1.79	2.11	0.96	1.32
A3	2.17	0.79	1.00	1.12	1.36	1.30	1.42	1.67	0.76	1.05
A4	1.94	0.71	0.89	1.00	1.21	1.16	1.26	1.49	0.68	0.93
A5	1.60	0.58	0.73	0.82	1.00	0.96	1.04	1.22	0.56	0.77
A6	1.67	0.61	0.77	0.86	1.05	1.00	1.09	1.28	0.58	0.80
A7	1.53	0.56	0.71	0.79	0.96	0.92	1.00	1.18	0.54	0.74
A8	1.30	0.47	0.60	0.67	0.82	0.78	0.85	1.00	0.46	0.63
A9	2.86	1.04	1.31	1.47	1.79	1.71	1.86	2.19	1.00	1.38
A10	2.08	0.76	0.96	1.07	1.30	1.24	1.36	1.59	0.73	1.00
	18.91	6.88	8.69	9.75	11.84	11.31	12.33	14.50	6.61	9.10

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.53	5.29%	10.0
A2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.45	14.53%	10.0
A3	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.15	11.50%	10.0
A4	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.03	10.26%	10.0
A5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.84	8.45%	10.0
A6	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.88	8.84%	10.0
A7	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.81	8.11%	10.0
A8	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.69	6.90%	10.0
A9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.51	15.13%	10.0
A10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.99%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.46 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x2 (Weight).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.11	0.11
A2	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A3	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A4	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A5	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A6	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A7	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A8	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20
A9	9.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	1.00	1.00
A10	9.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	1.00	1.00
	68.00	17.14	17.14	17.14	17.14	17.14	17.14	17.14	3.51	3.51

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.14	1.36%	10.1
A2	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A3	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A4	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A5	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A6	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A7	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A8	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.3
A9	0.13	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.28	2.74	27.44%	10.4
A10	0.13	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.28	2.74	27.44%	10.4
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.3

lambda max	10.29	n =	10
consistency index (CI)	0.03196		
consistency ratio (CR)	0.02145		OK, quite consistent

C.47 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x3 (Screen size).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
A2	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A3	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A4	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A5	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A6	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A7	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A8	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A9	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A10	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2.80	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	3.57	35.71%	10.0
A2	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A3	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A4	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A5	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A6	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A7	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A8	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A9	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
A10	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.71	7.14%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	-2E-16		
consistency ratio (CR)	-1E-16		OK, quite consistent

C.48 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x4 (Memory).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	9.00	9.00
A2	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A3	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A4	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A5	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A6	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A7	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A8	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A9	0.11	0.20	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00
A10	0.11	0.20	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00
	2.22	14.40	14.40	14.40	14.40	14.40	14.40	14.40	46.00	46.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.45	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.20	0.20	4.24	42.44%	10.7
A2	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A3	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A4	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A5	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A6	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A7	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A8	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.77	7.68%	10.3
A9	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.19	1.91%	10.1
A10	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.19	1.91%	10.1
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.3

lambda max	10.28	n =	10
consistency index (CI)	0.03118		
consistency ratio (CR)	0.02093		OK, quite consistent

C.49 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x7 (Bar code reader).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A2	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A3	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A4	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A5	9.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	9.00	1.00
A6	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A7	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A8	9.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	9.00	1.00
A9	1.00	1.00	1.00	1.00	0.11	1.00	1.00	0.11	1.00	0.11
A10	9.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	9.00	1.00
	34.00	34.00	34.00	34.00	3.78	34.00	34.00	3.78	34.00	3.78

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A3	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A5	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	2.65	26.47%	10.0
A6	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A7	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A8	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	2.65	26.47%	10.0
A9	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	2.94%	10.0
A10	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	2.65	26.47%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.50 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x10 (Digital camera).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	9.00	9.00	1.00	1.00	9.00	1.00	1.00	9.00	9.00
A2	0.11	1.00	1.00	0.11	0.11	1.00	0.11	0.11	1.00	1.00
A3	0.11	1.00	1.00	0.11	0.11	1.00	0.11	0.11	1.00	1.00
A4	1.00	9.00	9.00	1.00	1.00	9.00	1.00	1.00	9.00	9.00
A5	1.00	9.00	9.00	1.00	1.00	9.00	1.00	1.00	9.00	9.00
A6	0.11	1.00	1.00	0.11	0.11	1.00	0.11	0.11	1.00	1.00
A7	1.00	9.00	9.00	1.00	1.00	9.00	1.00	1.00	9.00	9.00
A8	1.00	9.00	9.00	1.00	1.00	9.00	1.00	1.00	9.00	9.00
A9	0.11	1.00	1.00	0.11	0.11	1.00	0.11	0.11	1.00	1.00
A10	0.11	1.00	1.00	0.11	0.11	1.00	0.11	0.11	1.00	1.00
	5.56	50.00	50.00	5.56	5.56	50.00	5.56	5.56	50.00	50.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.80	18.00%	10.0
A2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.20	2.00%	10.0
A3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.20	2.00%	10.0
A4	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.80	18.00%	10.0
A5	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.80	18.00%	10.0
A6	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.20	2.00%	10.0
A7	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.80	18.00%	10.0
A8	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.80	18.00%	10.0
A9	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.20	2.00%	10.0
A10	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.20	2.00%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.51 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x13 (Operating system).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
A2	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A3	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A4	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A5	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A6	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A7	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A8	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A9	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A10	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2.29	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	4.38	43.75%	10.0
A2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A6	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A9	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
A10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.63	6.25%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.52 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x16 (Battery life).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
A2	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A3	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A4	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A5	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A6	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A7	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A8	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A9	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A10	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	64.00	9.14	9.14	9.14	9.14	9.14	9.14	9.14	9.14	9.14

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.16	1.56%	10.0
A2	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A3	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A4	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A5	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A6	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A7	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
A10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.09	10.94%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.53 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x17 (Wi-Fi internet connectivity).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A2	0.11	1.00	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
A3	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A4	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A5	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A6	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A7	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A8	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A9	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A10	1.00	9.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	9.11	82.00	9.11	9.11	9.11	9.11	9.11	9.11	9.11	9.11

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.12	1.22%	10.0
A3	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A4	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A5	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A6	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A7	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
A10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.10	10.98%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.54 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x18 (Screen type).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
A2	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A3	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A4	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A5	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A6	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A7	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A8	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.00	5.00
A9	0.11	0.20	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00
A10	0.11	0.20	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00
	2.00	16.40	16.40	16.40	16.40	16.40	16.40	16.40	46.00	46.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.50	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.20	0.20	4.73	47.33%	11.0
A2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A6	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.11	0.70	7.00%	10.4
A9	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.18	1.84%	10.2
A10	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.18	1.84%	10.2
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.4

lambda max	10.41	n =	10
consistency index (CI)	0.04502		
consistency ratio (CR)	0.03021		OK, quite consistent

C.55 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x19 (Web camera).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
A2	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A3	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A4	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A5	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A6	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A7	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A8	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A9	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A10	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	5.00	50.00%	10.0
A2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A6	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A9	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
A10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.56	5.56%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.56 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x20 (Mobile internet connectivity).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	1.00	1.00	1.00	1.00	0.11	0.11	0.11	1.00	1.00
A2	1.00	1.00	1.00	1.00	1.00	0.11	0.11	0.11	1.00	1.00
A3	1.00	1.00	1.00	1.00	1.00	0.11	0.11	0.11	1.00	1.00
A4	1.00	1.00	1.00	1.00	1.00	0.11	0.11	0.11	1.00	1.00
A5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	9.00
A6	9.00	9.00	9.00	9.00	1.00	1.00	1.00	1.00	9.00	9.00
A7	9.00	9.00	9.00	9.00	1.00	1.00	1.00	1.00	9.00	9.00
A8	9.00	9.00	9.00	9.00	1.00	1.00	1.00	1.00	9.00	9.00
A9	1.00	1.00	1.00	1.00	0.11	0.11	0.11	0.11	1.00	1.00
A10	1.00	1.00	1.00	1.00	0.11	0.11	0.11	0.11	1.00	1.00
	34.00	34.00	34.00	34.00	8.22	4.67	4.67	4.67	42.00	42.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.03	0.03	0.03	0.03	0.12	0.02	0.02	0.02	0.02	0.02	0.36	3.58%	11.1
A2	0.03	0.03	0.03	0.03	0.12	0.02	0.02	0.02	0.02	0.02	0.36	3.58%	11.1
A3	0.03	0.03	0.03	0.03	0.12	0.02	0.02	0.02	0.02	0.02	0.36	3.58%	11.1
A4	0.03	0.03	0.03	0.03	0.12	0.02	0.02	0.02	0.02	0.02	0.36	3.58%	11.1
A5	0.03	0.03	0.03	0.03	0.12	0.21	0.21	0.21	0.21	0.21	1.31	13.11%	10.7
A6	0.26	0.26	0.26	0.26	0.12	0.21	0.21	0.21	0.21	0.21	2.25	22.52%	11.3
A7	0.26	0.26	0.26	0.26	0.12	0.21	0.21	0.21	0.21	0.21	2.25	22.52%	11.3
A8	0.26	0.26	0.26	0.26	0.12	0.21	0.21	0.21	0.21	0.21	2.25	22.52%	11.3
A9	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.25	2.50%	11.3
A10	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.25	2.50%	11.3
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	11.2

lambda max	11.18	n =	10
consistency index (CI)	0.13148		
consistency ratio (CR)	0.08824		OK, quite consistent

C.57 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x21 (Hard disk drive).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
A2	0.11	1.00	0.20	0.20	0.20	0.14	0.14	0.14	3.00	3.00
A3	0.11	5.00	1.00	1.00	1.00	0.33	0.33	0.33	5.00	5.00
A4	0.11	5.00	1.00	1.00	1.00	0.33	0.33	0.33	5.00	5.00
A5	0.11	5.00	1.00	1.00	1.00	0.33	0.33	0.33	5.00	5.00
A6	0.11	7.00	3.00	3.00	3.00	1.00	1.00	1.00	7.00	7.00
A7	0.11	7.00	3.00	3.00	3.00	1.00	1.00	1.00	7.00	7.00
A8	0.11	7.00	3.00	3.00	3.00	1.00	1.00	1.00	7.00	7.00
A9	0.11	0.33	0.20	0.20	0.20	0.14	0.14	0.14	1.00	1.00
A10	0.11	0.33	0.20	0.20	0.20	0.14	0.14	0.14	1.00	1.00
	2.00	46.67	21.60	21.60	21.60	13.43	13.43	13.43	50.00	50.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.50	0.19	0.42	0.42	0.42	0.67	0.67	0.67	0.18	0.18	4.31	43.13%	12.9
A2	0.06	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.06	0.26	2.57%	9.9
A3	0.06	0.11	0.05	0.05	0.05	0.02	0.02	0.02	0.10	0.10	0.58	5.76%	10.8
A4	0.06	0.11	0.05	0.05	0.05	0.02	0.02	0.02	0.10	0.10	0.58	5.76%	10.8
A5	0.06	0.11	0.05	0.05	0.05	0.02	0.02	0.02	0.10	0.10	0.58	5.76%	10.8
A6	0.06	0.15	0.14	0.14	0.14	0.07	0.07	0.07	0.14	0.14	1.13	11.26%	11.6
A7	0.06	0.15	0.14	0.14	0.14	0.07	0.07	0.07	0.14	0.14	1.13	11.26%	11.6
A8	0.06	0.15	0.14	0.14	0.14	0.07	0.07	0.07	0.14	0.14	1.13	11.26%	11.6
A9	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.16	1.62%	10.6
A10	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.16	1.62%	10.6
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	11.1

lambda max	11.14	n =	10
consistency index (CI)	0.12611		
consistency ratio (CR)	0.08464		OK, quite consistent

C.58 Pair-wise comparison matrix and normalized matrix for Trimble models, based on factor x22 (Temperature of operation).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.00	1.00
A2	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A3	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A4	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A5	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A6	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A7	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A8	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00
A9	1.00	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.00	1.00
A10	1.00	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.00	1.00
	24.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	24.00	24.00

Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Sum	Priority vector	Lambda
A1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.42	4.17%	10.0
A2	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.25	12.50%	10.0
A9	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.42	4.17%	10.0
A10	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.42	4.17%	10.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00	10.0

lambda max	10.00	n =	10
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.59 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x6 (RFID reader).

	A1	A2	A3	A4
A1	1.00	3.00	3.00	5.00
A2	0.33	1.00	3.00	5.00
A3	0.33	0.33	1.00	3.00
A4	0.20	0.20	0.33	1.00
	1.87	4.53	7.33	14.00

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.54	0.66	0.41	0.36	1.96	49.09%	4.4
A2	0.18	0.22	0.41	0.36	1.17	29.13%	4.3
A3	0.18	0.07	0.14	0.21	0.60	15.07%	4.1
A4	0.11	0.04	0.05	0.07	0.27	6.70%	4.1
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.2

lambda max	4.20	n =	4
consistency index (CI)	0.06633		
consistency ratio (CR)	0.0737		OK, quite consistent

C.60 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x6 (RFID reader).

	A1	A2	A3	A4
A1	1.00	1.00	0.11	0.11
A2	1.00	1.00	0.11	0.11
A3	9.00	9.00	1.00	1.00
A4	9.00	9.00	1.00	1.00
	20.00	20.00	2.22	2.22

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.05	0.05	0.05	0.05	0.20	5.00%	4.0
A2	0.05	0.05	0.05	0.05	0.20	5.00%	4.0
A3	0.45	0.45	0.45	0.45	1.80	45.00%	4.0
A4	0.45	0.45	0.45	0.45	1.80	45.00%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.61 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x6 (Bar code reader).

	A1	A2	A3	A4
A1	1.00	1.00	1.00	0.11
A2	1.00	1.00	1.00	0.11
A3	1.00	1.00	1.00	0.11
A4	9.00	9.00	9.00	1.00
	12.00	12.00	12.00	1.33

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.08	0.08	0.08	0.08	0.33	8.33%	4.0
A2	0.08	0.08	0.08	0.08	0.33	8.33%	4.0
A3	0.08	0.08	0.08	0.08	0.33	8.33%	4.0
A4	0.75	0.75	0.75	0.75	3.00	75.00%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.62 Pair-wise comparison matrix and normalized matrix for Nexcom models, based on factor x20 (Mobile internet connectivity).

	A1	A2	A3	A4
A1	1.00	0.11	0.11	0.11
A2	9.00	1.00	1.00	1.00
A3	9.00	1.00	1.00	1.00
A4	9.00	1.00	1.00	1.00
	28.00	3.11	3.11	3.11

Normalized matrix

	A1	A2	A3	A4	Sum	Priority vector	Lambda
A1	0.04	0.04	0.04	0.04	0.14	3.57%	4.0
A2	0.32	0.32	0.32	0.32	1.29	32.14%	4.0
A3	0.32	0.32	0.32	0.32	1.29	32.14%	4.0
A4	0.32	0.32	0.32	0.32	1.29	32.14%	4.0
Sum	1.00	1.00	1.00	1.00	4.00	1.00	4.0

lambda max	4.00	n =	4	
consistency index (CI)	0			
consistency ratio (CR)	0			OK, quite consistent

C.63 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x1 (Cost).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.96	1.25	1.39	0.21	0.33	2.03	0.76	1.53	1.73	1.72
B2	0.51	1.00	0.64	0.71	0.11	0.17	1.04	0.39	0.78	0.88	0.88
B3	0.80	1.57	1.00	1.11	0.17	0.26	1.62	0.60	1.23	1.38	1.38
B4	0.72	1.41	0.90	1.00	0.15	0.24	1.46	0.54	1.10	1.24	1.24
B5	4.80	9.39	6.00	6.68	1.00	1.57	9.73	3.63	7.36	8.30	8.28
B6	3.05	5.97	3.81	4.25	0.64	1.00	6.18	2.30	4.68	5.28	5.26
B7	0.49	0.97	0.62	0.69	0.10	0.16	1.00	0.37	0.76	0.85	0.85
B8	1.32	2.59	1.65	1.84	0.28	0.43	2.68	1.00	2.03	2.29	2.28
B9	0.65	1.28	0.81	0.91	0.14	0.21	1.32	0.49	1.00	1.13	1.12
B10	0.58	1.13	0.72	0.80	0.12	0.19	1.17	0.44	0.89	1.00	1.00
B11	0.58	1.13	0.72	0.81	0.12	0.19	1.18	0.44	0.89	1.00	1.00
	14.52	28.39	18.12	20.19	3.02	4.76	29.40	10.96	22.25	25.09	25.01

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.76	6.89%	11.0
B2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.39	3.52%	11.0
B3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.61	5.52%	11.0
B4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.54	4.95%	11.0
B5	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.64	33.09%	11.0
B6	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	2.31	21.02%	11.0
B7	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.37	3.40%	11.0
B8	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1.00	9.12%	11.0
B9	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.49	4.49%	11.0
B10	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.44	3.99%	11.0
B11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.44	4.00%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.64 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x2 (Weight).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.73	0.30	0.85	0.07	0.76	1.43	0.28	0.63	0.91	0.73
B2	1.38	1.00	0.42	1.17	0.10	1.04	1.97	0.38	0.87	1.25	1.01
B3	3.29	2.39	1.00	2.79	0.23	2.49	4.72	0.91	2.09	2.99	2.41
B4	1.18	0.86	0.36	1.00	0.08	0.89	1.69	0.32	0.75	1.07	0.86
B5	14.40	10.47	4.37	12.22	1.00	10.90	20.63	3.97	9.12	13.09	10.54
B6	1.32	0.96	0.40	1.12	0.09	1.00	1.89	0.36	0.84	1.20	0.97
B7	0.70	0.51	0.21	0.59	0.05	0.53	1.00	0.19	0.44	0.63	0.51
B8	3.63	2.64	1.10	3.08	0.25	2.75	5.20	1.00	2.30	3.30	2.66
B9	1.58	1.15	0.48	1.34	0.11	1.19	2.26	0.43	1.00	1.43	1.16
B10	1.10	0.80	0.33	0.93	0.08	0.83	1.58	0.30	0.70	1.00	0.81
B11	1.37	0.99	0.41	1.16	0.09	1.03	1.96	0.38	0.87	1.24	1.00
	30.94	22.50	9.40	26.25	2.15	23.42	44.32	8.52	19.60	28.12	22.65

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.36	3.23%	11.0
B2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.49	4.44%	11.0
B3	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B4	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.42	3.81%	11.0
B5	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	5.12	46.54%	11.0
B6	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.47	4.27%	11.0
B7	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.25	2.26%	11.0
B8	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.29	11.73%	11.0
B9	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56	5.10%	11.0
B10	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.39	3.56%	11.0
B11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.49	4.42%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.65 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x3 (Screen size).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.20	2.40	1.00	2.40	0.87	0.81	1.68	1.50	0.81	0.81
B2	0.83	1.00	2.00	0.83	2.00	0.72	0.67	1.40	1.25	0.67	0.67
B3	0.42	0.50	1.00	0.42	1.00	0.36	0.34	0.70	0.63	0.34	0.34
B4	1.00	1.20	2.40	1.00	2.40	0.87	0.81	1.68	1.50	0.81	0.81
B5	0.42	0.50	1.00	0.42	1.00	0.36	0.34	0.70	0.63	0.34	0.34
B6	1.15	1.39	2.77	1.15	2.77	1.00	0.93	1.94	1.73	0.93	0.93
B7	1.24	1.49	2.97	1.24	2.97	1.07	1.00	2.08	1.86	1.00	1.00
B8	0.60	0.71	1.43	0.60	1.43	0.52	0.48	1.00	0.89	0.48	0.48
B9	0.67	0.80	1.60	0.67	1.60	0.58	0.54	1.12	1.00	0.54	0.54
B10	1.24	1.49	2.97	1.24	2.97	1.07	1.00	2.08	1.86	1.00	1.00
B11	1.24	1.49	2.97	1.24	2.97	1.07	1.00	2.08	1.86	1.00	1.00
	9.80	11.76	23.51	9.80	23.51	8.48	7.91	16.46	14.70	7.91	7.91

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.12	10.21%	11.0
B2	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.94	8.51%	11.0
B3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.47	4.25%	11.0
B4	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.12	10.21%	11.0
B5	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.47	4.25%	11.0
B6	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.30	11.79%	11.0
B7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.39	12.64%	11.0
B8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.67	6.08%	11.0
B9	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.75	6.80%	11.0
B10	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.39	12.64%	11.0
B11	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.39	12.64%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.66 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x4 (Memory).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.00	7.81	1.00	15.63	0.06	1.00	1.00	0.50	0.25	0.50
B2	1.00	1.00	7.81	1.00	15.63	0.06	1.00	1.00	0.50	0.25	0.50
B3	0.13	0.13	1.00	0.13	2.00	0.01	0.13	0.13	0.06	0.03	0.06
B4	1.00	1.00	7.81	1.00	15.63	0.06	1.00	1.00	0.50	0.25	0.50
B5	0.06	0.06	0.50	0.06	1.00	0.00	0.06	0.06	0.03	0.02	0.03
B6	16.00	16.00	125.00	16.00	250.00	1.00	16.00	16.00	8.00	4.00	8.00
B7	1.00	1.00	7.81	1.00	15.63	0.06	1.00	1.00	0.50	0.25	0.50
B8	1.00	1.00	7.81	1.00	15.63	0.06	1.00	1.00	0.50	0.25	0.50
B9	2.00	2.00	15.63	2.00	31.25	0.13	2.00	2.00	1.00	0.50	1.00
B10	4.00	4.00	31.25	4.00	62.50	0.25	4.00	4.00	2.00	1.00	2.00
B11	2.00	2.00	15.63	2.00	31.25	0.13	2.00	2.00	1.00	0.50	1.00
	29.19	29.19	228.06	29.19	456.13	1.82	29.19	29.19	14.60	7.30	14.60

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.43%	11.0
B2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.43%	11.0
B3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.44%	11.0
B4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.43%	11.0
B5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.22%	11.0
B6	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	6.03	54.81%	11.0
B7	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.43%	11.0
B8	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.43%	11.0
B9	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.75	6.85%	11.0
B10	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	1.51	13.70%	11.0
B11	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.75	6.85%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.67 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factors x6 (RFID reader) and x7 (Bar code reader).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B10	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	1.00
B11	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	1.00
	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	3.00	3.00

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B4	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B5	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B6	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B7	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B8	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B9	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B10	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.67	33.33%	11.0
B11	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.67	33.33%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.68 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x9 (Ruggedized construction).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.33	0.33	1.00	9.00	9.00	0.33	9.00	0.33	1.00	1.00
B2	3.00	1.00	1.00	3.00	9.00	9.00	1.00	9.00	1.00	3.00	3.00
B3	3.00	1.00	1.00	3.00	9.00	9.00	1.00	9.00	1.00	3.00	3.00
B4	1.00	0.33	0.33	1.00	9.00	9.00	0.33	9.00	0.33	1.00	1.00
B5	0.11	0.11	0.11	0.11	1.00	1.00	0.11	1.00	0.11	0.11	0.11
B6	0.11	0.11	0.11	0.11	1.00	1.00	0.11	1.00	0.11	0.11	0.11
B7	3.00	1.00	1.00	3.00	9.00	9.00	1.00	9.00	1.00	3.00	3.00
B8	0.11	0.11	0.11	0.11	1.00	1.00	0.11	1.00	0.11	0.11	0.11
B9	3.00	1.00	1.00	3.00	9.00	9.00	1.00	9.00	1.00	3.00	3.00
B10	1.00	0.33	0.33	1.00	9.00	9.00	0.33	9.00	0.33	1.00	1.00
B11	1.00	0.33	0.33	1.00	9.00	9.00	0.33	9.00	0.33	1.00	1.00
	16.33	5.67	5.67	16.33	75.00	75.00	5.67	75.00	5.67	16.33	16.33

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.06	0.06	0.06	0.06	0.12	0.12	0.06	0.12	0.06	0.06	0.06	0.84	7.64%	11.5
B2	0.18	0.18	0.18	0.18	0.12	0.12	0.18	0.12	0.18	0.18	0.18	1.80	16.37%	11.8
B3	0.18	0.18	0.18	0.18	0.12	0.12	0.18	0.12	0.18	0.18	0.18	1.80	16.37%	11.8
B4	0.06	0.06	0.06	0.06	0.12	0.12	0.06	0.12	0.06	0.06	0.06	0.84	7.64%	11.5
B5	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.15	1.32%	11.1
B6	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.15	1.32%	11.1
B7	0.18	0.18	0.18	0.18	0.12	0.12	0.18	0.12	0.18	0.18	0.18	1.80	16.37%	11.8
B8	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.15	1.32%	11.1
B9	0.18	0.18	0.18	0.18	0.12	0.12	0.18	0.12	0.18	0.18	0.18	1.80	16.37%	11.8
B10	0.06	0.06	0.06	0.06	0.12	0.12	0.06	0.12	0.06	0.06	0.06	0.84	7.64%	11.5
B11	0.06	0.06	0.06	0.06	0.12	0.12	0.06	0.12	0.06	0.06	0.06	0.84	7.64%	11.5
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.5

lambda max	11.50	n =	11
consistency index (CI)	0.04964		
consistency ratio (CR)	0.03287		OK, quite consistent

C.69 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x10 (Digital camera).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	3.00	0.33	9.00	9.00	9.00	9.00	9.00	9.00	0.33	9.00
B2	0.33	1.00	0.20	9.00	9.00	9.00	9.00	9.00	9.00	0.20	9.00
B3	3.00	5.00	1.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	9.00
B4	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B5	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B6	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B7	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B8	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B9	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B10	3.00	5.00	1.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	9.00
B11	0.11	0.11	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
	8.11	14.78	3.31	43.00	43.00	43.00	43.00	43.00	43.00	3.31	43.00

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.12	0.20	0.10	0.21	0.21	0.21	0.21	0.21	0.21	0.10	0.21	1.99	18.12%	12.4
B2	0.04	0.07	0.06	0.21	0.21	0.21	0.21	0.21	0.21	0.06	0.21	1.69	15.41%	11.4
B3	0.37	0.34	0.30	0.21	0.21	0.21	0.21	0.21	0.21	0.30	0.21	2.78	25.25%	12.9
B4	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
B5	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
B6	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
B7	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
B8	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
B9	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
B10	0.37	0.34	0.30	0.21	0.21	0.21	0.21	0.21	0.21	0.30	0.21	2.78	25.25%	12.9
B11	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.25	2.28%	11.1
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.6

lambda max	11.57	n =	11
consistency index (CI)	0.05661		
consistency ratio (CR)	0.03749		OK, quite consistent

C.70 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x13 (Operating system).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B2	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B3	0.20	0.20	1.00	0.20	1.00	0.20	0.20	0.20	0.20	0.20	0.20
B4	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B5	0.20	0.20	1.00	0.20	1.00	0.20	0.20	0.20	0.20	0.20	0.20
B6	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B7	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B8	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B9	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B10	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
B11	1.00	1.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00
	9.40	9.40	47.00	9.40	47.00	9.40	9.40	9.40	9.40	9.40	9.40

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B2	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.23	2.13%	11.0
B4	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.23	2.13%	11.0
B6	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B7	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
B11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.64%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	1.8E-16		
consistency ratio (CR)	1.2E-16		OK, quite consistent

C.71 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x14 (Environment protection).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.11	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
B2	9.00	1.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
B3	1.00	0.11	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
B4	1.00	0.11	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
B5	1.00	0.11	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
B6	9.00	1.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
B7	1.00	0.11	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
B8	1.00	0.11	1.00	1.00	1.00	0.11	1.00	1.00	0.11	0.11	0.11
B9	9.00	1.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	3.00
B10	9.00	1.00	9.00	9.00	9.00	1.00	9.00	9.00	1.00	1.00	1.00
B11	9.00	1.00	9.00	9.00	9.00	1.00	9.00	9.00	0.33	1.00	1.00
	51.00	5.67	51.00	51.00	51.00	5.67	51.00	51.00	5.00	5.67	7.67

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.21	1.94%	11.1
B2	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.20	0.18	0.13	1.92	17.44%	11.1
B3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.21	1.94%	11.1
B4	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.21	1.94%	11.1
B5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.21	1.94%	11.1
B6	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.20	0.18	0.13	1.92	17.44%	11.1
B7	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.21	1.94%	11.1
B8	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.21	1.94%	11.1
B9	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.20	0.18	0.39	2.18	19.81%	11.4
B10	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.20	0.18	0.13	1.92	17.44%	11.1
B11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.07	0.18	0.13	1.79	16.23%	11.1
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.1

lambda max	11.10	n =	11
consistency index (CI)	0.00961		
consistency ratio (CR)	0.00637		OK, quite consistent

C.72 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x15 (Handwriting recognition).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.00	0.11	0.14	0.14	1.00	0.11	0.11	0.11	0.11	0.14
B2	1.00	1.00	0.11	0.14	0.14	1.00	0.11	0.11	0.11	0.11	0.14
B3	9.00	9.00	1.00	5.00	5.00	9.00	1.00	1.00	1.00	1.00	5.00
B4	7.00	7.00	0.20	1.00	1.00	3.00	0.20	0.20	0.20	0.20	1.00
B5	7.00	7.00	0.20	1.00	1.00	7.00	0.20	0.20	0.20	0.20	1.00
B6	1.00	1.00	0.11	0.33	0.14	1.00	0.11	0.11	0.11	0.11	0.14
B7	9.00	9.00	1.00	5.00	5.00	9.00	1.00	1.00	1.00	1.00	5.00
B8	9.00	9.00	1.00	5.00	5.00	9.00	1.00	1.00	1.00	1.00	5.00
B9	9.00	9.00	1.00	5.00	5.00	9.00	1.00	1.00	1.00	1.00	5.00
B10	9.00	9.00	1.00	5.00	5.00	9.00	1.00	1.00	1.00	1.00	5.00
B11	7.00	7.00	0.20	1.00	1.00	7.00	0.20	0.20	0.20	0.20	1.00
	69.00	69.00	5.93	28.62	28.43	65.00	5.93	5.93	5.93	5.93	28.43

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.01	0.01	0.02	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.15	1.39%	11.0
B2	0.01	0.01	0.02	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.15	1.39%	11.0
B3	0.13	0.13	0.17	0.17	0.18	0.14	0.17	0.17	0.17	0.17	0.18	1.77	16.08%	12.2
B4	0.10	0.10	0.03	0.03	0.04	0.05	0.03	0.03	0.03	0.03	0.04	0.52	4.75%	11.6
B5	0.10	0.10	0.03	0.03	0.04	0.11	0.03	0.03	0.03	0.03	0.04	0.58	5.31%	11.5
B6	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.16	1.45%	11.2
B7	0.13	0.13	0.17	0.17	0.18	0.14	0.17	0.17	0.17	0.17	0.18	1.77	16.08%	12.2
B8	0.13	0.13	0.17	0.17	0.18	0.14	0.17	0.17	0.17	0.17	0.18	1.77	16.08%	12.2
B9	0.13	0.13	0.17	0.17	0.18	0.14	0.17	0.17	0.17	0.17	0.18	1.77	16.08%	12.2
B10	0.13	0.13	0.17	0.17	0.18	0.14	0.17	0.17	0.17	0.17	0.18	1.77	16.08%	12.2
B11	0.10	0.10	0.03	0.03	0.04	0.11	0.03	0.03	0.03	0.03	0.04	0.58	5.31%	11.5
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.7

lambda max	11.70	n =	11
consistency index (CI)	0.0699		
consistency ratio (CR)	0.04629		OK, quite consistent

C.73 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x16 (Battery life).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.38	0.30	0.45	0.86	0.30	0.67	0.86	0.33	0.75	0.60
B2	2.67	1.00	0.80	1.19	2.29	0.80	1.78	2.29	0.89	2.00	1.60
B3	3.33	1.25	1.00	1.49	2.86	1.00	2.22	2.86	1.11	2.50	2.00
B4	2.23	0.84	0.67	1.00	1.91	0.67	1.49	1.91	0.74	1.68	1.34
B5	1.17	0.44	0.35	0.52	1.00	0.35	0.78	1.00	0.39	0.88	0.70
B6	3.33	1.25	1.00	1.49	2.86	1.00	2.22	2.86	1.11	2.50	2.00
B7	1.50	0.56	0.45	0.67	1.29	0.45	1.00	1.29	0.50	1.13	0.90
B8	1.17	0.44	0.35	0.52	1.00	0.35	0.78	1.00	0.39	0.88	0.70
B9	3.00	1.13	0.90	1.34	2.57	0.90	2.00	2.57	1.00	2.25	1.80
B10	1.33	0.50	0.40	0.60	1.14	0.40	0.89	1.14	0.44	1.00	0.80
B11	1.67	0.63	0.50	0.75	1.43	0.50	1.11	1.43	0.56	1.25	1.00
	22.40	8.40	6.72	10.03	19.20	6.72	14.93	19.20	7.47	16.80	13.44

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.49	4.46%	11.0
B2	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.31	11.90%	11.0
B3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.64	14.88%	11.0
B4	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.10	9.97%	11.0
B5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.57	5.21%	11.0
B6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.64	14.88%	11.0
B7	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.74	6.70%	11.0
B8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.57	5.21%	11.0
B9	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.47	13.39%	11.0
B10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.65	5.95%	11.0
B11	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.82	7.44%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.74 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x19 (Web camera).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B2	9.00	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	3.00	1.00
B3	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B4	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B5	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B6	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B7	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B8	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B9	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.11	0.11
B10	9.00	0.33	9.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	0.33
B11	9.00	1.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	3.00	1.00
	35.00	3.22	35.00	35.00	35.00	35.00	35.00	35.00	35.00	7.89	3.22

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B2	0.26	0.31	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.38	0.31	3.06	27.80%	11.7
B3	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B6	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B7	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B8	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B9	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.31	2.83%	11.0
B10	0.26	0.10	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.13	0.10	2.39	21.73%	11.2
B11	0.26	0.31	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.38	0.31	3.06	27.80%	11.7
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.2

lambda max	11.17	n =	11
consistency index (CI)	0.01698		
consistency ratio (CR)	0.01124		OK, quite consistent

C.75 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x20 (Mobile internet connectivity).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B2	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B3	9.00	9.00	1.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	9.00
B4	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B5	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B6	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B7	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B8	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B9	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
B10	9.00	9.00	1.00	9.00	9.00	9.00	9.00	9.00	9.00	1.00	9.00
B11	1.00	1.00	0.11	1.00	1.00	1.00	1.00	1.00	1.00	0.11	1.00
	27.00	27.00	3.00	27.00	27.00	27.00	27.00	27.00	27.00	3.00	27.00

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B3	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.67	33.33%	11.0
B4	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B5	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B6	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B7	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B8	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B9	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
B10	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.67	33.33%	11.0
B11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.41	3.70%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.76 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x21 (Hard disk drive).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.89	4.00	2.00	8.00	2.67	1.14	1.60	0.80	1.14	0.80
B2	1.13	1.00	4.50	2.25	9.00	3.00	1.29	1.80	0.90	1.29	0.90
B3	0.25	0.22	1.00	0.50	2.00	0.67	0.29	0.40	0.20	0.29	0.20
B4	0.50	0.44	2.00	1.00	4.00	1.33	0.57	0.80	0.40	0.57	0.40
B5	0.13	0.11	0.50	0.25	1.00	0.33	0.14	0.20	0.10	0.14	0.10
B6	0.38	0.33	1.50	0.75	3.00	1.00	0.43	0.60	0.30	0.43	0.30
B7	0.88	0.78	3.50	1.75	7.00	2.33	1.00	1.40	0.70	1.00	0.70
B8	0.63	0.56	2.50	1.25	5.00	1.67	0.71	1.00	0.50	0.71	0.50
B9	1.25	1.11	5.00	2.50	10.00	3.33	1.43	2.00	1.00	1.43	1.00
B10	0.88	0.78	3.50	1.75	7.00	2.33	1.00	1.40	0.70	1.00	0.70
B11	1.25	1.11	5.00	2.50	10.00	3.33	1.43	2.00	1.00	1.43	1.00
	8.25	7.33	33.00	16.50	66.00	22.00	9.43	13.20	6.60	9.43	6.60

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.33	12.12%	11.0
B2	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	1.50	13.64%	11.0
B3	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.33	3.03%	11.0
B4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.67	6.06%	11.0
B5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.17	1.52%	11.0
B6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.50	4.55%	11.0
B7	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.61%	11.0
B8	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.83	7.58%	11.0
B9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.67	15.15%	11.0
B10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.17	10.61%	11.0
B11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.67	15.15%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.77 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x22 (Temperature of operation).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	0.80	0.80	1.33	8.00	1.60	1.00	8.00	2.67	2.00	2.67
B2	1.25	1.00	1.00	1.67	10.00	2.00	1.25	10.00	3.33	2.50	3.33
B3	1.25	1.00	1.00	1.67	10.00	2.00	1.25	10.00	3.33	2.50	3.33
B4	0.75	0.60	0.60	1.00	6.00	1.20	0.75	6.00	2.00	1.50	2.00
B5	0.13	0.10	0.10	0.17	1.00	0.20	0.13	1.00	0.33	0.25	0.33
B6	0.63	0.50	0.50	0.83	5.00	1.00	0.63	5.00	1.67	1.25	1.67
B7	1.00	0.80	0.80	1.33	8.00	1.60	1.00	8.00	2.67	2.00	2.67
B8	0.13	0.10	0.10	0.17	1.00	0.20	0.13	1.00	0.33	0.25	0.33
B9	0.38	0.30	0.30	0.50	3.00	0.60	0.38	3.00	1.00	0.75	1.00
B10	0.50	0.40	0.40	0.67	4.00	0.80	0.50	4.00	1.33	1.00	1.33
B11	0.38	0.30	0.30	0.50	3.00	0.60	0.38	3.00	1.00	0.75	1.00
	7.38	5.90	5.90	9.83	59.00	11.80	7.38	59.00	19.67	14.75	19.67

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	1.49	13.56%	11.0
B2	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	1.86	16.95%	11.0
B3	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	1.86	16.95%	11.0
B4	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.12	10.17%	11.0
B5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.19	1.69%	11.0
B6	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.93	8.47%	11.0
B7	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	1.49	13.56%	11.0
B8	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.19	1.69%	11.0
B9	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56	5.08%	11.0
B10	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.75	6.78%	11.0
B11	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56	5.08%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

C.78 Pair-wise comparison matrix and normalized matrix for the final analysis, based on factor x23 (Warranty).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1.00	2.00	0.67	0.40	2.00	1.00	0.67	0.67	0.67	0.67	0.67
B2	0.50	1.00	0.33	0.20	1.00	0.50	0.33	0.33	0.33	0.33	0.33
B3	1.50	3.00	1.00	0.60	3.00	1.50	1.00	1.00	1.00	1.00	1.00
B4	2.50	5.00	1.67	1.00	5.00	2.50	1.67	1.67	1.67	1.67	1.67
B5	0.50	1.00	0.33	0.20	1.00	0.50	0.33	0.33	0.33	0.33	0.33
B6	1.00	2.00	0.67	0.40	2.00	1.00	0.67	0.67	0.67	0.67	0.67
B7	1.50	3.00	1.00	0.60	3.00	1.50	1.00	1.00	1.00	1.00	1.00
B8	1.50	3.00	1.00	0.60	3.00	1.50	1.00	1.00	1.00	1.00	1.00
B9	1.50	3.00	1.00	0.60	3.00	1.50	1.00	1.00	1.00	1.00	1.00
B10	1.50	3.00	1.00	0.60	3.00	1.50	1.00	1.00	1.00	1.00	1.00
B11	1.50	3.00	1.00	0.60	3.00	1.50	1.00	1.00	1.00	1.00	1.00
	14.50	29.00	9.67	5.80	29.00	14.50	9.67	9.67	9.67	9.67	9.67

Normalized matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	Sum	Priority vector	Lambda
B1	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.76	6.90%	11.0
B2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.45%	11.0
B3	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.14	10.34%	11.0
B4	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	1.90	17.24%	11.0
B5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.38	3.45%	11.0
B6	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.76	6.90%	11.0
B7	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.14	10.34%	11.0
B8	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.14	10.34%	11.0
B9	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.14	10.34%	11.0
B10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.14	10.34%	11.0
B11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.14	10.34%	11.0
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00	11.0

lambda max	11.00	n =	11
consistency index (CI)	0		
consistency ratio (CR)	0		OK, quite consistent

Appendix D Slide show presented to subjects during the testing phase of the proposed system.

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

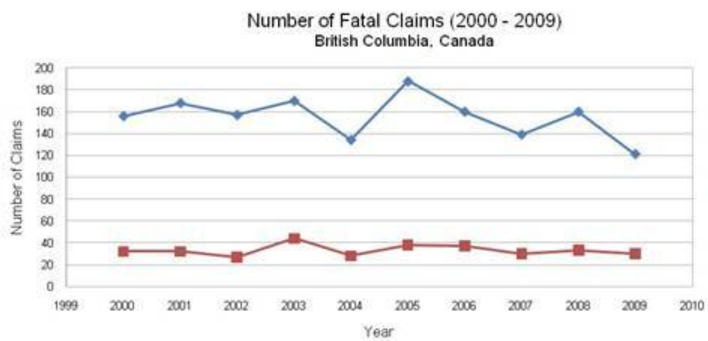
Real Time Information and Communication System to Improve Construction Safety (C-RTICS^2)

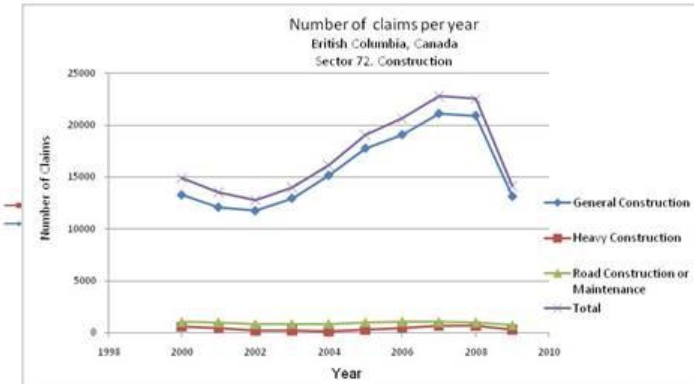
Gustavo E. Aguilar
MASc Student
Civil Engineering

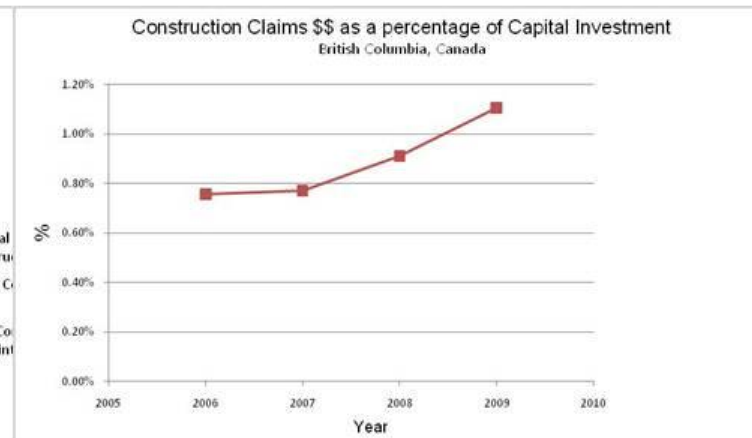
Supervisor: Kasun N. Hewage, P.Eng., PhD
Assistant Professor
Civil Engineering

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

WHY CONSTRUCTION SAFETY?





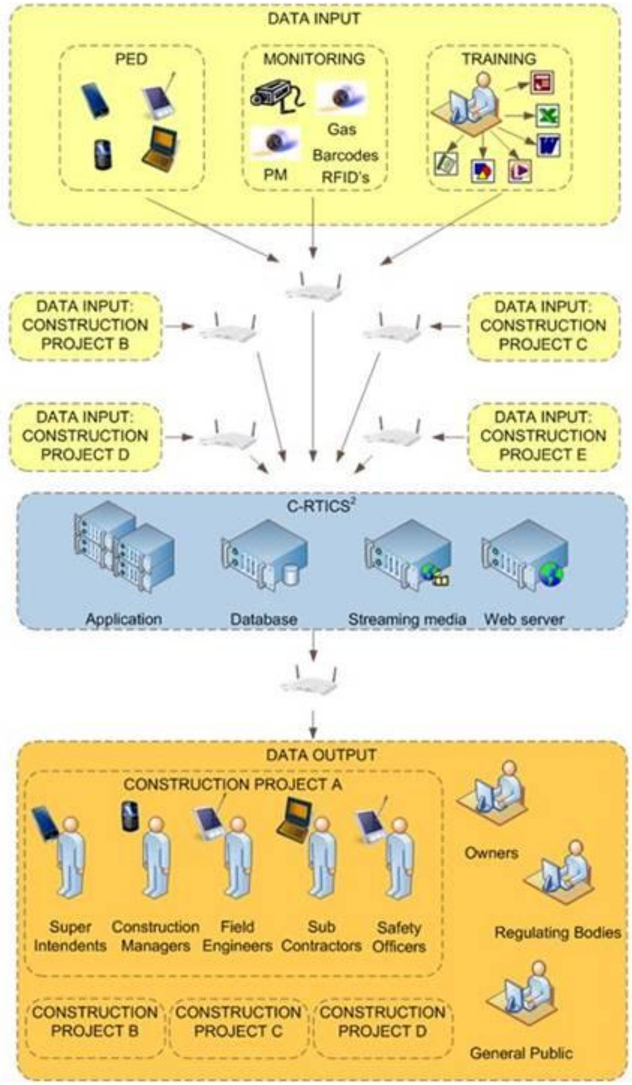


2

Construction-Real Time Information and Communication System for Safety (C-RTICS²)

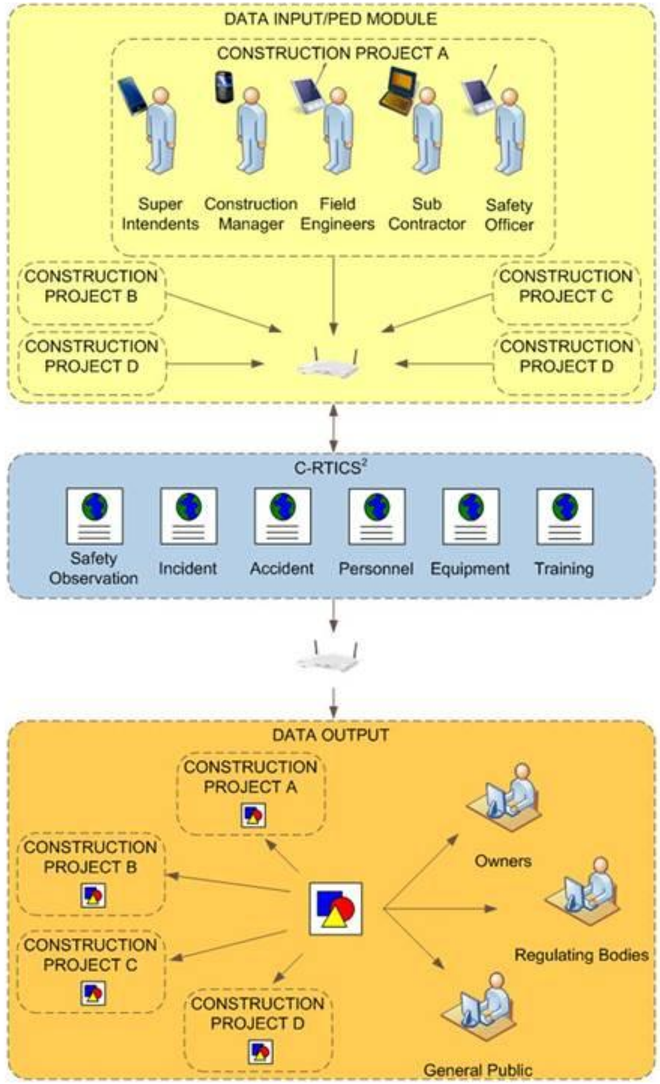
- Founding principles:
  - Free use and access
  - RIR and LTCR per project (RIR_{PP}, $LTCR_{PP}$) and project type (RIR_C , $LTCR_C$,RIR_R , $LTCR_R$,RIR_I , $LTCR_I$,RIR_T , $LTCR_T$)
  - Industry wide information (Collaboration!)
  - UBC-O as the administrator of the system (phase 1)

• C-RTICS^2

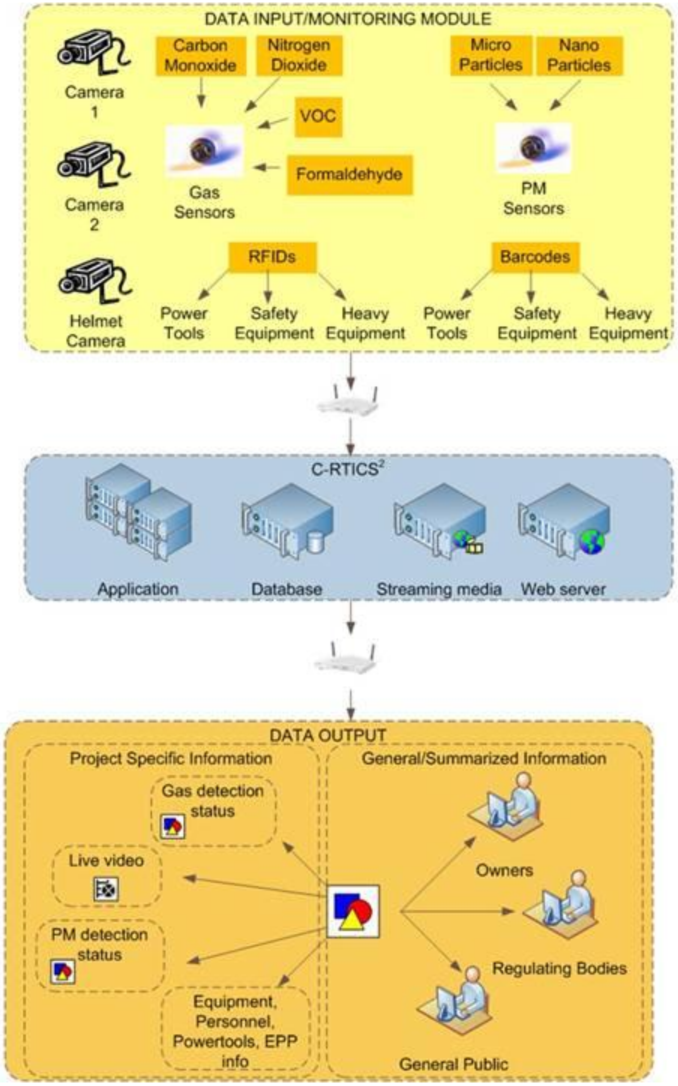


DATA INPUT
PED
MONITORING
Gas
Barcodes
PM
RFID's
TRAINING
DATA INPUT: CONSTRUCTION PROJECT B
DATA INPUT: CONSTRUCTION PROJECT C
DATA INPUT: CONSTRUCTION PROJECT D
DATA INPUT: CONSTRUCTION PROJECT E
C-RTICS2
Application
Database
Streaming media
Web server
DATA OUTPUT
CONSTRUCTION PROJECT A
Super Intendents
Construction Managers
Field Engineers
Sub Contractors
Safety Officers
Owners
Regulating Bodies
General Public
CONSTRUCTION PROJECT B
CONSTRUCTION PROJECT C
CONSTRUCTION PROJECT D

C-RTICS^2
PED Module



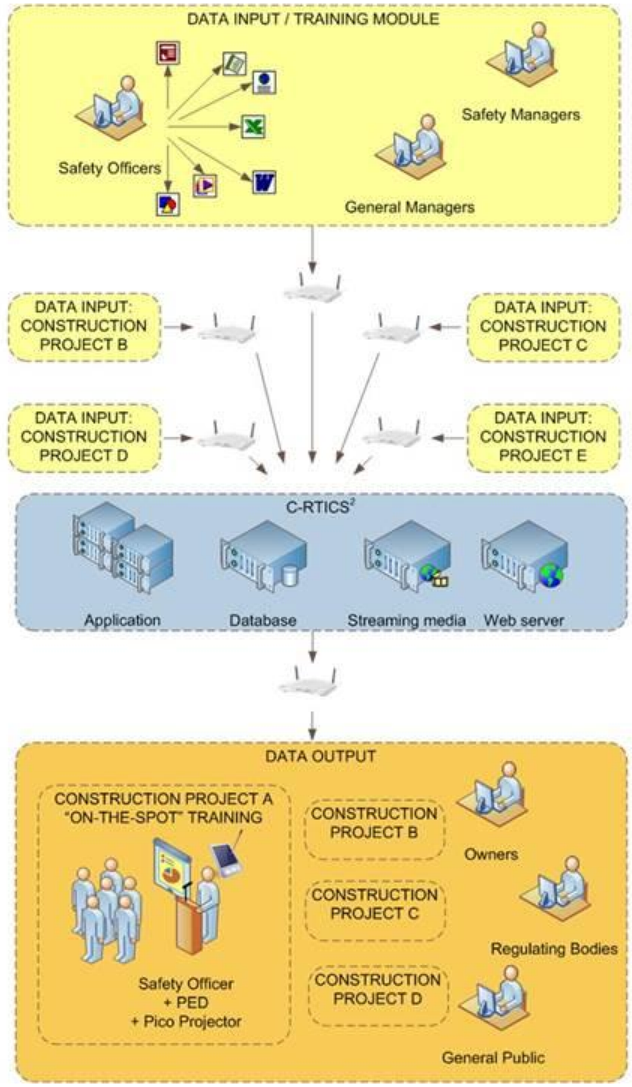
C-RTICS^2
Monitoring Module



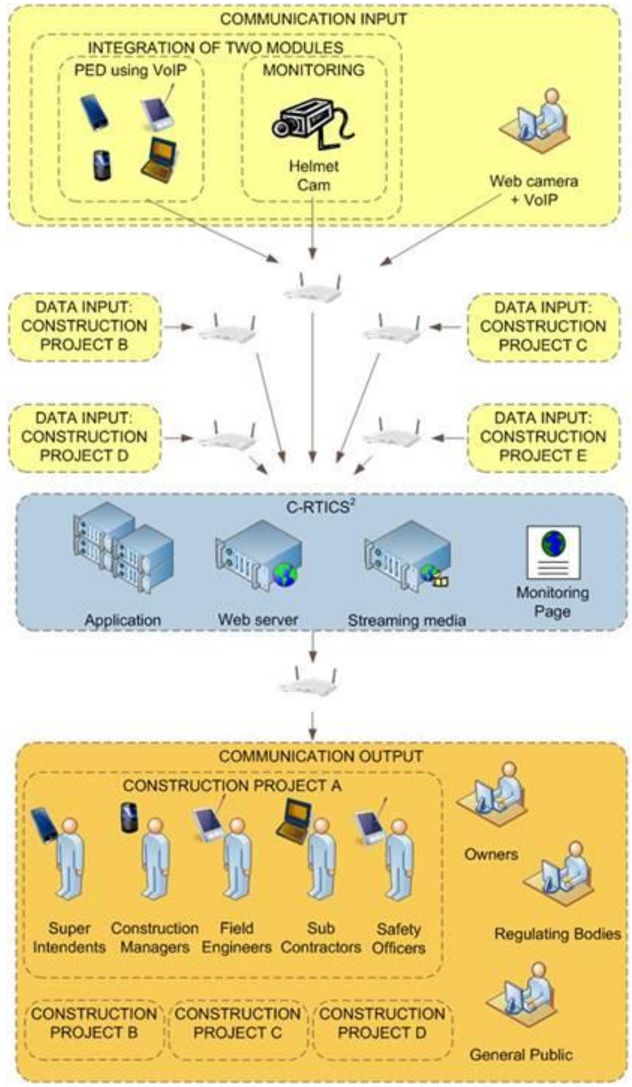
a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

6

C-RTICS^2
Training Module



C-RTICS^2
Communication



8

C-RTICS² Project Report

Project: UBC-O Engineering and Management Building
Project Type: Commercial
Start date: January 2009
End Date: June 2011
Total Employees: 250
Total Worked Hours: 1,620,000
Number of Incidents: 25
Number of Accidents: 10
RIR_{pp}: 1.54E-5 **RIR_{C}:** 2.2E-5
$LTCR_{pp}$: 0.62E-5 **$LTCR_{C}$:** 0.3E-5

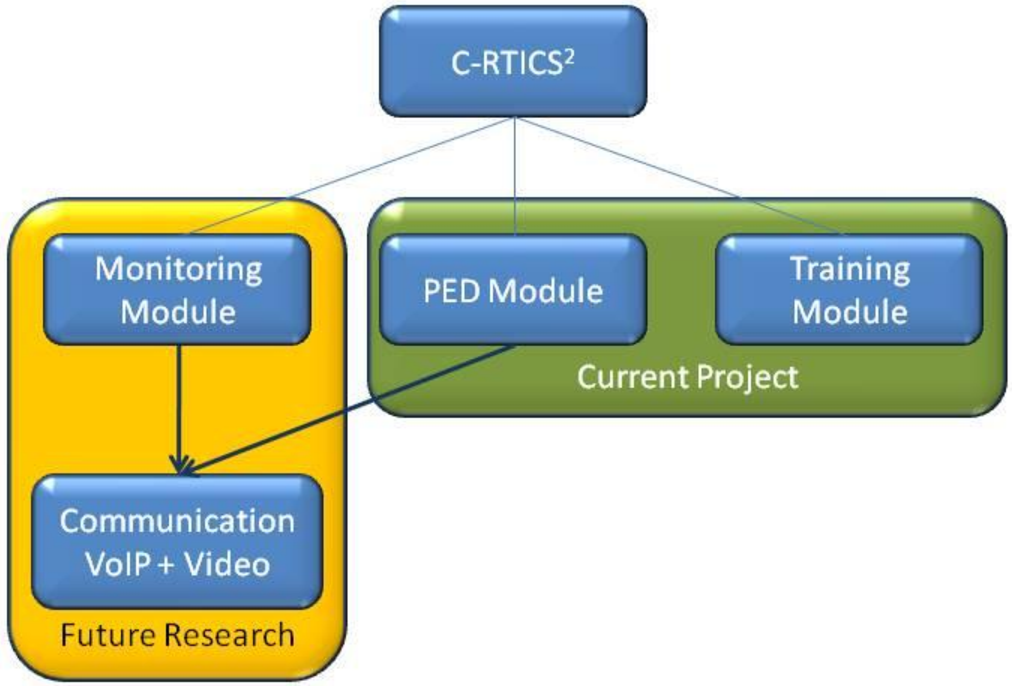
Incidents, Accidents, and Safety Observations

Date	SubC	Pers.	Equip	Root Cause	Const. Zone	Trade	Activity	Consequence	Body Part
Feb.25,2011	A	Mike Harris	Excavator 1	Weather /rain	Parking lot	Equip. Operators	Excavation	Broken Water main	N/A
Feb.26,2011	A	Mike Harris	Excavator 1	Distraction	Parking lot	Equip. Operators	Excavation	Broken Gas Pipe	N/A

9

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

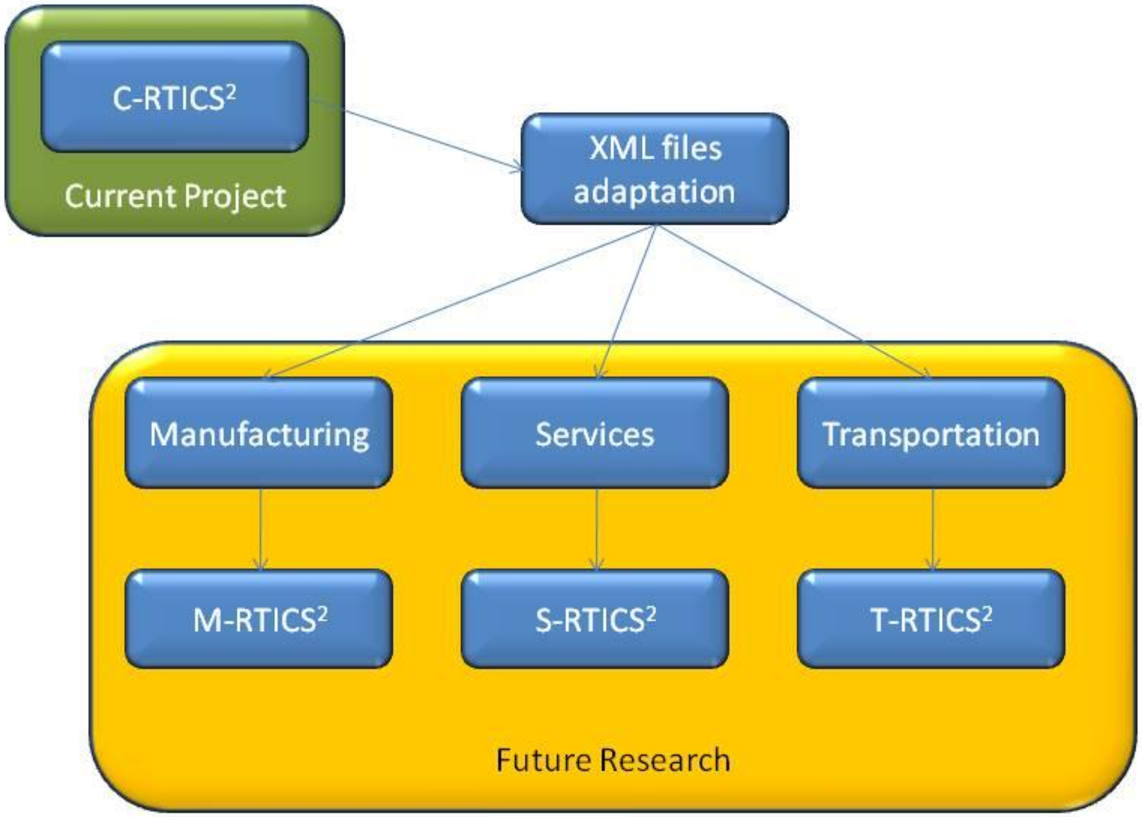
Future research



10

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Future research



11

Appendix E Investment Analysis

As described in chapter 2, a crucial element of the proposed system is eliminating the cost barrier for potential users. This founding principle calls for a major sponsor to cover the costs attached to its full programming, development, testing and implementation. An investment analysis was performed from the perspective of BC's WCB. However, the analysis procedure can be easily adapted to WCBs from other Canadian provinces by using their historical information.

The analysis was performed in three steps, described as follows: Step 1: estimation of the present worth value under current practices (PW_{CP}). Step 2: estimation of C-RTICS^2 present worth ($PW_{C\text{-}RTICS2}$). Step 3: estimation of the minimum required annual savings to justify the investment in C-RTICS^2. Each one of the steps is described in the following sections.

E.1 Step 1: estimation of the present worth value under current practices (PW_{CP})

Figure E.1 shows the cash flow diagram used for the calculation of PW_{CP}. Historical information was obtained for the following variables included in the analysis: a) amount of money paid by BC's WCB due to construction claims from 2006 to 2010 (WorkSfeBC 2011), and b) capital investment in BC's CI for the same period of time (CSC 2011). This information was used to calculate the percentage of the capital investment in BC's CI used to pay compensations derived from accepted claims. It was found that in 2006 the amount paid due to construction claims represented a 0.71% of the capital investment in BC's CI for the same year. This percentage increased to 0.74% in 2007 (3.7% increase), then to 0.86% in 2008 (16.4% increase), and to 1.00% in 2009 (16.4% increase). In 2010, such percentage dropped to 0.92% (8.6% reduction from 2009 value). From 2006 to 2010, a yearly average of 0.85% of the capital investment in BC's CI was used to pay for compensations due to injuries, with a standard deviation of 0.12%. As shown in Figure E.2, a normal distribution test plot was performed to verify the distribution of the sample. A good fit to the linear trend was obtained (R^2= 0.95).

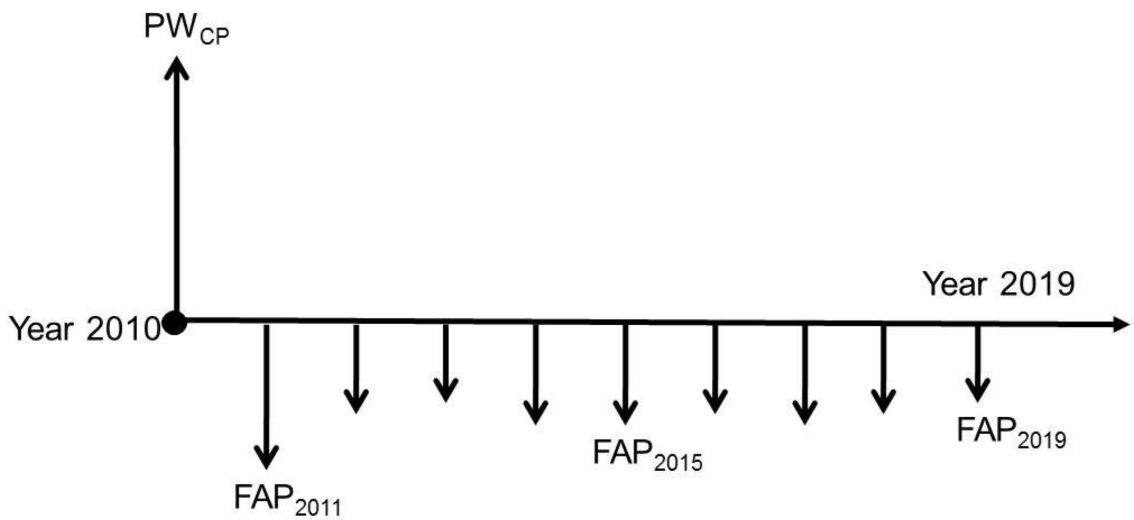


Figure E. 1 Cash Flow Diagram used to calculate the present worth under current practices (PW_{CP})

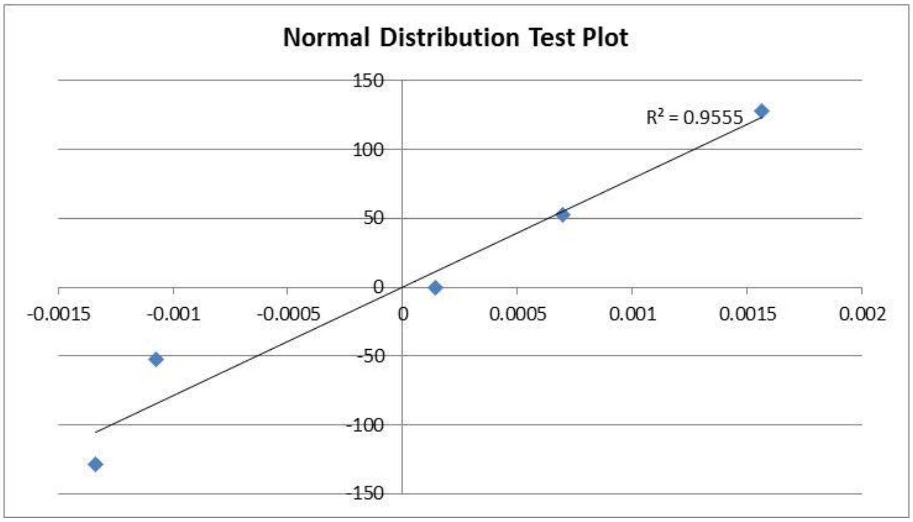


Figure E. 2 Normal distribution test plot for the percentage of the capital investment in BC's CI used to pay for construction claims

Future annual payments (FAP) were estimated for each year from 2011 to 2019, as shown in Table E.1.

Table E. 1 Interest rates obtained from analysis, 2011-2019

Year	Interest Rate (%)	
	Mean	Standard Deviation
2011	0.69	0.31
2012	0.67	0.33
2013	1.50	1.26
2014	2.27	1.73
2015	2.65	1.73
2016	2.66	1.58
2017	2.61	1.48
2018	2.65	1.38
2019	2.64	1.31

To estimate each FAP, a Monte Carlo Simulation (MCS) was used to obtain the percentage construction claims had on the total capital investment in BC's CI. Once obtained, that percentage was multiplied by the forecasted capital investment in BC's CI for each year from 2011 to 2019 (CSC 2011).

These FAPs were then converted into present worth (PW) values in 2011 using the formula suggested by Fraser et al. (2009), as follows:

$$PW = FW / (1 + i)^N = FAP / (1 + i)^N$$

The only missing value to be able to proceed with the calculation was that of the interest rate (i). To account for the uncertainty and variability attached to this value, historical information from the Bank of Canada was used to estimate the values for the interest rate in future years. As shown in Figure E.3 the corporate prime rate in Canada had a considerable variation since the year 2000 to date. A normal distribution was assigned to this variable. The normal distribution was confirmed as being accurate after drawing a normal probability test plot and obtaining a good fit to a linear trend (R^2=0.968), as shown in Figure E.4.

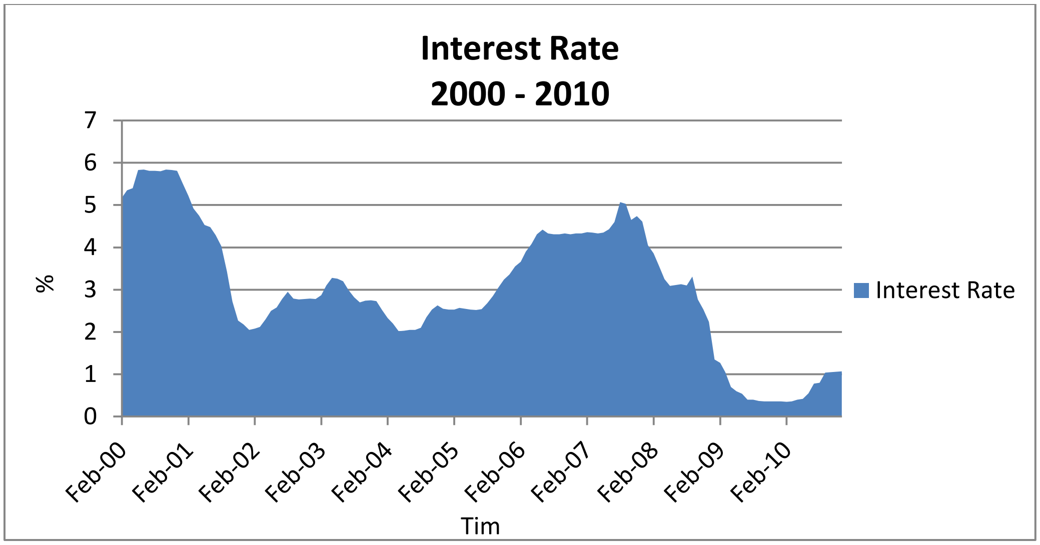


Figure E. 3. Corporate prime rate in Canada from 2000 to 2010

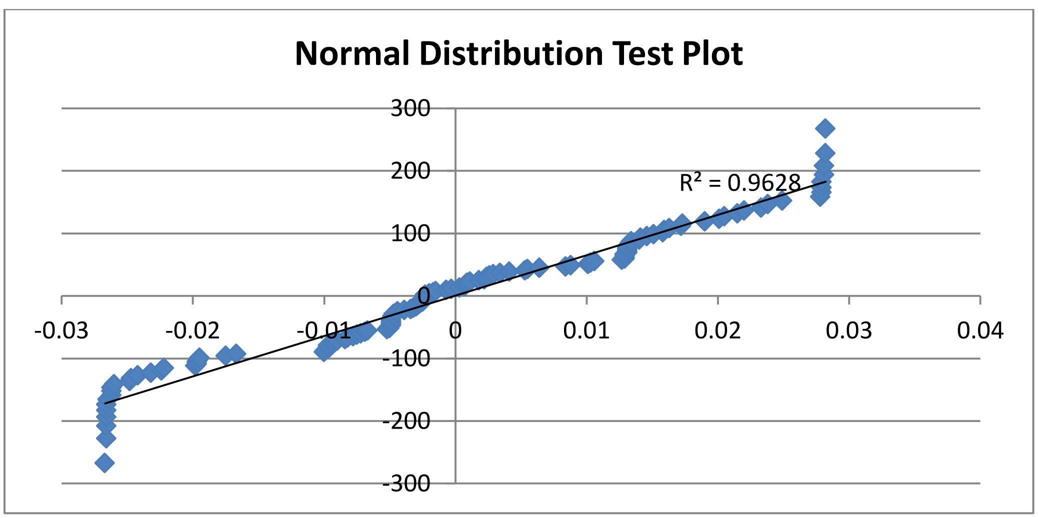


Figure E. 4. Normal probability test plot for the corporate prime rate in Canada, 2000 - 2009

Interest rates for the year 2010 were used to calculate the mean and standard deviation of the interest rate in 2011 (i_{2011}). Interest rates from 2009 and 2010 were used to calculate the mean and standard deviation of the interest rate in 2012 (i_{2012}). Interest rates from 2008 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2013 (i_{2013}). Interest rates from 2007 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2014 (i_{2014}). Interest rates from 2006 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2015 (i_{2015}). Interest rates from 2005 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2016 (i_{2016}). Interest rates from 2004 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2017 (i_{2017}). Interest rates from 2003 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2018 (i_{2018}). Interest rates from 2002 to 2010 were used to calculate the mean and standard deviation of the interest rate in 2019 (i_{2019}).

Once the PWs were obtained for each FAP, all PWs from 2011 to 2019 were added to obtain the present worth under current practices (PW_{CP}), as follows:

$$PW_{CP} = PW_{2011} + PW_{2012} + PW_{2013} + \ldots + PW_{2018} + PW_{2019}$$

As shown in Figures E.5 and E.6, the mean of the PW_{CP} amounts to \$1,175million, with a 95th Percentile value of \$1,279 million. This is the estimated amount of money that will be paid by BC’s WCB from 2011 to 2019 due to claims originating in the CI.

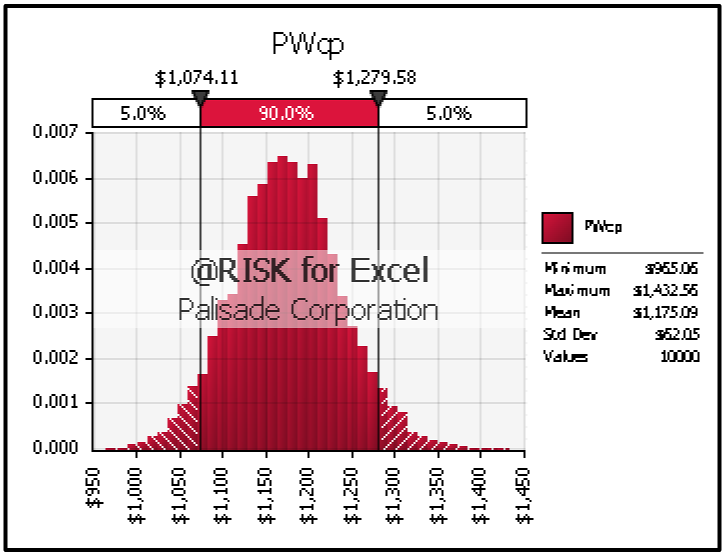


Figure E. 5. Probability density function for the present worth under current practices (PW_{CP}).

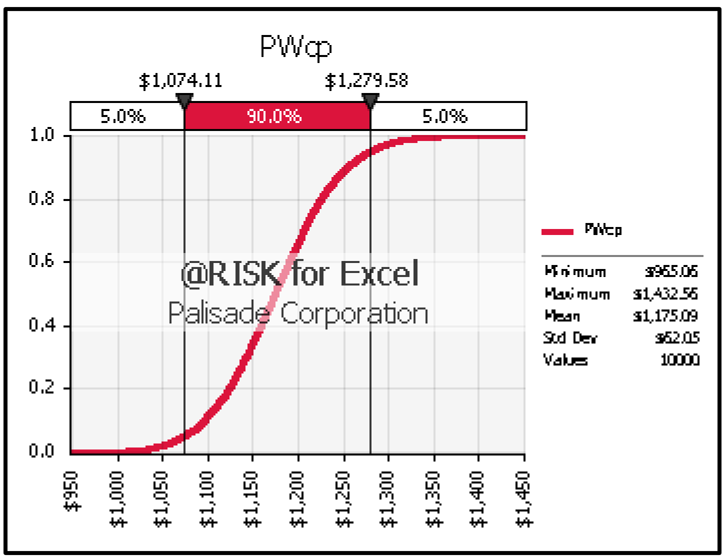


Figure E. 6. Cumulative density function for the present worth under current practices (PW_{CP}).

E.2 Step 2: Estimation of C-RTICS^2 Present Worth ($PW_{C\text{-}RTICS2}$)

Initial Investment

Figure E.7 shows the cash flow diagram used for the calculation of $PW_{C\text{-}RTICS2}$.

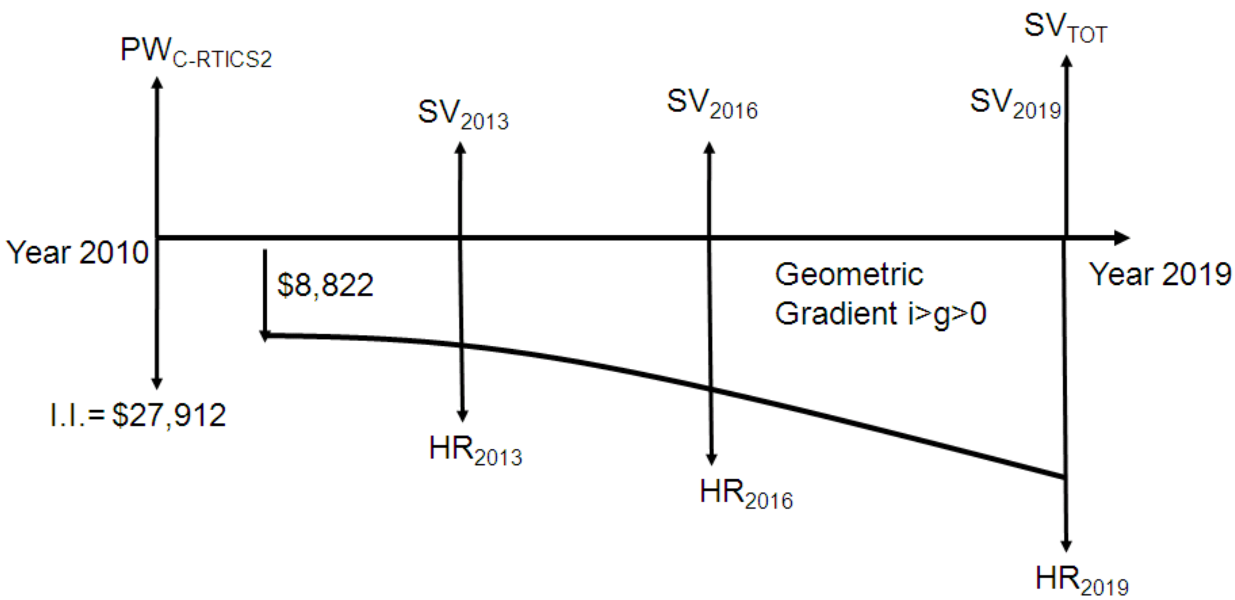


Figure E. 7. Cash Flow Diagram for the calculation of $PW_{CRTICS2}$

As it is observed, an initial investment of $27,917 is considered in 2010. Table E.2 summarizes the estimated initial costs of C-RTICS^2.

Table E. 2. Initial Investment required for C-RTICS[2]

Description	Cost
Software Programming (SP)	$5,000
Microsoft Server License (MSL)	$500
PED	$3,500
Servers	$15,152
Installation	$3,760
Initial Investment (II) =	$27,912

$5,000 was estimated for software programming. This cost was obtained by considering the scope of the first version of the system and its correspondent programming demands, with a total of 160 programming hours at an average hourly wage of $31.39 (BCStats 2011). The use of Microsoft SQL for database management purposes demanded the acquisition of a Microsoft Server License at the time of testing and for future operation. The cost of this license was $129, but it was considered appropriate to increase it to $500 to account for potential new licenses required for the administration of the system throughout its life span (conservative approach). Investment on a portable electronic device was considered essential to be able to fully test the system, as well as demonstrating its capabilities to potential new users, both at private and public levels. A market research of the available devices returned prices ranging from $379 to $3,697. It was considered appropriate to use a conservative approach by selecting the upper bound price of $3,500 for this purpose. The servers' investment considered the acquisition of a Dell Server (Dell R710 1x Xeon 2.13Ghz L5520, 2x250GB SATA,12GB Ram, 2x2 Port GB NIC (4)), and a Dell storage solution (DELL MD1200, 12x2TB 7.2K RPM SAS, PERC H800A Controller). Selection of these equipment was recommended by IT experts at UBC-O based on the full scope of the proposed system.

Installation costs considered the correspondent costs attached to installation of both the server and the storage solution within a secured server room at UBC Okanagan.

Operation and maintenance

Operation and maintenance costs were estimated at an annual cost of $8,822. As shown in Table E.3 this annual cost (annuity) included extended support and service for the acquired hardware ($1,200), and placement of the server and storage solution in a secured and monitored datacenter -server room- ($6,372). These costs were obtained from the hardware manufacturers and from UBC-O IT experts. Finally, the annual costs considered an annual programming expense of $1,250, estimated at forty programming hours invested in C-RTICS[2] software touch-ups on a yearly basis.

Table E. 3. Initial Investment (I.I) required for C-RTICS[2].

Description	Cost
Storage Extended Support and Service (Tier 1)	$600
Physical Server Rack Space in Secure/Monitored Datacenter (Per U)	$5,664
Server Extended Support and Service (Tier 1)	$600
Physical Server Rack Space in Secure/Monitored Datacenter (Per U)	$708
Software maintenance and improvement	$1,250
Annual costs of operation and maintenance =	$8,822

Operation and maintenance costs throughout the period of analysis (2011 – 2019) defined a geometric gradient based on the fact that it is affected by the interest and the inflation rates. As shown in Figure E.3 and Figure E.8, historical values of these variables are different from each other.

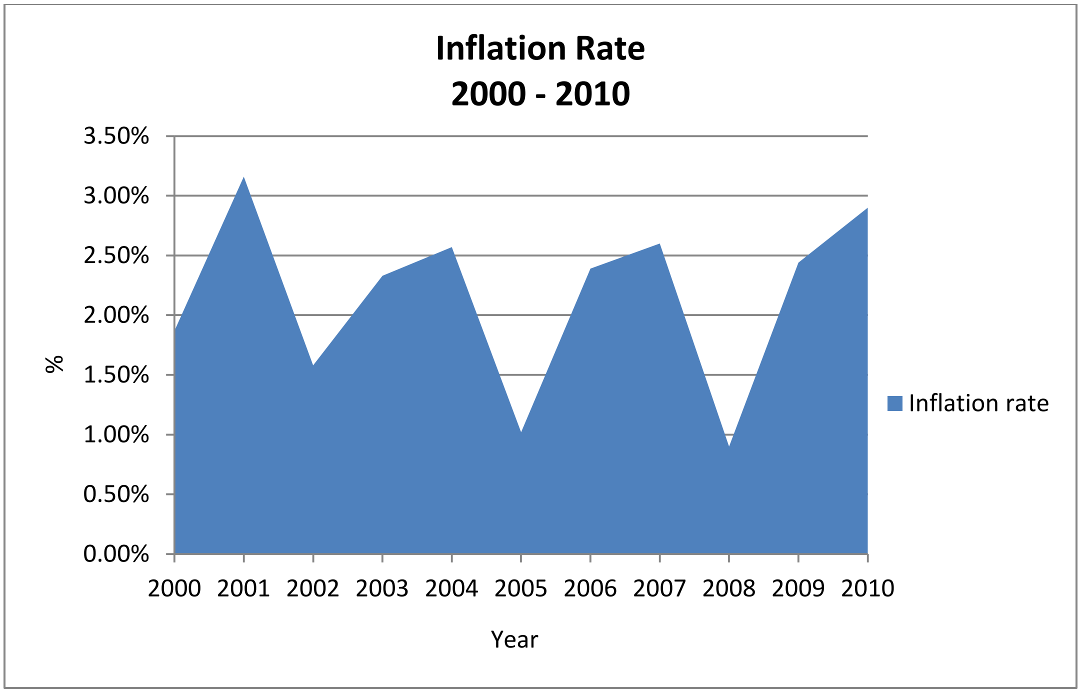


Figure E. 8. Inter annual inflation rate in Canada, 2000 – 2010.

Analyzing the movements of the inflation and interest rates, the interest rate reached its highest value in 2000 (5.84%) and its lowest value in 2009 (0.36%). The inflation rate reached its highest value in 2002 (4.51%), and its lowest value in 2008 (1.07%). These historical information was used to estimate the interest rate from 2011 to 2019 ($i_{2011\text{-}2019}$), and the inflation rate from 2011 to 2019 ($i_{F2011\text{-}2019}$). The inflation rate was assumed to be the "g" factor in the geometric gradient multiplication factor (P/A,i,g,N) (Fraser et al. 2009) used in the analysis. A normal distribution was assigned to inflation rates on all simulations after obtaining a good fit (R^2 = 0.887) to a linear trend in a normal probability test plot, as shown in Figure E.9.

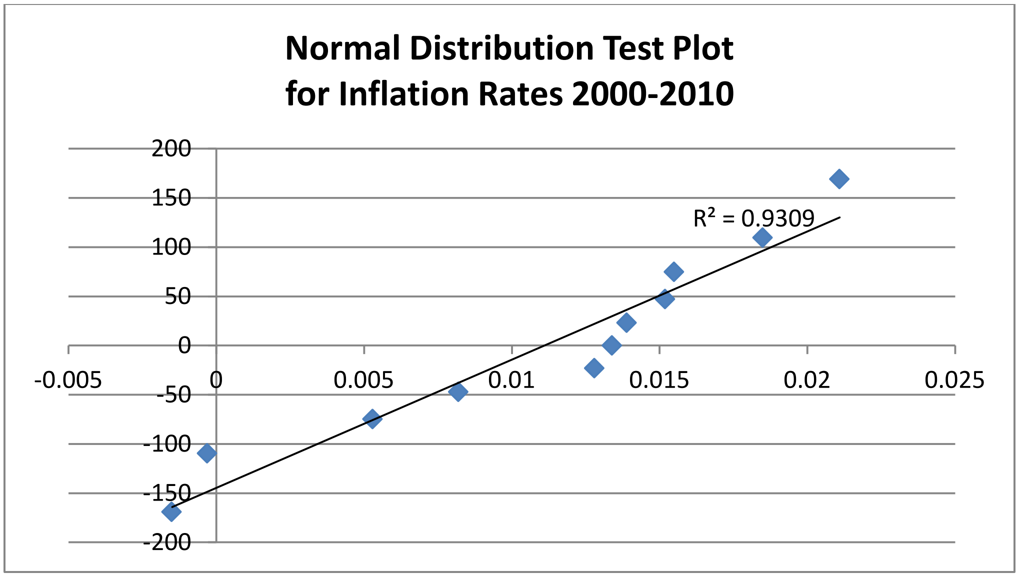


Figure E. 9. Normal distribution test plot for the inter annual inflation rate in Canada, 2000 – 2010.

Table E. 4. Summarized results for operation and maintenance calculations.

Description	Mean	Standard Deviation
Interest rate from 2011 to 2019 ($i_{2011\text{-}2019}$)	2.64%	1.31%
Inflation rate from 2011 to 2019 ($i_{F2011\text{-}2019}$)	2.09%	0.73%
Combined rate ($i\hat{}_{2011\text{-}2019}$)	0.55%	1.47%
(P/A,i^,N)	0.96	0.11
(P/A,i,g,N)	0.94	0.11
PW_{OM}	$8,332	$948

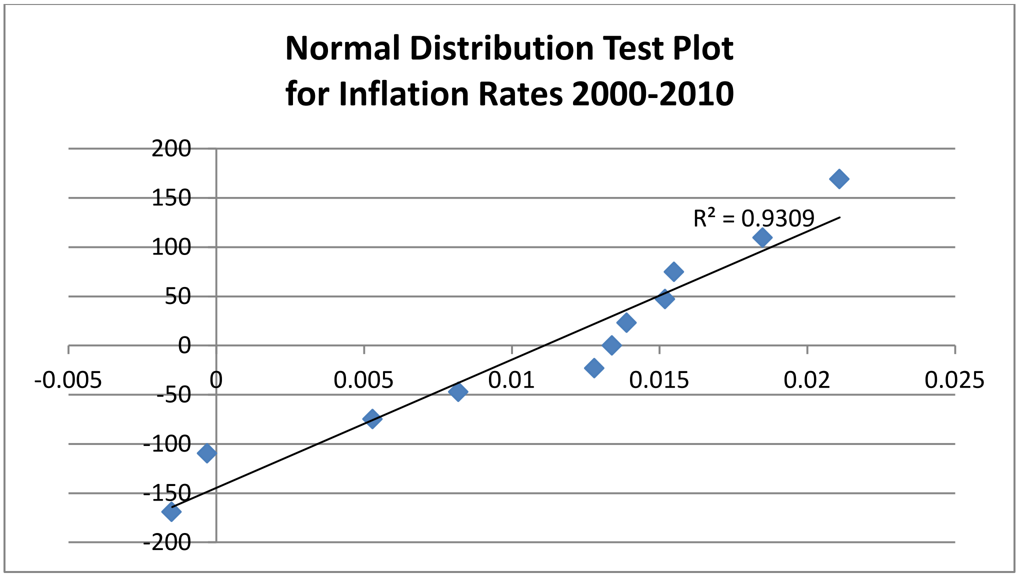


Figure E. 10. Normal distribution test plot for inter annual inflation rate in Canada, 2000 - 2010.

As observed in Table E.4, the MCS returned values indicating that $i_{2011\text{-}2019} > i_{F2011\text{-}2019}$. Therefore, the combined rate ($i\wedge_{2011\text{-}2019}$) for a geometric gradient analysis (Fraser et al. 2009) was calculated as follows:

$$i\wedge = [(1 + i_{2011\text{-}2019}) / (1 + i_{F2011\text{-}2019})] - 1$$

Once i^ was obtained, the factor (P/A,i,g,N) was calculated as follows:

$$(P/A,i,g,N) = [(P/A,i\wedge,N) / (1 + i_{F2010\text{-}2019})]$$

where:

N = 8

$$(P/A,i\wedge,N) = [((1 + i\wedge) - 1) / ((i\wedge * (1 + i\wedge)^{N})]$$

The final estimation of the present worth of the operation and maintenance costs (PW_{OM}) was calculated as:

$$PW_{OM} = \$8,822 * (P/A,i,g,N)$$

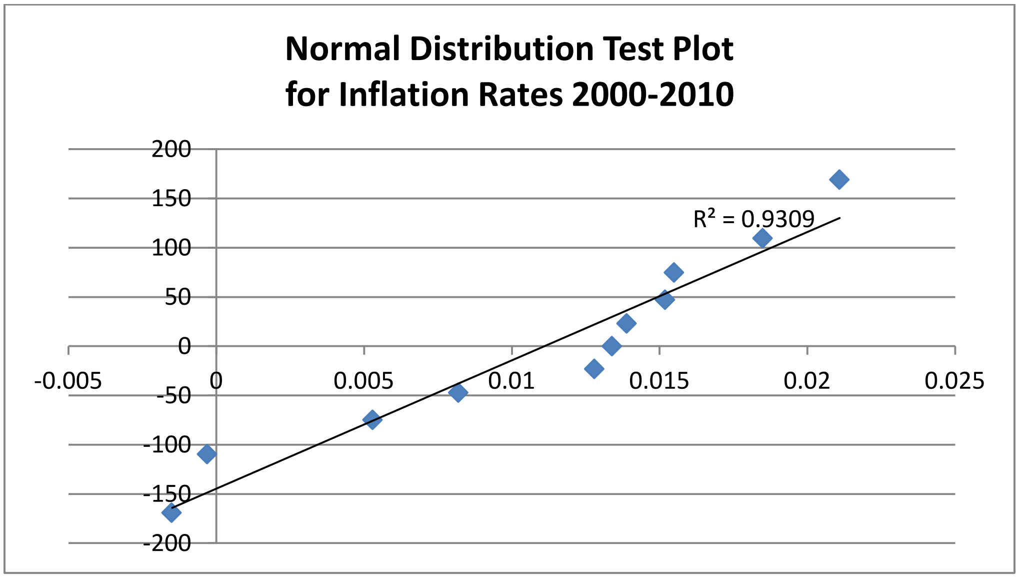


Figure E. 9. Normal distribution test plot for the inter annual inflation rate in Canada, 2000 – 2010.

It can be observed that the mean of PW_{OM} amounts to \$8,332, with a standard deviation of \$948. Figures E.11 and E.12 provide a broader view of the results obtained after performing the MCS.

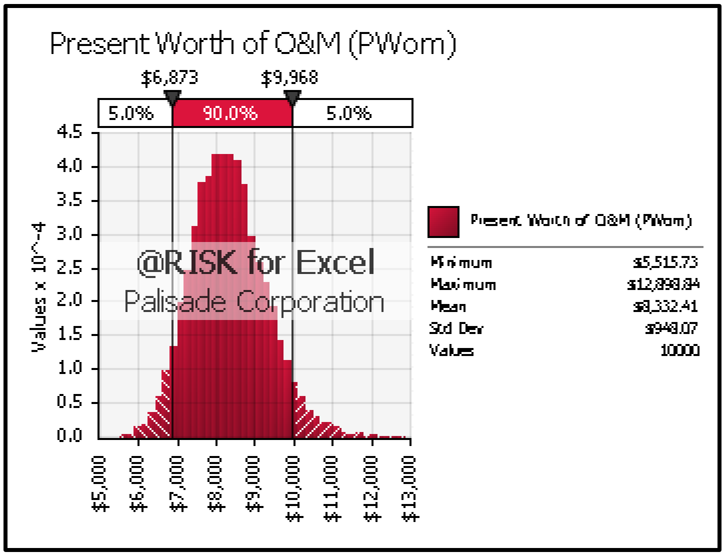


Figure E. 11. Probability density function for the present worth of the operation and maintenance.

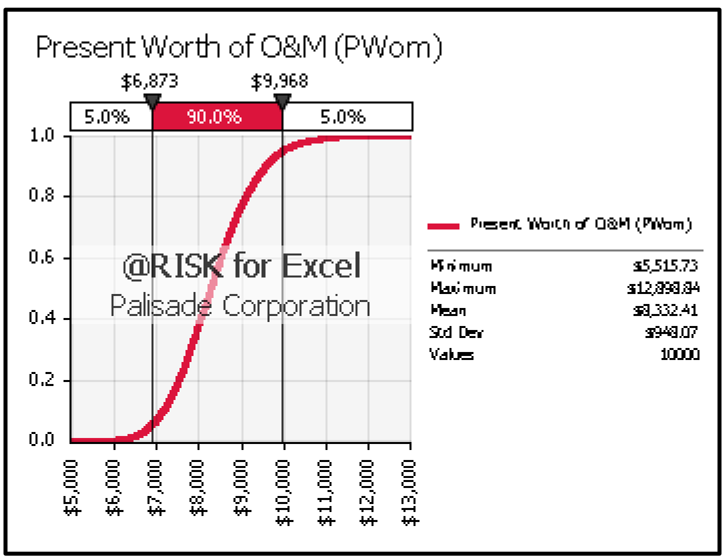


Figure E. 12. Cumulative density function for the present worth of operation and maintenance.

Hardware replacement

An estimated three year lifespan was assumed for the servers and storage solution previously described. This assumption was based on a 30% annual depreciation of computers and electronic equipment (Fraser et al. 2009). It was considered that a hardware replacement (HR) cost would occur every three years until the end of the period of analysis in 2019. Therefore, as shown in the cash flow diagram for the analysis (Figure E.7) a HR occurs in the years 2013, 2016, and 2019 (named HR_{2013}, HR_{2016}, and HR_{2019} respectively). The estimation of each HR was obtained as follows:

$$HR_{2013} = (II - SP – PED) * (1 + i_{F-2013})^{N}$$

$$HR_{2016} = (II - SP – PED) * (1 + i_{F-2016})^{N}$$

$$HR_{2019} = (II - SP – PED) * (1 + i_{F-2019})^{N}$$

As shown, the costs associated with software programming (SP) and portable electronic device (PED) were subtracted from the initial investment (II) calculated for the year 2010. This result was then multiplied by an engineering economics factor (Fraser et al. 2009) to convert them to the correspondent future values. A MCS was performed to obtain the inflation rate in years 2013 (i_{F-2013}), 2016 (i_{F-2016}), and 2019 (i_{F-2019}). Historical information from the Bank of Canada for the annual inflation rates from 2001 to 2010 were used to calculate the mean and standard deviation. Inter annual inflation rates from 2008 to 2010 were used to calculate the mean and standard deviation of the annual inflation rate in 2013 (i_{F-2013}). Inter annual inflation rates from 2005 to 2010 were used to calculate the mean and standard deviation of the annual inflation rate in 2016 (i_{F-2016}). Inter annual inflation rates from 2003 to 2010 were used to calculate the mean and standard deviation of the annual inflation rate in 2019 ($i_{F\text{-}2019}$).

Description	Mean	Standard Deviation
Inflation rate in 2013	2.08%	1.05%
Inflation rate in 2016	2.04%	0.86%
Inflation rate in 2019	2.08%	0.73%
Hardware replacement cost in 2013 (HR2013)	$20,462	
Hardware replacement cost in 2016 (HR2016)	$21,692	
Hardware replacement cost in 2019 (HR2019)	$23,002	

Table E.5 summarizes the results obtained for all inflation rates. The inflation rate variable was used to calculate the HR_{2013}, HR_{2016}, and HR_{2019}. Obtained results are shown in Table E.5.

Table E. 5. Summarized results for the hardware replacement costs, part 1.

Description	Mean	Standard Deviation
Inflation rate in 2013	2.08%	1.05%
Inflation rate in 2016	2.04%	0.86%
Inflation rate in 2019	2.08%	0.73%
Hardware replacement cost in 2013 (HR_{2013})	$20,462	
Hardware replacement cost in 2016 (HR_{2016})	$21,692	
Hardware replacement cost in 2019 (HR_{2019})	$23,002	

Once the HR costs were obtained, a similar procedure as that applied to calculate PW_{CP} was applied to calculate the correspondent present worth values for each HR (named PW_{HR2013}, PW_{HR2016}, and PW_{HR2019} respectively). A MCS was performed to obtain the interest rate in the years 2013 (i_{2013}), 2016 (i_{2016}), and 2019 (i_{2019}). Interest rate historical information from the Bank of Canada from 2001 to 2009 was used to calculate the mean and standard deviation of this variable. Interest rates from 2008 to 2010 were used for the simulation of the interest rate in 2013 (i_{2013}). Interest rates from 2005 to 2010 were used for the simulation of the interest rate in 2016 (i_{2016}). Interest rates from 2002 to 2010 were used for the simulation of the interest rate in 2019 (i_{2019}). As mentioned in previous sections, a normal distribution was assigned to all interest rates. The interest rate variable, with its correspondent normal distribution obtained from the MCS mentioned previously, was used to calculate the correspondent PW_{HR2013}, PW_{HR2016}, and PW_{HR2019}, as follows:

$$PW_{HR2013} = HR_{2013} / (1 + i_{2013})^3$$

$$PW_{HR2016} = HR_{2016} / (1 + i_{2016})^6$$

$$PW_{HR2019} = HR_{2019} / (1 + i_{2019})^9$$

Obtained results are shown in Table E.6.

Table E. 6. Summarized results for hardware replacement costs, part 2.

Description	Mean	Standard Deviation
Present Worth of Hardware Replacement in 2013 (PW_{HR2013})	\$19,586	\$730

Present Worth of Hardware Replacement in 2016 (PW_{HR2016})	\$18,621	\$1,728
Present Worth of Hardware Replacement in 2019 (PW_{HR2019})	\$18,332	\$2,111

Present Worth of C-RTICS^2 ($PW_{C\text{-}RTICS2}$)

Once the present worth values were obtained for all the costs attached to the proposed system from 2011 to 2019, the $PW_{C\text{-}RTICS2}$ was calculated as follows:

$$PW_{C\text{-}RTICS2} = II + PW_{HR2013} + PWHR_{HR2016} + PW_{HR2019} + PW_{OM}$$

As shown in Figures E.13 and E.14, the mean value of $PW_{C\text{-}RTICS2}$ amounts to \$92,785, with a standard deviation of \$2,981, a minimum value of \$82,690, a maximum value of \$105,503, and a 95th Percentile value of \$97,893.

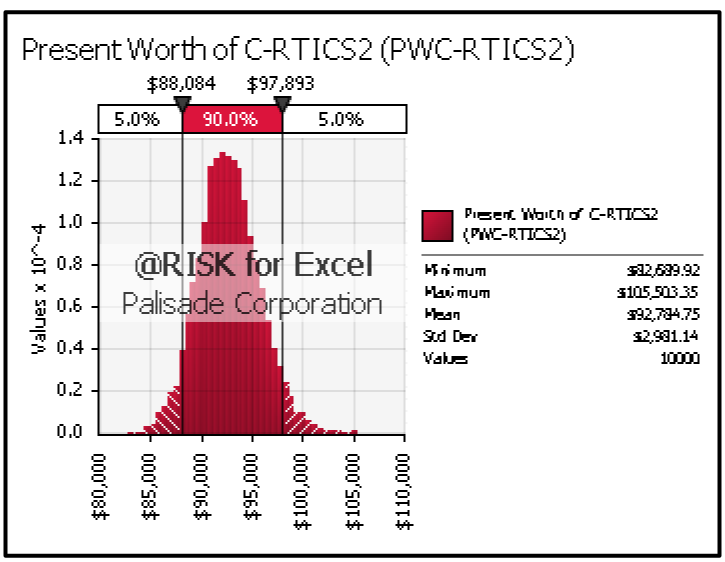


Figure E. 11. Probability density function for the present worth of C-RTICS^2.

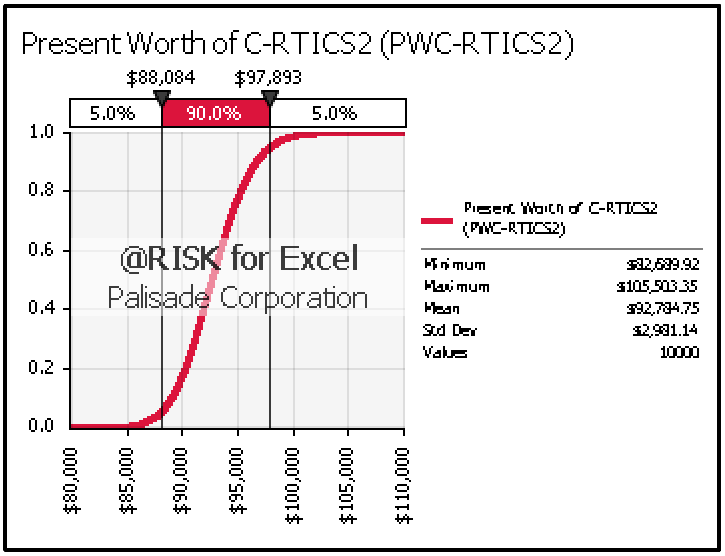


Figure E. 12. Cumulative density function for the present worth of C-RTICS^2.

Comparing the present worth under current practices (PW_{CP}) estimated previously, and the obtained $PW_{C\text{-}RTICS2}$, it is observed that the investment in the proposed system represents a 0.00514% of the estimated amount of money that will be paid by the BC's WCB due to claims originating in the CI.

E.3 Step 3: Minimum required annual savings to justify the investment in C-RTICS^2

In order to estimate the required annual savings to justify the investment on the proposed system, the theory proposed by Fraser et al. (2009) was used as follows:

$$\text{Annual Savings (A)} = (PW_{C\text{-}RTICS2} - SV_{TOT}) * (A/P , i_{2010\text{-}2019} , N) + (SV_{TOT} * i_{2010\text{-}2019})$$

As shown in the equation, a total salvage value (SV_{TOT}) is involved in the calculation of the required annual savings. This SV_{TOT} was obtained by estimating the salvage value of the proposed system in the years 2013 (SV_{2013}), 2016 (SV_{2016}), and 2019 (SV_{2019}), and transforming them into a unique future value in 2019, as follows:

$$SV_{TOT} = SV_1 * (F/P,i,6) + SV_2 * (F/P,i,3) + SV_{2019}$$

Each salvage value can be considered as the market value of the replaced hardware (performed in years 2013, 2016, and 2019). However, it is well known that estimation of the market value of electronic equipment in the future (after it has been used for several years) is a complex exercise that involves great uncertainty. On the other hand, analyzing the equation for estimation of the required annual savings, it can be observed that the inclusion of SV_{TOT} (whatever value greater than zero is used) will decrease the final value of A. Hence, a conservative approach was used to calculate A by using a SV_{TOT} equal to zero. Therefore, the estimation of A was performed using the following formula (a simplified version of the formula proposed by Fraser et al. (2009), when SV = 0).

$$\text{Annual Savings (A)} = PW_{C\text{-}RTICS2} * (A/P , i_{2011\text{-}2019} , N)$$

The values for $i_{2011-2019}$, and N had been obtained already (estimated in previous sections). Factor (A/P , $i_{2011-2019}$, N) was estimated as follows:

$$(A/P , i_{2011\text{-}2019} , N) = (i_{2011\text{-}2019} * (1+ i_{2011\text{-}2019})^8) / ((1 + i_{2011\text{-}2019})^8 -1)$$

Once the factor (A/P , $i_{2010-2019}$, N) was obtained, a MCS was performed to obtain A. As shown in Figures E.15 and E.16, the required annual savings to justify the investment in the proposed system amounts to \$10,079 (mean), with a standard deviation of \$730, a minimum value of \$10,079, a maximum value of \$16,497, and a 95th percentile value of \$14,259.

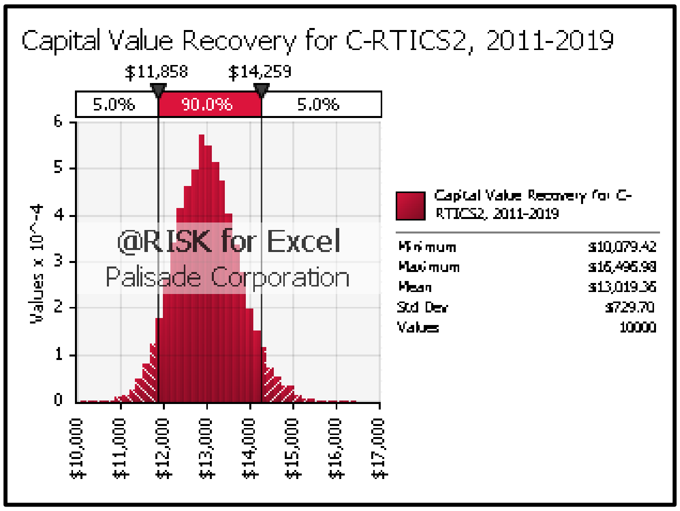


Figure E. 13. Probability density function for the annual savings required to justify the investment in C-RTICS2.

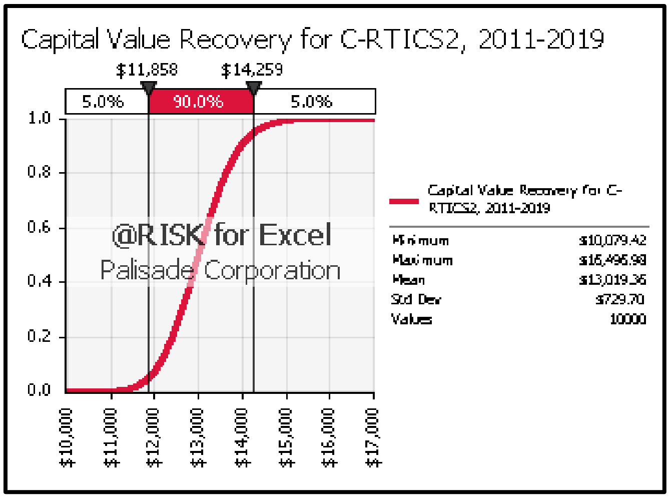


Figure E. 14. Cumulative density function for the annual savings required to justify the investment in C-RTICS^2.

Historical information related to the number of claims and money paid as compensation by WCB (Figure 1.2) was used to estimate an average cost per claim, as follows:

Average Cost per claim = Total $ paid from 2000 to 2010 / Total claims from 2000 to 2010

This returned a result of an average cost per claim of $7,900. With this value, it was possible to estimate the minimum annual required reduction of claims in BC's CI to justify the investment in C-RTICS^2, as follows:

Required annual reduction of claims = Annual Savings (A) / Average cost per claim

As it can be observed in Figures E.17 and E. 18, the 95th percentile value for the minimum annual required reduction of claims in BC's construction industry in order to justify the investment in C-RTICS^2, is only 1.8 claims.

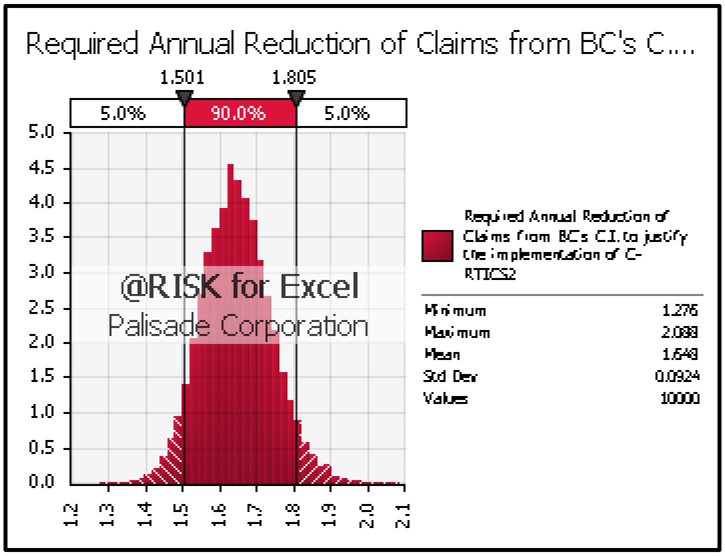


Figure E. 15. Probability density function for the annual reduction of claims in BC's CI to justify the investment in C-RTICS^2.

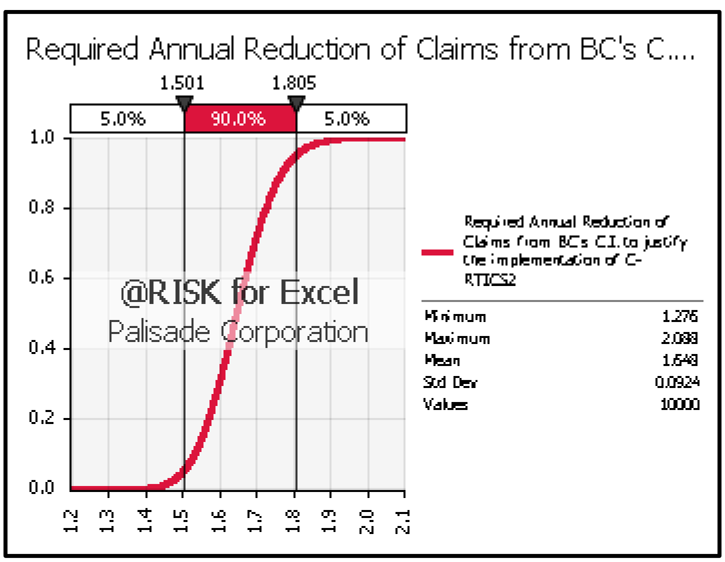


Figure E. 16. Cumulative density function for the annual reduction of claims in BC's CI to justify the investment in C-RTICS^2.

An item considered for the initial investment on the proposed system is related to the software or system programming. On the first stage of analysis, it was considered that 160 hours of programming would provide an operational version of the proposed system. However, feedback obtained from IT experts motivated the researcher to increase the required programming hours and run the simulation again. Arguments brought by IT experts related to the complexity of some of the modules included in the proposed system (e.g., the monitoring and communication modules). To account for this complexity and the required additional programming hours to obtain a professional end product suitable for the CI, two additional scenarios were established. A scenario that considered a multiplying factor of 4 to the software programming line ($20,000 initial investment for software programming), and a scenario that considered a multiplying factor of 10 to the original estimation for software programming, representing an initial investment of $50,000. Figures E.20 and E.21 show the results obtained for the required reduction of claims to justify the investment on C-RTICS^2 after running the simulation for both additional scenarios.

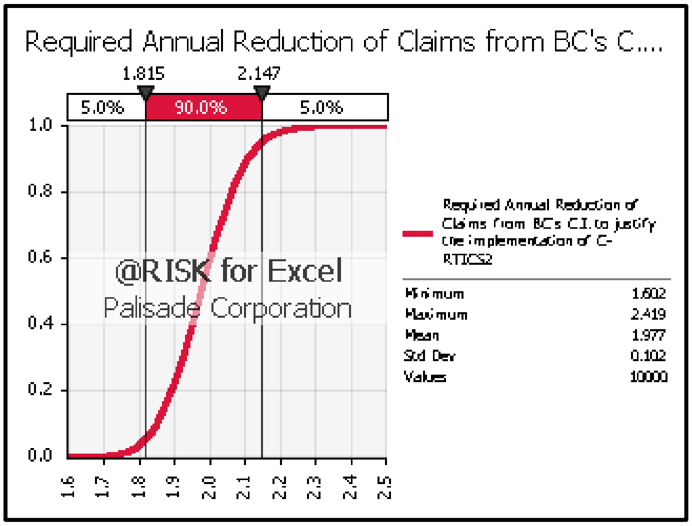


Figure E. 17. Cumulative density function for the required reduction of claims for scenario 2.

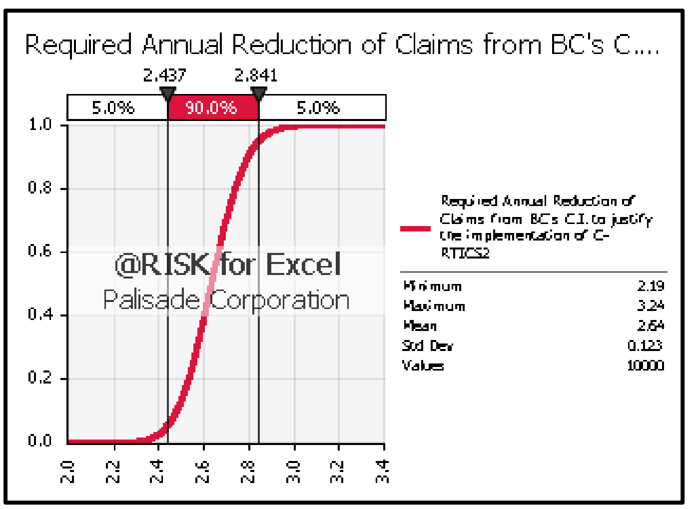


Figure E. 18. Cumulative density function for the required reduction of claims for scenario 3.

As it is observed in Table E.7, no significant change occurred to the required reduction of claims between the three scenarios.

Table E. 7. Required reduction of claims to justify the investment in C-RTICS[2].

Scenario	Required reduction of claims per year (95th percentile)
1: $5,000 investment in software programming	1.8
2: $20,000 investment in software programming	2.1
3: $50,000 investment in software programming	2.8

Social cost benefit analysis

Workers' lives and wellbeing call for the development of a social cost benefit analysis as part of the implementation of the proposed system. That type of analysis requires a thorough research and discussion by itself and therefore is not included or developed in this thesis. However, it can't be denied that reduction of accidents in construction sites will positively impact many aspects or our society.