A Context-Aware Model to Improve Usability of Information Presented on Mobile Devices

Felix Fred Ntawanga

April 2014
A Context-Aware Model to Improve Usability of Information Presented on Mobile Devices

Felix Fred Ntawanga

Promoters: Prof. A.P. Calitz and Dr. L. Barnard

Submitted in fulfilment of the requirements for the degree of Philosophiae Doctor in the Faculty of Science at the Nelson Mandela Metropolitan University
DECLARATION

I, Felix Fred Ntawanga (207059758), hereby declare that the thesis for PhD Computer Science is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

_____________________________
Felix Fred Ntawanga
ACKNOWLEDGEMENT

First and foremost praise be to the Almighty God for everything I am.

This work would never have been possible if it were not for the support I was given by the Department of Computing Sciences at Nelson Mandela Metropolitan University (NMMU) to pursue my dream. It has been a great pleasure working with the members of staff and my fellow students in the Department of Computing Sciences. Many thanks to the kindness, mentoring, motivation, belief and support provided by Prof André Calitz and Dr Lynette Barnard, my long-time promoters. Thank you André and Lynette for the time you dedicated to reading every word of my thesis and your direction and guidance throughout my postgraduate studies at NMMU. It has been an honour and privilege for me to work and learn from you.

I would like to thank SAP Research for the sponsorship that enabled this research, Mr Danie Kok, Prof Jan Eloff and Prof Ernest Ngassam for direction and support during the four years I have spent working on this thesis. I thank my colleagues Dr Wonga Ntshinga, Mr Donovan Isherwood and Ms Boitumelo Nkaelang for all their support. Thanks to the participants from the Kgautswane community in Limpopo Province on providing useful feedback during the evaluation, especially Mr Ishmael Adams and Ms Clara Masinga. To Dr Jacques Pietersen of the Unit for Statistical Consultation (USC) at NMMU for statistical advice and data analysis, Mr John Cullen and Dr Annelie Pretorius for improving the quality of the thesis through language and technical editing respectively.

To my wife Olipa, thank you for everything, your understanding and love kept me going. Thank you for believing in me and supporting me all the way. To my daughters, I say you will see Daddy more. Mr Owen Chamdimba, thank you for your support and for being there to allow me to discuss so many ideas and issues with you. Last, but not least, I would like to thank my family and friends, I could feel your prayers and support during the past four years.

This work is dedicated to my Mum, for the unconditional love and to my late brother Shadreck, we miss you every day.
ABSTRACT

Online information access on mobile devices is increasing as a result of the growth in the use of Internet-enabled handheld (or pocket-size) devices. The combined influence of recent enabling technologies such as Web 2.0, mobile app stores and improved wireless networks have driven the increase in online applications that allow users to access various types of information on mobile devices regardless of time and location. Examples of such applications (usually shortened to app) include: social media, such as FacebookTM App and TwitterTM App, banking applications such as (Standard Bank South Africa)TM Mobile Banking App and First National Bank (FNB) BankingTM App, and news application such as news 24TM App and BBC™ News App.

Online businesses involved in buying, selling and business transaction processing activities via the Internet have exploited the opportunity to extend electronic commerce (e-commerce) initiatives into mobile commerce (m-commerce). Online businesses that interact with end user customers implement business to consumer (B2C) m-commerce applications that enable customers to access and browse product catalogue information on mobile devices, anytime, anywhere. Customers accessing electronic product catalogue information on a mobile device face a number of challenges such as a long list of products presented on a small screen and a longer information download time. These challenges mainly originate from the limiting and dynamic nature of the mobile apps operating environment, for example, dynamic location, bandwidth fluctuations and, diverse and limited device features, collectively referred to as context.

The goal of this research was to design and implement a context-aware model that can be incorporated into an m-commerce application in order to improve the presentation of product catalogue information on m-commerce storefronts. The motivation for selecting product catalogue is prompted by literature which indicates that improved presentation of information in m-commerce (and e-commerce) applications has a positive impact on usability of the websites. Usable m-commerce (and e-commerce) websites improve efficiency in consumer behaviour that impacts sales, profits and business growth. The context-aware model aimed at collecting context information within the user environment and utilising it to determine optimal retrieval and presentation of product catalogue in m-commerce.
An integrated logical context sensor and Mathematical algorithms were implemented in the context-aware model. The integrated logical context sensor was responsible for the collection of different types of predetermined context information such as device specification or capabilities, connection bandwidth, location and time of the day as well as the user profile. The algorithms transformed the collected context information into usable formats and enabled optimal retrieval and presentation of product catalogue data on a specific mobile device. Open-source implementation tools were utilised to implement components of the model including: HTML5, PHP, JavaScript and MySQL database. The context-aware model was incorporated into an existing m-commerce application.

Two user evaluation studies were conducted during the course of the research. The first evaluation was to evaluate the accuracy of information collected by the context sensor component of the model. This survey was conducted with a sample of 30 users from different countries across the world. In-between the context sensor and main evaluation surveys, a pilot study was conducted with a sample of 19 users with great experience in mobile application development and use from SAP Next Business and Technology, Africa. Finally an overall user evaluation study was conducted with a sample of 30 users from a remote area called Kgautswane in Limpopo Province, South Africa.

The results obtained indicate that the context-aware model was able to determine accurate context information in real-time and effectively determine how much product information should be retrieved and how the information should be presented on a mobile device interface. Two main contributions emerged from the research, first the research contributed to the field of mobile Human Computer Interaction. During the research, techniques of evaluating and improving usability of mobile applications were demonstrated. Secondly, the research made a significant contribution to the upcoming field of context-aware computing. The research brought clarity with regard to context-aware computing which is lacking in existing, current research despite the field’s proven impact of improving usability of applications. Researchers can utilise contributions made in this research to develop further techniques and usable context-aware solutions.

**Keywords:** Context, Context-aware, m-commerce, usability, product catalogue information.
TABLE OF CONTENTS

Declaration ........................................................................................................................................... i
Acknowledgement ............................................................................................................................... ii
Abstract ................................................................................................................................................ iii
Table of Contents .............................................................................................................................. v
List of Figures ..................................................................................................................................... xiii
List of Tables ....................................................................................................................................... xvi
List of acronyms and abbreviations ................................................................................................... xvii

CHAPTER 1: INTRODUCTION ........................................................................................................... 1

1.1 BACKGROUND ............................................................................................................................. 2
   1.1.1 Challenges in Browsing Product Catalogue Information in M-commerce .................... 5
   1.1.2 Existing Remedies to Catalogue Browsing Challenges in M-commerce .................... 5
   1.1.3 Context Information ............................................................................................................. 6
   1.1.4 Proposed Solution ................................................................................................................ 7

1.2 RESEARCH PROBLEM AND RELEVANCE OF THE RESEARCH ........................................ 8

1.3 THESIS STATEMENT ................................................................................................................ 10

1.4 RESEARCH OVERVIEW .......................................................................................................... 10
   1.4.1 Research Objectives .......................................................................................................... 10
   1.4.2 Research Questions ............................................................................................................. 11
   1.4.3 Scope and Constraints ......................................................................................................... 12
   1.4.4 Research Contribution ........................................................................................................ 14
   1.4.5 Research Methodology ...................................................................................................... 14

1.5 THESIS STRUCTURE ................................................................................................................ 17

CHAPTER 2: RESEARCH DESIGN .................................................................................................. 19

2.1 INTRODUCTION ......................................................................................................................... 20

2.2 THEORETICAL BACKGROUND ............................................................................................... 21
   2.2.1 General Definitions ............................................................................................................. 21
   2.2.2 Research Philosophy .......................................................................................................... 22
   2.2.3 Research Approach .............................................................................................................. 23
   2.2.4 Research Methods and Strategies ....................................................................................... 24
2.3 RESEARCH PROCESS .................................................................................................................. 26
  2.3.1 Literature Study ...................................................................................................................... 26
  2.3.2 Development Methodology ................................................................................................... 27
  2.3.3 Evaluation Design.................................................................................................................... 28
    2.3.3.1 Sampling ........................................................................................................................... 28
    2.3.3.2 Pilot Study ............................................................................................................................. 30
    2.3.3.3 Data Collection and Analysis .............................................................................................. 31
  2.4 ETHICAL CONSIDERATIONS .................................................................................................... 32
  2.5 LIMITATIONS ............................................................................................................................. 33
  2.6 CONCLUSION ............................................................................................................................... 33

CHAPTER 3: ONLINE BUSINESS ................................................................................................. 35
  3.1 INTRODUCTION ............................................................................................................................ 36
  3.2 ONLINE BUSINESS OVERVIEW ............................................................................................... 37
    3.2.1 Introduction ............................................................................................................................. 37
    3.2.2 Definitions (e-commerce and m-commerce) .......................................................................... 38
    3.2.3 Categories of Online Business ............................................................................................... 40
    3.2.4 Benefits for Conducting Business Online ............................................................................... 42
    3.2.5 Challenges for Conducting Business Online .......................................................................... 43
    3.2.6 Online Shopping Systems Architecture ................................................................................. 44
    3.2.7 Components of an E-commerce Website ............................................................................... 46
    3.2.8 Online Business Overview Summary .................................................................................... 47
  3.3 CONSUMER BEHAVIOUR-CONVENTIONAL VS. ONLINE PURCHASING ..... 47
    3.3.1 Consumer Behaviour Processes ............................................................................................ 48
    3.3.2 Information Retrieval (IR) ....................................................................................................... 50
      3.3.2.1 Definition ............................................................................................................................. 50
      3.3.2.2 Information Retrieval Techniques .................................................................................... 52
      3.3.2.3 Information Retrieval Data Sources .................................................................................. 52
      3.3.2.4 State of the Art in Information Retrieval .......................................................................... 54
    3.3.3 Decision Making ..................................................................................................................... 55
    3.3.4 Consumer Behaviour - Conventional vs. Online Summary .................................................. 56
  3.4 CONCLUSION ............................................................................................................................... 56
CHAPTER 4: USABILITY OF ONLINE PRODUCT CATALOGUES .......... 58

4.1 INTRODUCTION .................................................................................................................. 59

4.2 PRODUCT CATALOGUES ....................................................................................................... 60
  4.2.1 Definition ........................................................................................................................... 60
  4.2.2 Types of Product Catalogues .............................................................................................. 61
    4.2.2.1 Paper-Based Product Catalogues .................................................................................. 61
    4.2.2.2 Electronic Product Catalogues ...................................................................................... 62
  4.2.3 Product Catalogues Summary .............................................................................................. 65

4.3 USABILITY ............................................................................................................................... 65
  4.3.1 Definition ........................................................................................................................... 66
  4.3.2 Usability Evaluation Methods .............................................................................................. 67
    4.3.2.1 User-Based Usability Evaluation ..................................................................................... 68
    4.3.2.2 Expert Oriented Usability Evaluation ............................................................................. 69
    4.3.2.3 Model-Based Usability Evaluation ............................................................................... 70
  4.3.3 Usability Metrics .................................................................................................................. 72
  4.3.4 Tools for Collecting Usability Evaluation Data .................................................................... 72

4.4 USABILITY EVALUATION IN MOBILE COMPUTING ............................................................ 73
  4.4.1 Factors that Influence Usability in Mobile Computing .......................................................... 74
  4.4.2 Mobile Computing Usability Evaluation Methods ............................................................... 75
  4.4.3 Challenges in Mobile Computing Usability Evaluation and Methods ................................. 76

4.5 USABILITY WITH REGARD TO BROWSING ONLINE PRODUCT CATALOGUES ON MOBILE DEVICES .................................................................................................................. 77

4.6 TECHNIQUES USED TO IMPROVE USABILITY OF ONLINE BUSINESS APPLICATIONS .............................................................................................................................. 78
  4.6.1 Examples of Specific Techniques ......................................................................................... 78
  4.6.2 Determining User Similarities in Recommendation Techniques ........................................ 80
  4.6.3 Usability Summary .............................................................................................................. 81

4.7 CONCLUSION .......................................................................................................................... 81

CHAPTER 5: CONTEXT-AWARENESS ......................................................................................... 83

5.1 INTRODUCTION ...................................................................................................................... 84

5.2 CONTEXT AND CONTEXT-AWARENESS ............................................................................. 85
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2.1.1</td>
<td>Model Definition</td>
<td>116</td>
</tr>
<tr>
<td>6.2.1.2</td>
<td>Realisation of Models in MBSE</td>
<td>117</td>
</tr>
<tr>
<td>6.2.1.3</td>
<td>Modelling Languages (UML)</td>
<td>118</td>
</tr>
<tr>
<td>6.2.1.4</td>
<td>Model Driven Architecture (MDA)</td>
<td>122</td>
</tr>
<tr>
<td>6.2.1.5</td>
<td>Properties of Models in MBSE</td>
<td>123</td>
</tr>
<tr>
<td>6.2.1.6</td>
<td>Advantages of Models in MBSE</td>
<td>123</td>
</tr>
<tr>
<td>6.2.1.7</td>
<td>Challenges in MBSE</td>
<td>124</td>
</tr>
<tr>
<td>6.2.1.8</td>
<td>MBSE Summary</td>
<td>124</td>
</tr>
<tr>
<td>6.2.2</td>
<td>Mathematical Optimisation</td>
<td>125</td>
</tr>
<tr>
<td>6.2.2.1</td>
<td>Definition</td>
<td>125</td>
</tr>
<tr>
<td>6.2.2.2</td>
<td>Types of Optimisation Problems</td>
<td>126</td>
</tr>
<tr>
<td>6.2.2.3</td>
<td>Formulation of a Mathematical Optimisation Problem</td>
<td>127</td>
</tr>
<tr>
<td>6.2.2.4</td>
<td>Mathematical Optimisation Summary</td>
<td>127</td>
</tr>
<tr>
<td>6.2.3</td>
<td>Mobile Information Visualisation</td>
<td>128</td>
</tr>
<tr>
<td>6.2.3.1</td>
<td>Definition</td>
<td>128</td>
</tr>
<tr>
<td>6.2.3.2</td>
<td>Mobile Information Visualisation Techniques</td>
<td>129</td>
</tr>
<tr>
<td>6.2.3.3</td>
<td>Mobile Information Visualisation Summary</td>
<td>130</td>
</tr>
<tr>
<td>6.3</td>
<td>CONTEXT-AWARE MODEL DESIGN CONSIDERATIONS</td>
<td>130</td>
</tr>
<tr>
<td>6.4</td>
<td>CONTEXT-AWARE MODEL COMPONENTS</td>
<td>132</td>
</tr>
<tr>
<td>6.4.1</td>
<td>Context Sensor</td>
<td>133</td>
</tr>
<tr>
<td>6.4.1.1</td>
<td>Introduction</td>
<td>133</td>
</tr>
<tr>
<td>6.4.1.2</td>
<td>Function</td>
<td>134</td>
</tr>
<tr>
<td>6.4.2</td>
<td>Data Retrieval</td>
<td>136</td>
</tr>
<tr>
<td>6.4.2.1</td>
<td>Introduction</td>
<td>137</td>
</tr>
<tr>
<td>6.4.2.2</td>
<td>Function</td>
<td>138</td>
</tr>
<tr>
<td>6.4.3</td>
<td>Data Repositories</td>
<td>142</td>
</tr>
<tr>
<td>6.4.4</td>
<td>Optimisation Engine</td>
<td>142</td>
</tr>
<tr>
<td>6.4.4.1</td>
<td>Introduction</td>
<td>143</td>
</tr>
<tr>
<td>6.4.4.2</td>
<td>Function</td>
<td>143</td>
</tr>
<tr>
<td>6.4.5</td>
<td>UI Adaptation</td>
<td>146</td>
</tr>
<tr>
<td>6.4.5.1</td>
<td>Introduction</td>
<td>146</td>
</tr>
<tr>
<td>6.4.5.2</td>
<td>Function</td>
<td>146</td>
</tr>
</tbody>
</table>
6.4.6 Context-Aware Model Diagram ................................................................. 147
6.5 MOBILE SOFTWARE DEVELOPMENT .......................................................... 149
  6.5.1 Background ......................................................................................... 149
  6.5.2 Mobile Operating Systems Market Share .............................................. 150
  6.5.3 Mobile Web Application Implementation ............................................. 151
    6.5.3.1 Data Repository Implementation .................................................. 152
    6.5.3.2 Application Logic Implementation ................................................ 152
    6.5.3.3 Presentation Logic Implementation .............................................. 153
6.6 UML CLASSES OF THE MODEL IMPLEMENTATION ................................. 154
6.7 M-COMMERCE APPLICATION ................................................................. 157
  6.7.1 Introduction to the Rustica System ....................................................... 157
  6.7.2 Functional Requirements .................................................................... 158
  6.7.3 Context-Aware Rustica System ............................................................ 160
  6.7.4 Summary of POC Prototype Implementation Tools ............................ 162
6.8 CONCLUSION ............................................................................................. 164

CHAPTER 7: RESEARCH EVALUATION AND ANALYSIS OF RESULTS 166

7.1 INTRODUCTION ............................................................................................ 167
7.2 DATA COLLECTION AND ANALYSIS INSTRUMENTS ................................ 168
7.3 EVALUATION OF THE RESEARCH ............................................................ 170
  7.3.1 Context Sensor Evaluation Validation Survey ....................................... 171
  7.3.2 Context Sensor Evaluation .................................................................... 172
    7.3.2.1 Context Sensor Evaluation Objectives .......................................... 173
    7.3.2.2 Context Sensor Evaluation Sampling and Participants’ Profile ........... 173
    7.3.2.3 Context Sensor Evaluation Procedure .......................................... 175
    7.3.2.4 Context Sensor Evaluation Data Collection ..................................... 177
  7.3.3 Pilot Study ............................................................................................... 178
    7.3.3.1 Pilot Study Objectives .................................................................... 179
    7.3.3.2 Pilot Study Sampling and Participants’ Profile .................................. 179
    7.3.3.3 Pilot Study Procedure .................................................................... 181
    7.3.3.4 Pilot Study Task List ...................................................................... 183
    7.3.3.5 Pilot Study Data Collection ............................................................ 183
7.3.4 Context-Aware Model Evaluation (Main Evaluation) ........................................... 184
7.3.4.1 Context-Aware Model Evaluation Objectives ........................................... 185
7.3.4.2 Context-Aware Model Evaluation Sampling and Participants’ Profile .. 185
7.3.4.3 Descriptive Statistics of the Sample......................................................... 187
7.3.4.4 Context-Aware Model Evaluation Procedure......................................... 188
7.3.4.5 Data Collection ......................................................................................... 190
7.4 EVALUATION RESULTS ................................................................................. 192
7.4.1 Context Sensor Evaluation Results............................................................ 192
  7.4.1.1 Quantitative Results ............................................................................... 192
  7.4.1.2 Qualitative Results .............................................................................. 195
  7.4.1.3 Limitations of the Context Sensor Evaluation ................................... 195
  7.4.1.4 Context Sensor Evaluation Discussion ............................................. 196
  7.4.1.5 POC Improvement Suggestions .......................................................... 197
7.4.2 Pilot Study Results....................................................................................... 197
  7.4.2.1 Quantitative Results ............................................................................... 197
  7.4.2.2 Qualitative Results .............................................................................. 203
  7.4.2.3 Limitations of the Pilot Study ............................................................ 205
  7.4.2.4 Pilot Study Evaluation Discussion .................................................... 205
  7.4.2.5 POC Improvements Suggestions ....................................................... 206
7.4.3 Context-Aware Model Evaluation Results ................................................. 206
  7.4.3.1 Quantitative Results ............................................................................... 207
  7.4.3.2 Inferential Statistics ............................................................................ 216
  7.4.3.3 Qualitative Results ............................................................................. 218
7.5 EVALUATION RESULTS SUMMARY AND DISCUSSION............................... 218
7.6 CONCLUSION ...................................................................................................... 220

CHAPTER 8: CONCLUSIONS ....................................................................................... 222
8.1 INTRODUCTION ..................................................................................................... 223
8.2 REVISITING RESEARCH OBJECTIVES .......................................................... 225
8.3 RESEARCH ACHIEVEMENTS .......................................................................... 228
  8.3.1 Theoretical Achievements ......................................................................... 228
  8.3.2 Practical Achievements ............................................................................ 229
# 8.4 Research Contributions

- Theoretical Contributions
- Practical Contributions
- Unplanned Output

# 8.5 Recommendations

- Recommendations for Theory
- Recommendations for Practice
- Recommendations for Future Research

# 8.6 Limitations and Challenges

# 8.7 Concluding Remarks

# References

# Appendices

- Appendix A: University Research Ethical Clearance – Human (REC-H)
- Appendix B: Context Sensor Evaluation Written Information for Participants
- Appendix C: Context Sensor Evaluation Task List
- Appendix D: Context Sensor Evaluation Accuracy Questionnaire
- Appendix E: Pilot Study Evaluation Written Information for Participants
- Appendix F: Pilot Study Evaluation Task List
- Appendix G: Pilot Study Evaluation Questionnaire
- Appendix H: Screenshot Example of the Online Pilot Study Evaluation Questionnaire
- Appendix I: Context-Aware Model POC Prototype Evaluation Information for participants and Consent Form
- Appendix J: Context-Aware Model POC Prototype Evaluation Task List
- Appendix K: First Sipedi Translated Version of the Context-Aware Model POC Prototype Evaluation Questionnaire
- Appendix L: Second Sipedi Translated Version of the Context-Aware Model POC Prototype Evaluation Questionnaire
LIST OF FIGURES

Figure 1-1: Chapter 1 context ........................................................................................................ 1
Figure 1-2: Examples of mobile apps interfaces ............................................................................. 2
Figure 1-3: Thesis outline .............................................................................................................. 16
Figure 2-1: Chapter 2 context ....................................................................................................... 19
Figure 2-2: Research onion ........................................................................................................... 21
Figure 2-3: Deductive and inductive research approach ................................................................. 24
Figure 2-4: Research methods/strategies ...................................................................................... 25
Figure 3-1: Chapter 3 context ....................................................................................................... 35
Figure 3-2: Overview of electronic and mobile business and commerce ...................................... 38
Figure 3-3: Examples of mobile devices ........................................................................................ 39
Figure 3-4: Bid or buy c2c website ................................................................................................ 41
Figure 3-5: E-commerce (m-commerce) categories ..................................................................... 42
Figure 3-6: Online business systems architecture ......................................................................... 45
Figure 3-7: Basic information retrieval process ............................................................................. 51
Figure 4-1: Chapter 4 context ....................................................................................................... 58
Figure 4-2: Electronic product catalogue on e-commerce version of Amazon ............................... 63
Figure 4-3: Electronic product catalogue page on m-commerce version of Amazon .................. 64
Figure 4-4: User experience honeycomb ..................................................................................... 67
Figure 4-5: Usability evaluation lab .............................................................................................. 69
Figure 5-1: Chapter 5 context ....................................................................................................... 83
Figure 5-2: Context classification .................................................................................................. 88
Figure 5-3: Architecture for context-aware applications ............................................................... 92
Figure 5-4: Static customer information (profile) registration page ............................................. 98
Figure 5-5: Customer preference/dynamic information acquisition page .................................. 100
Figure 5-6: Context manager ....................................................................................................... 109
Figure 6-1: Chapter 6 context ....................................................................................................... 112
Figure 6-2: MBSE maturity ......................................................................................................... 116
Figure 6-3: Examples of UML structural diagrams ..................................................................... 119
Figure 6-4: Example of UML behaviour diagrams ..................................................................... 120
Figure 6-5: UML diagrams ......................................................................................................... 121
Figure 6-6: Application of MDA in various software domains .................................................... 122
Figure 6-7: SOA architecture .................................................................................................................. 131
Figure 6-8: Context based IR .................................................................................................................. 141
Figure 6-9: The context-aware model for product catalogue data retrieval and presentation .................. 148
Figure 6-10: Mobile device development ............................................................................................... 150
Figure 6-11: Context-aware model technical architecture ...................................................................... 154
Figure 6-12: Context-aware model UML class interfaces ..................................................................... 156
Figure 6-13: User authentication and main menu screens ...................................................................... 159
Figure 6-14: Product catalogue list and order confirmation screens ...................................................... 160
Figure 6-15: Implemented context-aware application use case diagram ............................................. 162
Figure 7-1: Chapter 7 context ................................................................................................................ 166
Figure 7-2: Context sensor evaluation participants’ profile: Gender and Age groups ........................... 174
Figure 7-3: Number of participants from various locations ................................................................. 175
Figure 7-4: Screenshot of the context sensor application ........................................................................ 177
Figure 7-5: Standalone context sensor application log file ................................................................. 178
Figure 7-6: Pilot Study evaluation participants’ age range .................................................................... 180
Figure 7-7: Pilot study evaluation participants profile: Highest qualification and ethnicity .................... 181
Figure 7-8: Range of mobile devices possessed by pilot study participants ......................................... 182
Figure 7-9: Examples of smartphones (devices) used in the pilot study ............................................. 182
Figure 7-10: Map of South Africa indicating the location of Kgautswane community ....................... 186
Figure 7-11: An example of a shop and operators .................................................................................. 187
Figure 7-12: Context-Aware Model evaluation participant’s highest qualification and age group range .......................................................................................................................... 188
Figure 7-13: Research assistant and a participant during the evaluation ................................................ 190
Figure 7-14: System log file .................................................................................................................... 191
Figure 7-15: Accuracy of location and time Information ......................................................................... 194
Figure 7-16: Context determination-pilot study vs. context sensor evaluation ..................................... 199
Figure 7-17: Participants’ responses to adaptation .................................................................................. 201
Figure 7-18: Total interaction time between first device and second device ......................................... 203
Figure 7-19: Type of devices utilised by participants during the main evaluation .................................. 208
Figure 7-20: Uses of smartphones ........................................................................................................ 208
Figure 7-21: Participants’ Internet experience in years and Internet browsing time per day .................. 209
Figure 7-22: Business ownership and number of operating years ...................................................... 210
Figure 7-23: General usability of the Rustica system ................................................................. 212
Figure 7-24: Rustica system product catalogue usability evaluation results .................. 214
Figure 7-25: Usability of product catalogue: Rustica vs. Context-aware Rustica system ..... 215
Figure 7-26: Summary of product catalogue usability: Rustica vs. Context-aware system .. 216
Figure 8-1: Chapter 8 context ..................................................................................................... 222
LIST OF TABLES

Table 1-1: Research objective, secondary research questions, methodology and deliverables .................................................................................................................................................................................. 13
Table 3-1: Comparison between e-commerce and m-commerce ................................................. 40
Table 3-2: Customer activities when purchasing products online ................................................. 49
Table 4-1: Comparison of usability evaluation methods ................................................................. 71
Table 5-1: Generic mobile device features ..................................................................................... 101
Table 6-1: i x j user-item matrix .................................................................................................. 139
Table 6-2: Mobile devices operating system market share Q2 2013 .......................................... 151
Table 7-1: Context sensor validation participants profile (n=6) ................................................... 171
Table 7-2: Bandwidth measure ................................................................................................... 195
Table 7-3: Likert scale for information presentation on a mobile device evaluation ................. 200
Table 7-4: t-test results ............................................................................................................... 217
Table 8-1: Summary of research objectives and questions .......................................................... 227
Table 8-2: Comparison of existing context-aware models and the proposed model ................. 236
## LIST OF ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHS</td>
<td>Adaptive Hypermedia Systems</td>
</tr>
<tr>
<td>ASP.NET</td>
<td>Active Server Pages .NET</td>
</tr>
<tr>
<td>B2B</td>
<td>Business-to-Business</td>
</tr>
<tr>
<td>B2C</td>
<td>Business-to-Consumer</td>
</tr>
<tr>
<td>B2G</td>
<td>Business-to-Government</td>
</tr>
<tr>
<td>BBC</td>
<td>British Broadcasting Corporation</td>
</tr>
<tr>
<td>C2C</td>
<td>Consumer to Consumer</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CSS</td>
<td>Cascading Style Sheet</td>
</tr>
<tr>
<td>FNB</td>
<td>First National Bank</td>
</tr>
<tr>
<td>GAF</td>
<td>Generic Adaptation Framework</td>
</tr>
<tr>
<td>GOMS</td>
<td>Goals Objectives Methods and Selections rules</td>
</tr>
<tr>
<td>HDML</td>
<td>Handheld Device Mark-up Language</td>
</tr>
<tr>
<td>HTML</td>
<td>Hypertext Mark-up Language</td>
</tr>
<tr>
<td>iOS</td>
<td>iPhone operating system</td>
</tr>
<tr>
<td>ISO</td>
<td>International standard organisation</td>
</tr>
<tr>
<td>KLM</td>
<td>Keystroke-Level Model</td>
</tr>
<tr>
<td>MBSD</td>
<td>Model Based Software Development</td>
</tr>
<tr>
<td>MBSE</td>
<td>Model Based Software Engineering</td>
</tr>
<tr>
<td>MDA®</td>
<td>Model Driven Architecture</td>
</tr>
<tr>
<td>MDD</td>
<td>Model Driven Design (or Development)</td>
</tr>
<tr>
<td>MDE</td>
<td>Model Driven Engineering</td>
</tr>
<tr>
<td>NMMU</td>
<td>Nelson Mandela Metropolitan University</td>
</tr>
<tr>
<td>OMG</td>
<td>Object Management Group</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
</tr>
<tr>
<td>PDF</td>
<td>Portable Document Format</td>
</tr>
<tr>
<td>POC</td>
<td>Proof of Concept</td>
</tr>
<tr>
<td>QoC</td>
<td>Quality of Context</td>
</tr>
<tr>
<td>REC-H</td>
<td>Research Ethics Committee: Human</td>
</tr>
<tr>
<td>SDLC</td>
<td>Software Development Lifecycle</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>SOAP</td>
<td>Simple Object Access Protocol</td>
</tr>
<tr>
<td>SOC</td>
<td>Service-Oriented Computing</td>
</tr>
<tr>
<td>SQL</td>
<td>Structured Query Language</td>
</tr>
<tr>
<td>TCP/IP</td>
<td>Transmission Control Protocol/Internet Protocol</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modelling Language</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>WML</td>
<td>Wireless Mark-up Language</td>
</tr>
<tr>
<td>WURFL</td>
<td>Wireless Universal Resource File</td>
</tr>
<tr>
<td>XML</td>
<td>Extensible Mark-up Language</td>
</tr>
</tbody>
</table>
CHAPTER 1: INTRODUCTION

1.1 Background
1.2 Research Problem and Relevance of the Research
1.3 Thesis Statement
1.4 Research Overview
1.5 Thesis Structure

1.1.1 Challenges in Browsing Product Catalogue Information in M-commerce
1.1.2 Existing Remedies to Catalogue Browsing Challenges in M-commerce
1.1.3 Context Information
1.1.4 Proposed Solution

1.4.1 Research Objectives
1.4.2 Research Questions
1.4.3 Scope and Constrictions
1.4.4 Research Contribution
1.4.5 Research Methodology

Deliverables: Research Setting

CHAPTER 1
Introduction

CHAPTER 2
Research Design

CHAPTER 3
Online Business

CHAPTER 4
Usability of Online Product Catalogues

CHAPTER 5
Context-Awareness

CHAPTER 6
Context-Aware Model

CHAPTER 7
Research Evaluation and Analysis of Results

CHAPTER 8
Conclusions

Research Objectives (RO)
Research Questions (RQ)
Research Strategy

RQ1: Understanding of Online Business and Consumer Behaviour
RQ2: Exploiting Usability Challenges in Catalogue Browsing on a Mobile Device
RQ3: Gaps in Existing Solutions to Address Identified Usability Challenges
RQ4: Conceptual Context-Aware Model and POC Prototype
RQ5: Usability of the Context-Aware Model in Addressing Usability Challenges in Browsing a Catalogue on a Mobile Device
RQ6: Research Findings, Contributions and Recommendations

A Context-Aware Model to Improve Usability of Information Presented on Mobile Devices

Figure 1-1: Chapter 1 context
1.1 BACKGROUND

Online information access on a mobile device is increasing as a result of the increase in the use of Internet-enabled handheld (or pocket-size) mobile devices by end users and recent improvements in wireless Internet innovations (Zhang and Lai, 2011). The combined influence of recent enabling technologies such as Web 2.0, App stores, and improved wireless networks have propelled the surge in online applications that allows users to access various types of information on mobile devices regardless of time and location (Tiwari, Buse and Herstatt, 2008; Rose, Hair and Clark, 2011; Nayebi, Desharnais and Abran, 2012). Examples of such applications (usually shortened to app) include: social media, such as Facebook App™ and Twitter App™, banking applications such as Standard Bank South Africa Mobile Banking App™ (StandardBank, 2013), and First National Bank (FNB) Banking App™ (FirstNationalBank, 2013), news, such as news 24 App™ and BBC News App™, and other websites that have been adapted for mobile presentation. Figure 1-2 shows interface examples for selected mobile apps.

Online businesses, that is, businesses which conduct buying, selling, and business transactions by processing activities online using the Internet, have taken this opportunity to extend electronic commerce (e-commerce) initiatives into mobile commerce (m-commerce) (Stafford and Gillenson, 2003; Orjuela-Parra, Carrillo-Ramos and Martinez, 2009; Schmeidl,
Online businesses that interact with end user customers implement B2C m-commerce applications that enable customers to access and browse product catalogue information on mobile devices, anytime, anywhere (Gallego and Huecas, 2012; Amazon, 2013b). Product catalogues contain information about products which a business is selling and play an essential role in disseminating information about what a business is offering on the market (Callahan and Koenemann, 2000; Mao Lin, Quang Vinh, Viet Cuong and Junhu, 2009; Chang and Wang, 2010). Product catalogues can be accessed manually on paper brochures or electronically by using a digital device in e-commerce and m-commerce and, in the latter case, they are referred to as electronic product catalogues.

Customers accessing electronic product catalogue information on a mobile device face a number of challenges, such as long list of products presented on a small screen and longer waiting times for information to load. These challenges mainly originate from the limiting and dynamic nature of the mobile apps’ operating environment, for example, location, bandwidth fluctuations, and diverse and limited device features, collectively referred to as context information (Poulcheria and Costas, 2012). A number of shortfalls have been discovered in existing context-aware solutions implemented to address these challenges, such as, failure to leverage the diverse range of context information during an applications’ runtime. For example, most context-aware research focused on location as the only context information and yet context includes more than location (Santos, Cardoso, Ferreira, Diniz and Chaínho, 2010; Asif and Krogstie, 2012). In addition, literature analysed thus far failed to show specific details of how context information is utilised during information retrieval and presentation in m-commerce environments.

This research sets out to design and implement a context-aware model that can be utilised to improve presentation of information on mobile web. The motivation for selecting a product catalogue is that literature has shown that improved presentation of information on online shopping storefronts has a positive impact on usability of the websites, improves efficiency in consumer behaviour that impacts sales, profits and business growth (Callahan and Koenemann, 2000; Mao Lin et al., 2009). It is envisaged that the use of such a model in m-
commerce applications can help to improve usability with regard to product catalogue browsing on a mobile device.

The bigger picture of the research is to propose a context-aware model that can be utilised to improve usability of information presented on the mobile web interfaces. There are different types of information that is presented on mobile web interfaces (for example Figure 1-2). In order to contain the scope of this research, product catalogue information was selected as a smaller domain within the various types of information that this research will focus on. The usefulness of product catalogue in online shopping is an additional motivation for the choice and furthermore, product catalogue information as discussed in Section 4.2 was found to be more structured and easy to use as a use case for the purposes of this research (Callahan and Koenemann, 2000; Mao Lin et al., 2009; Yuan and Fernandez, 2011).

Another areas in which the outcome of this research can have an impact is that of Adaptive Hypermedia Systems (AHS). AHS build a model of the individual user and apply it for adaptation to that specific user, for example, to adapt the content of a hypermedia page to the user’s knowledge and goals, or to suggest the most relevant links to follow (Brusilovsky, 1996; Lowe and Hall, 1999). There has been a number of applications that have been proposed in this area mostly focusing on frameworks for online education systems for example GALE, AHA and AHAM (De Bra, et al., 2013; De Bra et al., 2003). General examples of AHS include: on-line information systems, online help and information retrieval (Brusilovsky, 1996, 2001; Knutov, 2012). AHS are useful for adapting content for which users have different goals for accessing the system and the hyperspace is reasonably big (Brusilovsky, 1996, 2001). The model proposed in this research can be utilised in various AHS in order to improve the effectiveness of implemented adaptations. This research focuses on context modelling and general web information presentation, therefore AHS will not be explored in detail.

The following sub-sections discuss the background to the research by introducing challenges customers face when browsing a product catalogue on a mobile device. As it is the case with any other information accessed via a mobile interface, shortfalls occur in existing solutions implemented to solve these challenges. The sub-sections further introduce context and discuss the objective of the research by outlining the proposed context-aware model and how
it can address the challenges in accessing or browsing catalogue information about products on mobile devices.

1.1.1 Challenges in Browsing Product Catalogue Information in M-commerce

Browsing a product catalogue online when using a mobile device is a cumbersome task for customers (Zhang and Lai, 2011). This is because there are a number of factors in addition to the limited physical properties inherent in a mobile device that makes browsing the product catalogue a tedious task. Examples of such factors include the user’s profile, connection strength and specific mobile device properties, such as, low memory, limited processing power, small screen size and limited user input modes, for example, a small keyboard (Ho and Kwok, 2003; Glissmann, Smolnik, Schierholz, Kolbe and Brenner, 2005; Issel and Mrozik, 2008; Schmeidl et al., 2009; Xining et al., 2010; Zhang and Lai, 2011).

The identified challenging factors and constrained physical characteristics of mobile devices raise a number of usability problems in mobile web information access. In m-commerce, for example, long lists of product or general information extend the screen and require scrolling (vertical or horizontal) on a small screen (Ho and Kwok, 2003; Zhang and Lai, 2011). Usability and specific usability challenges with regard to browsing a product catalogue on a mobile device are discussed in Chapter 4. Such problems create a need for special considerations regarding product catalogue information retrieval and presentation in order to improve overall usability of m-commerce applications (Zhang and Lai, 2011).

1.1.2 Existing Remedies to Catalogue Browsing Challenges in M-commerce

A number of solutions have been implemented to resolve challenges customers face when browsing information on the web, with recommender systems being the most commonly utilised (Amazon, 2013a). Recommender systems utilise some form of created user models (customer profiles) to make suggestions on products (or content in the case of other types of information, such as news) to customers, during future visits in order to improve their online experience (Xiaohui and Murata, 2011; Asif and Krogstie, 2012). A number of techniques are utilised to determine what items to suggest to customers in recommender systems, for example, content-based filtering, collaborative filtering and hybrid techniques (Xiaohui and Murata, 2011). User models or customer profiles play an important role in recommender systems since these models provide user preferences that are utilised to determine appropriate

Recommender systems assist end users (or customers) by presenting them with suggestions consisting of a smaller amount of information, be it product catalogue or any information, in order to help users to make efficient and effective decisions. Literature, however, shows that approaches, such as recommender systems, have not been extensively investigated in m-commerce to curb product recommendation and challenges concerning presentation of product information in the catalogue (Ricci and Nguyen, 2005; Maheswari and Reddy, 2009).

1.1.3 Context Information
Despite the usability challenges which customers experience in m-commerce, the mobile web environment that embraces m-commerce, is rich with context that can effectively be used to provide information to improve the accuracy of product and catalogue information recommendations about products (Barnard, Yi, Jacko and Sears, 2007; Zhang, Shan, Xu, Yang and Zhang, 2007; Ismail, Osman and Wahab, 2009; Bohmer and Bauer, 2010; Bohmer, Bauer and Kruger, 2010; Schmidt, 2013). Context in computing can be explained as information that is available and can be used to characterise the users’ interaction space but does not form part of the application itself, for example, the user’s profile and the characteristics and location from which the user is accessing the application (Barnard et al., 2007; Bohmer and Bauer, 2010; Lowe, Mandl and Weber, 2012).

Context-aware computing aims at leveraging context information in order to improve interaction between the user and a computer or mobile application depending on a particular context (Dey, 2001; Dey and Hakkila, 2008; Turban et al., 2011; Lowe et al., 2012). Regardless of the fact that context information is proving useful in improving usability of both desktop and mobile web applications, most recent context-aware studies are, however, biased towards mobile web computing because of varying contexts of use that exist in the mobile environment (Schilit, Adams and Want, 1994; Anagnostopoulos, Tsounis and Hadjiefthymiades, 2007; Dey and Hakkila, 2008; Poulcheria and Costas, 2011; Schmidt, 2013). There are many context parameters in a mobile environment. Research however shows that very few context parameters are normally utilised in isolation to improve usability (Lowe
et al., 2012; Ntawanga, Calitz and Barnard, 2013). For example, location has mainly been utilised to develop location-aware mobile applications (Orjuela-Parra et al., 2009; Asif and Krogstie, 2012).

1.1.4 Proposed Solution

This research sets out to propose, develop and evaluate a context-aware model that can be incorporated into an m-commerce application in order to optimally retrieve and present product catalogue information on a mobile device interface. The context-aware model will be able to collect accurate context information in real-time within the user’s environment. The collected context information is used as a constraint during retrieval and presentation of product catalogue information on a mobile device interface. Secondly, the research aims to assess the improvement in usability of an m-commerce application with regard to browsing a catalogue when context information is utilised through the context-aware model to facilitate optimal retrieval and presentation on a mobile device of product information on a catalogue.

The model’s functionality will be evaluated in terms of the following criteria (Santos et al., 2010):

1. Ability to efficiently and accurately collect selected context information in real-time (Sections 6.4.1 and 7.3.1);
2. Ability to aid optimal retrieval and presentation based on determined context information (Sections 6.4.2 and 7.3.4);
3. Overall efficiency of the model (Section 7.3.4).

Section 1.4.2 presents the research questions that will be addressed in order to achieve the goals of the research. The evaluation to assess the model’s ability to improve usability will proceed as follows:

1. Identification of an existing m-commerce application with a product catalogue management system;
2. Integrating the implemented context-aware model into the system identified in Step 1 above;
3. Two within-subject end user evaluations of an existing m-commerce website will be conducted. The first evaluation will be conducted on the original system that will not
be using the context-aware model, while the second evaluation will be conducted on the second version of the system with a context-aware model for optimal retrieval and presentation of product catalogue information running in the background;

4. Conducting statistical data analysis on the results of the two evaluation surveys in order to empirically determine usability improvement.

It is envisaged that the model will support efficient browsing of product catalogues on mobile interfaces, thus improving overall usability of m-commerce applications in the process. Contextual constraints will be used to help narrow the search results and to determine the optimal way of presenting the results on a mobile device user interface. Findings from this research will constitute recommendations that can be used to improve the usability of m-commerce applications, and general presentation of information on mobile web.

1.2 RESEARCH PROBLEM AND RELEVANCE OF THE RESEARCH

Accessing product information and conducting business transactions online by using a mobile device is becoming very popular because of a number of factors, such as convenience, easy connection, ubiquity and cheaper costs of the hardware (Kim, Chan and Gupta, 2007; Natchetoi, Kaufman and Shapiro, 2008; Turban et al., 2011; Gallego and Huecas, 2012). In m-commerce, customers with diverse profiles, for instance, varying levels of computer experience, are now able to access e-commerce websites by using a mobile device to browse online product catalogues and purchase products (Stafford and Gillenson, 2003; Jahanshahi et al., 2011; Amazon, 2013a).

Efficient browsing of online product catalogues can increase traffic and sales for an online store (Mao Lin et al., 2009). Browsing a product catalogue, however, on a mobile device is a tedious task because of the constrained physical features of mobile devices, for example, low memory, limited processing power, small and varying screen sizes and limited user input modes (Glissmann et al., 2005; Koukia, Rigou and Sirmakessis, 2006). These factors raise a number of usability problems with regard to browsing a product catalogue on a mobile device and have a negative impact on the overall user experience and consequently on sales. Challenges experienced by m-commerce users while browsing a catalogue on a mobile device form the basis of the problem which this research aims to address. The following is the main problem to be addressed in this research:
Usability problems exist in m-commerce environments with regard to browsing an online product catalogue by using a mobile device.

The mobile environment is rich with context information that can be utilised to correctly determine factors within the user’s interacting space that may influence accomplishment of an intended goal through the use of the application (Barnard et al., 2007; Bohmer and Bauer, 2010; Bohmer et al., 2010). This information can be used to determine, for example, what will be the most likely items of interest to the user in a particular context. Researchers have devised various techniques, including physical and logical sensors, that determine different types of context information within the user’s environment.

These techniques are continuously utilised to develop adaptive m-commerce applications that deliver online mobile services while taking into consideration opportunities and challenges within the user’s context. For example, various research projects have been undertaken to discover which context, such as location, has been utilised in order to determine suitable location-aware services to present to online users (Bellavista, Corradi and Montanari, 2006; Coppola, Mella, Di Gaspero, Menegon, Mischis, Mizzaro, Scagnetto and Vassena, 2009; Ismail et al., 2009; Orjuela-Parra et al., 2009; Schmidt, 2013). Results indicated that usability of applications improved after a determined user location was utilised within the application in order to provide information relevant to the users’ current location.

Literature analysed thus far has failed to show full use of context information during information retrieval and presentation in m-commerce environments. For example, most context-aware research has been focusing on location as the only context information (Ismail et al., 2009; Schmidt, 2013). Specific literature on optimal information retrieval and presentation of product catalogue information on mobile devices has not yet been found.

The above observation was also emphasised by Barnard et al. (2007:83) who acknowledged that:

“The domain of context-awareness is nearing a state where it is faced with an abundance of potentially relevant available data, but a deficit of knowledge of how to use it.”

The limitations discovered in literature thus provide a strong basis for further research. This research focuses on the use of various types of context information by means of a context-

9
aware model to facilitate optimal retrieval and presentation of product catalogue information on a mobile device. It is envisaged that the use of such a model in m-commerce applications can help improve usability with regard to product catalogue browsing on a mobile device.

1.3 THESIS STATEMENT

A Positivist research approach (Section 2.2.2) will be adopted and the following is the thesis statement that will guide this research:

A context-aware model for optimal retrieval and adaptive presentation of product catalogue information can help address usability problems in m-commerce with regard to online product catalogue browsing on a mobile device.

1.4 RESEARCH OVERVIEW

This section presents the research questions to be addressed in this research, methodologies to be used to address each research question as well as deliverables from each research question. The section also discusses the scope and constraints of the research. An overview of research design will also be presented.

1.4.1 Research Objectives

The main objective of the research is to:

**RO**<sub>M</sub>: Conceptualise (and design), implement and evaluate a context-aware model for the optimal retrieval and presentation of product catalogue data on a mobile phone.

The goal is twofold: first, to determine best practices in context-aware computing that can guide development of an efficient context-aware model for m-commerce applications and the second is to determine the impact of the context-aware model with regard to improving usability of product catalogues presented on m-commerce storefronts.

Specific objectives of the research aim to:

- **RO**<sub>1</sub>: Understand the state of the art in online business with regard to development and online consumer behaviour;
• **RO2a**: Investigate usability problems experienced by customers when browsing product catalogues when using a mobile phone;

• **RO2b**: Explore and analyse gaps in current techniques designed to address usability problems identified in RO2a;

• **RO3**: Explore the state of the art in context-aware computing with regard to background and the implementation of building blocks in m-commerce;

• **RO4**: Conceptualise, design and implement a Proof of Concept (POC) prototype of a context-aware model to be utilised for optimising retrieval of a personalised product catalogue and presentation thereof on a mobile device in m-commerce;

• **RO5**: Evaluate and present results of the context-aware model’s usefulness in improving usability with regard to product catalogue browsing on a mobile device;

• **RO6**: Make and present theoretical and practical recommendations with regard to the impacts of context-aware computing on improving usability of information retrieval and its presentation on mobile interface.

### 1.4.2 Research Questions

The following is the primary research question which this research aims to address:

\[ RQ_M: \text{How can a context-aware model for optimal retrieval and presentation of product catalogue information be implemented to improve the usability of online product catalogue browsing on a mobile device?} \]

The following are secondary research questions:

• **RQ1**: What is the state of the art in of online business with regard to development and consumer behaviour?

• **RQ2a**: What usability problems are experienced when browsing a product catalogue in m-commerce when using a mobile device?

• **RQ2b**: How are problems identified in research question 2a addressed?

• **RQ3**: What is the state of the art in context-aware computing with regard to background and implementation of building blocks?

• **RQ4**: How can a context-aware model for optimal retrieval and presentation of product catalogue information on a mobile device be implemented?
• **RQ5:** How useful can a context-aware model for optimal retrieval and presentation of product catalogue information be in addressing usability problems in m-commerce with regard to browsing a product catalogue when using a mobile device?

• **RQ6:** What recommendations can be made with regard to utilising context during retrieval and presentation of product catalogue information in order to improve the usability of product catalogue in m-commerce applications?

Table 1-1 summarises the relationship between specific research objectives (Section 1.4.1), secondary research questions (Section 1.4.2) and the chapter number in which a particular research objective and question are addressed. The table further shows the methodologies used to answer a specific research question and objective as well as the core deliverables to be obtained from the research questions. Figure 1-3 and Section 1.5 present the thesis structure that discusses the entire composition of the thesis including the supporting Chapters 1 and 2.

1.4.3 **Scope and Constraints**

The scope of this research is limited to designing, implementing and evaluating a context-aware model. A POC prototype of the model will be developed for evaluation purposes only. There exists a number of context parameters in m-commerce, for example, location, user preferences and device profiles (Pushpa and Venkataram, 2011). For the purposes of this research a set of context parameters will be used as constraints during optimisation of retrieval and presentation of product catalogue information on a mobile device. The specific context parameters suitable for this research will be selected from the main classes of context in mobile web (Section 5.3.1).

Measuring usability improvement with regard to browsing a catalogue on a mobile device when the model is incorporated into an m-commerce application will be limited to assessing the application’s effectiveness, efficiency and the user satisfaction with regard to retrieving and presenting product catalogue information on a mobile device in different contexts of use. User experience evaluation of the benefits of the model falls outside the scope of this research. The model will be incorporated into a selected, existing m-commerce system with a catalogue management system to provide a platform for end user evaluation of the model’s usefulness.
A sample of suitable users with prior experience with the existing m-commerce application to evaluate the model’s usability is a major constraint. As a remedy to this challenge, a suitable sample has been found in Kgautswane Village in Limpopo Province, South Africa.

<table>
<thead>
<tr>
<th>Research Objectives</th>
<th>Research Questions</th>
<th>Chapter</th>
<th>Methodology</th>
<th>Deliverable</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO₁</td>
<td>RQ₁</td>
<td>3</td>
<td>Literature study</td>
<td>Understanding of Online Business and Consumer Behaviour.</td>
</tr>
<tr>
<td>RO₂a</td>
<td>RQ₂a</td>
<td>4</td>
<td>Literature study</td>
<td>Exploring usability challenges in catalogue browsing on a mobile device.</td>
</tr>
<tr>
<td>RO₂b</td>
<td>RQ₂b</td>
<td></td>
<td>Literature study</td>
<td>Gaps in existing techniques designed to address identified usability challenges.</td>
</tr>
<tr>
<td>RO₃</td>
<td>RQ₃</td>
<td>5</td>
<td>Literature study</td>
<td>Best practices in context-aware computing that can guide development of the proposed context-aware model.</td>
</tr>
<tr>
<td>RO₄</td>
<td>RQ₄</td>
<td>6</td>
<td>Literature study and Prototyping</td>
<td>Conceptual context-aware model and POC prototype of the model.</td>
</tr>
<tr>
<td>RO₅</td>
<td>RQ₅</td>
<td>7</td>
<td>Field user evaluation</td>
<td>Usefulness of the context-aware model in addressing usability challenges with regards to browsing a catalogue on a mobile device.</td>
</tr>
<tr>
<td>RO₆</td>
<td>RQ₆</td>
<td>8</td>
<td>Recommendations</td>
<td>Research findings, contributions and recommendations.</td>
</tr>
</tbody>
</table>

Table 1-1: Research objective, secondary research questions, methodology and deliverables
1.4.4 Research Contribution

The research will contribute towards theoretical and practical ways of addressing m-commerce usability problems with regard to browsing a product catalogue when using a mobile device. Theoretically, the research will review the literature and aim at discovering concepts relating to how context can be utilised to improve the usability of m-commerce applications with regard to product catalogue browsing. Contribution to theory will be towards the fields of usability and context-aware computing. The theory will provide input for the design of a theoretical (conceptual) model that will be developed into a functional prototype.

Practically, the research will develop a POC prototype to demonstrate the feasibility and usefulness of the proposed context-aware model. The POC prototype will also be utilised for evaluation purposes. Evaluation results will constitute recommendations on how context can be utilised to address usability challenges in m-commerce applications with regard to browsing a catalogue on a mobile device. Similarly, recommendations from the research can be extrapolated and utilised to address the challenge of presenting relevant information on mobile devices across different domains, for example, news and social media.

1.4.5 Research Methodology

A Positivist research philosophy (Section 2.2.2) will be adopted and the following will be the main research methodologies to be utilised:

1. Literature study: A literature study will describe the foundation of the research by providing an understanding of the methods used to retrieve and present information on mobile devices. Furthermore, the literature study will clarify what type of context information is available in an m-commerce environment and how selected context information can be utilised to support optimal retrieval and presentation of product catalogue information;

2. Prototyping: A context-aware model will be designed and implemented into a functional prototype. The prototype will be utilised to conduct end user studies in order to assess both the feasibility of the model as well as its benefits in improving usability with regard to product catalogue browsing;
3. **End user studies:** End user studies will be central to evaluating the benefits of using the model during retrieval and presentation of product catalogue information on a mobile device.

Questionnaires will be the primary data collection method to be utilised in this research (Section 2.3.3.3). Additional secondary data will be collected from the system logs. Chapter 2 expands the research design and provides detailed steps on how the research will be conducted, including motivation for the selected research methods and techniques.

Figure 1-3 shows the thesis outline that extends the research methodology with a step-by-step indication of various activities to be carried out during the course of the research as well as outcomes in terms of chapters. The next section presents the thesis outline.
Figure 1-3: Thesis outline
1.5 THESIS STRUCTURE

The thesis chapter structure is as follows:

- Chapter 1 introduces the research, presents the goals and objectives of the research. The chapter covers the following main topics: background to the research, relevance of the research, thesis statement, research objectives and questions, and introduces the research design that is covered in details in Chapter 2.

- Chapter 2 discusses the research design that provides a detailed description of how the research will be conducted. Specific topics in this chapter include: research philosophy, research methodology, and data collection and analysis tools.

- Chapter 3 introduces the research setting by discussing the state of the art in online business. Main topics covered in this chapter include: an overview of e-commerce and m-commerce, e-commerce systems architecture, challenges and opportunities in e-commerce and factors that influence consumer behaviour in online shopping.

- Chapter 4 discusses usability of online product catalogues and tackles two of the three main topics covered in this research namely product catalogue and usability. The chapter defines product catalogue, types, and singles out the type of catalogue of interest in this research which is an online product catalogue. The chapter further discusses usability and outlines the usability problems which customers face when browsing a product catalogue on a mobile device. Remedies to address usability challenges with regard to browsing a catalogue in e-commerce have also been discussed in this chapter.

- Chapter 5 discusses the state of the art in context-aware computing which is the third main topic of this research. Context-aware computing is a relatively new field in computing and this chapter aims to explore the recent theory in context-aware computing. The chapter discusses definition, types of context, acquisition and use of context. The chapter further discusses relevant context information in an m-commerce environment for the purposes of this research.

- Chapter 6 will discuss the context-aware model’s conceptualisation, implementation techniques and its use case. The chapter will introduce how mathematical models are used to solve optimisation problems and a selected model will be discussed in relation to meeting the goals of this research. The chapter will discuss the
conceptualisation, implementation and integration of a context-aware model for optimal retrieval and presentation of product catalogue information on a mobile device. This chapter brings together the three main topics of the research in order to address the research objectives.

- Chapter 7 will discuss evaluation of the model and analysis of results. Topics to be covered in this chapter include: evaluation objectives and procedure, sample description, data collection and analysis. The chapter will also present the results of the research.

- Chapter 8 concludes the thesis by revisiting objectives and how they were met during the research. The chapter also discusses the specific research contribution by highlighting the research findings, contributions to the body of knowledge and recommendations. In addition, the chapter will present opportunities for further research that can emanate from this research.

The next chapter discusses research design that presents the research methods and techniques to be utilised to address the research objectives and questions (Sections 1.4.1 and 1.4.2). Motivation for selecting specific methods will also be discussed.
Figure 2-1: Chapter 2 context
2.1 INTRODUCTION

Research is a process of generating new knowledge by asking questions and seeking answers to those questions either by re-using what others have found or inventing new answers (Clough and Nutbrown, 2007). Chapter 1 presents the position of this research. The major outcomes of Chapter 1 are the background to the research problem and a motivation for exploration of the relevance of the research (Section 1.2), thesis statement (Section 1.3) and the research objectives and questions which this research aims to address (Sections 1.4.1 and 1.4.2). This current chapter builds upon the conceptual framework presented in Chapter 1 to discuss the research design to be employed for this research.

Research design can be defined as the general procedure or logical plan of how a researcher can go about answering research questions (Limpanitgul, 2009; Saunders, Lewis and Thornhill, 2009; Kumar, 2011). The objective of research design is to provide answers to questions, such as what relevant data will be collected, which methods will be employed to collect the data and how the data will be analysed in order to gather information that can be used to address the questions within the research process. Research design can be thought of as a blueprint detailing what will be done and how it will be accomplished in a research process (Kothari, 2009; Kumar, 2011).

The objective of this chapter is to discuss the research methodology and design which outlines the logical structure of how this research will be conducted. The logical structure will include the sequence and execution plan of various identified research activities targeted at addressing research questions outlined in Section 1.4.2. This chapter will motivate the selection of specific research techniques to be utilised when conducting various activities in this research.

Two main topics are covered in this chapter: firstly, a theoretical background about research (Section 2.2). Research philosophy, research approach and research methods will be discussed under this topic. Secondly, the research process (Section 2.3) will be explored. The main activities in this research, such as sampling techniques, and data collection and analysis will be discussed under this topic. Additional topics include ethical considerations and limitations of the selected techniques (Sections 2.4 and 2.5). The chapter discusses the research design by peeling off each layer of the research onion illustrated in Figure 2-2 that
was proposed by Saunders et al. (2009). The research onion outlines the necessary processes as well as techniques that can be utilised in a research process.

![Research onion diagram](image)

Figure 2-2: Research onion
Source: Saunders, Lewis and Thornhill (2009: 108)

### 2.2 THEORETICAL BACKGROUND

There is a number of theoretical aspects that a researcher must take into consideration during the research process (Section 2.3). This section discusses the general theoretical background that provides guidelines for conducting research. Applicability and motivations for selected theories to guide this research have also been discussed.

#### 2.2.1 General Definitions

Theories and terminologies in research have been inconsistently defined by various authors. (Edmonds and Kennedy, 2012). This section therefore outlines the adopted definitions and meaning of research terms that will be utilised in this chapter and the rest of the thesis in order to avoid confusion about research terms in this research (Figure 2-2):

1. **Research philosophy:** Research philosophy refers to the development of knowledge and the nature of the knowledge developed (Oates, 2008; Saunders et al., 2009).
2. *Research approach:* Research approach refers to the process that is followed by a researcher in pursuit of the truth or of evidence in research (Saunders *et al*., 2009).

3. *Research methods (or strategies):* Research methods (or strategies) can be defined as the actual techniques utilised to collect research data that is used to support theories in research (Kothari, 2009).

4. *Research methodology:* Research methodology provides the procedure for actual execution of a research method in responding to a research question.

### 2.2.2 Research Philosophy

Research philosophy provides a researcher with the basic guidelines on how research can be conducted by outlining beliefs about the way data regarding a phenomenon should be collected and analysed (Levin, 1988). The research onion (Figure 2-2) presents a number of research philosophies, however this section discusses the four main philosophical aspects of research as follows:

- **Positivism:** Positivist research philosophy states that reality is stable and can be observed and described from an objective viewpoint, that is, without the researcher interfering with the phenomena being studied (Levin, 1988; De Villiers, 2005; Oates, 2008; Saunders *et al*., 2009). Empirical evidence is regarded as valid and is required to support research findings in positivism (SocialResearchMethods, 2012). Positivism is the oldest and most commonly used research philosophy in information system research (Alavi and Carlson, 1992; Oates, 2008). Positivists believe that research is reliable if results can be replicated and Positivism is usually associated with quantitative research methods;

- **Interpretivism:** The Interpretivist research philosophy states that reality keeps on changing, things that are true today may not be true in the future or in another context (De Villiers, 2005; Oates, 2008). Therefore the meaning is usually interpreted by the subjective view of the researcher within a certain context and the researcher is part of what is being researched (Saunders *et al*., 2009). This implies that different researchers can draw different conclusions about a phenomenon even when a study is done within the same context. The Interpretivist approach usually involves qualitative research methodologies, such as observations and interviews and results are difficult to replicate;
• **Realism:** Realism states that things exist whether or not the human mind perceives them (Limpanitgul, 2009). Reality in a Realist approach is considered to be stable, but hidden social factors have an influence on its behaviour and it is the researcher’s duty to expose the hidden factors. Generally, it can be stated that the Realist view falls between Positivism and Interpretivism;

• **Pragmatism:** Pragmatism involves multiple views according to the research question that is to be answered (Saunders *et al.*, 2009). The researcher can have both the subjective and objective view of a phenomenon.

Based on the conceptual framework presented in Chapter 1, a suitable philosophical approach to address the research questions is Positivism. The current research aims at implementing a context-aware model and measuring the benefits of the model in improving usability of product catalogue browsing in m-commerce. Quantitative research results will be presented objectively and can be replicated. These factors justify the use of a Positivist approach in this research.

Evidence from similar research indicates that context information, such as location, is useful when taken into consideration during design and run-time of mobile applications (Coppola *et al.*, 2009; Ismail *et al.*, 2009; Orjuela-Parra *et al.*, 2009). This fact complements the suitability of a Positivist approach for use in this research in that the endeavours to be carried out in this research will aim at fulfilling or identifying evidence to support the thesis statement mentioned in Section 1.3.

2.2.3 Research Approach

Research approach has been defined as the processes of a researcher’s thinking during the pursuit of the truth or evidence in research. There are two main research approaches in a research process, namely, deductive and inductive approaches (Saunders *et al.*, 2009). These approaches were adopted from philosophy where they are used in the process of determining or finding the truth about a phenomenon (Dane, 2011).

In a deductive approach a researcher works to find the truth or prove a hypothesis by moving from general observations and determine specific information to support the observation. Specific information is utilised to test the validity of the general observation. In an inductive approach the researcher searches for the truth by gathering specific information to realise
general observations (Bryman and Bell, 2007; Saunders et al., 2009). There is no theory to test an inductive research approach and therefore this approach is suitable for topics that are new and where limited literature exists. Figure 2-3 shows how deductive and inductive research approaches relate to each other.

![Figure 2-3: Deductive and inductive research approach](image)

This research follows a process where general information (thesis statement in Section 1.3) will be supported by specific information (facts) that will be collected by various means such as user studies. This implies that this research will primarily employ a deductive approach in search of evidence to support the thesis statement (Section 1.3). An inductive approach will, however, be utilised to address the secondary premises of the research. For example, the context-aware model will be inductively designed and implemented where theory from model-based development and context-awareness will be utilised to develop the conceptual model. This means an inductive approach will also be utilised in this research. Complementing one research approach with the other during research has been highlighted as advantageous by other authors (De Villiers, 2005; Saunders et al., 2009).

### 2.2.4 Research Methods and Strategies

Research methods have been defined as the actual techniques that are utilised to collect data during research. Research methods fall into two categories, namely, quantitative and qualitative research methods (Quinlan, 2011; Edmonds and Kennedy, 2012). Quantitative research methods focus on collecting data that is in number form and can be measured in known units (Edmonds and Kennedy, 2012). Qualitative research methods on the other hand
focus on collecting data that is observable and can be described with no measurements involved (Edmonds and Kennedy, 2012).

The type of research questions usually determines whether qualitative or quantitative research methods can be utilised to collect the data. Researchers further argue that research philosophy and its approach have a direct influence on the research methods to be utilised (Saunders, Lewis and Thornhill, 2012). For example, a Positivist research philosophy follows a deductive approach that is usually followed by quantitative research methods in which empirical data is collected and analysed to prove a hypothesis. Similarly, an interpretive research philosophy follows an inductive research approach and it is usually accomplished by qualitative research methods.

Section 2.2.3 concluded that both deductive and inductive research approaches will be utilised in this research and therefore both quantitative and qualitative methods will be used. Field testing and end user evaluation surveys will be the main data collection techniques in this research. Motivation for selecting these methods is discussed in Research Process (Section 2.3).

Figure 2-4: Research methods/strategies
Source: Adapted from De Villiers (2005: 143)

Figure 2-4, adopted from De Villiers (2005), summarises the relationships that exist between research philosophies (Section 2.2.2), approach (Section 2.2.3) and methods (Section 2.2.4). The figure illustrates specific quantitative and qualitative research methods that can be
utilised in an inductive and deductive approach on the Positivist and Interpretivist axis (De Villiers, 2005). The following section discusses the research process that outlines the major activities to be completed in this study.

2.3 RESEARCH PROCESS

A research process can be defined as the means of effectively locating information to answer research questions that is normally accomplished by a research methodology. A research methodology can be defined as a way employed to tackle a research question during the course of the research (Oates, 2008). This section discusses the main methodologies, namely, literature study, prototyping and evaluation to be applied in answering the research questions (Section 1.4.2) set in this study. The research process discussed in this section is similar to the concepts of Design Science Research (DSR). The researcher decided not to follow DSR to avoid confusion as it was observed that DSR lacks rigour and it is in infant stages in IS research (Vaishnavi and Kuechler, 2007; Indulska and Recker, 2008; Gleasure, Feller and O’Flaherty, 2012).

2.3.1 Literature Study

A literature study is an effective account of research work that has been done in a field under consideration (Randolph, 2009). Typically, literature study is regarded as a foundation for any research so that the current research can be aligned to previous work in the selected field (Randolph, 2009; Kumar, 2011). The main literature topics to be covered in this research are in line with the conceptual framework presented in Chapter 1 and include the following: overview of online business (Chapter 3), product catalogue usability in m-commerce on mobile devices (Chapter 4), context and context-awareness (Chapter 5). Additional literature review will be conducted to gain understanding and elaborate on motivations for additional selected techniques to be utilised during development, for example, mathematical optimisation and model-based design (Chapter 6).

The literature review will provide further clarification of the problem and describe what attempts have been implemented by other researchers to address a similar problem. Furthermore the literature will provide a basis for the design and implementation of the proposed model.
2.3.2 Development Methodology

Part of this research involves the development of a software artefact and this section discusses the development methodology that will guide the development process. Software development process or Software Development Lifecycle (SDLC) is an organised set of processes that are followed during the development of a software product. There are four fundamental software development processes that must be followed during the development of any software product, namely, software specification, software development, software validation and software evolution (Sommerville, 2011).

A software development methodology in software engineering is defined as a framework structure for planning and controlling the SDLC processes during the development of a software product (Faridani, 2011). There are many software development methodologies that have been invented, however this section highlights the following, commonly used, methodologies (Faridani, 2011; Sommerville, 2011):

- **Waterfall model**: This model is a software development methodology in which various software development processes and activities are structured as cascades from one phase to another. A previous phase is normally finalised before moving on to the next phase in the waterfall model;

- **Incremental and iterative**: The software is developed by incrementing functionalities of the system with each cycle release. Different cycles with activities such as requirements elicitation, design, implementation and testing are iterated until the desired functionality is complete;

- **Prototyping**: Prototyping is defined as an iterative systems analysis, design and implementation technique usually utilised by developers or designers to get feedback on the product under construction from users during the software development lifecycle (Olivier, 2009; Sauter, 2012);

- **Spiral model**: Spiral model is a software development methodology that combines waterfall model and prototyping;

- **Extreme programming**: Extreme programming is a software development methodology that is based on incremental and iterative development, with the difference being that in extreme programming, requirements and solutions evolve through collaboration between cross-functional teams.
Based on the requirements of the proposed model to be developed in this research, prototyping has been selected as a suitable development methodology for this study. Prototyping is also widely used in developmental IS research in which the goal is usually to design a functional POC prototype that is used to prove a research concept (Olivier, 2009; Sauter, 2012).

In this research a context-aware model will be designed and implemented into a functional POC prototype. Model Based Software Engineering (MBSE) is the underlying paradigm that will be utilised in the SDLC of the model’s POC prototype development (Section 6.2.1). The context-aware POC prototype to be developed in this research will be integrated into an existing m-commerce application in order to improve retrieval and presentation of product catalogue data on a mobile phone. It is believed in this research that context-based retrieval and presentation of product catalogue data will improve usability with regard to product catalogue browsing on a mobile phone. End user studies (discussed next) will be conducted in order to assess the model’s feasibility as well as its benefits in improving usability with regard to product catalogue browsing. Chapters 6 and 7 discuss the detailed analysis, design, implementation, and evaluation of the model.

2.3.3 Evaluation Design

Evaluation of research is a process in which tests are conducted in order to collect data that can be used to draw major conclusions of the research (Dane, 2011). Evaluation is one important activity in a research process that involves various other sub-activities aiming at gathering relevant data for analysis. The outcomes of the data analysis are utilised to draw recommendations and conclusions (results) of the research. This section discusses how evaluation will be conducted by looking at sampling, a pilot study, data collection and analysis. Reliability and validity of results will be implicitly discussed in this section. Chapter 7 discusses the actual research evaluation.

2.3.3.1 Sampling

Sampling is a systematic process of selecting a small number of representatives from a population of interest in research so that by studying the small population, results can be generalised for the larger population from which the small selection was made (Edmonds and Kennedy, 2012; SocialResearchMethods, 2012). The selected population is referred to as a
Different techniques that are utilised in sampling fall into two main methods, namely probabilistic and non-probabilistic sampling (Edmonds and Kennedy, 2012; SocialResearchMethods, 2012).

a. **Probabilistic sampling:** Probabilistic sampling is a sampling technique that depends on probability theory to select members of the population that will form part of the sample (Kothari, 2009; Daniel, 2011; Edmonds and Kennedy, 2012). Every member of the population has a known and non-zero probability of being included into the sample (Daniel, 2011). The following are the main probabilistic sampling techniques (Kothari, 2009; Daniel, 2011; Edmonds and Kennedy, 2012; SocialResearchMethods, 2012):

- **Simple random sampling:** This is a technique in which every member of the whole population has an equal chance of being selected into a sample. Simple random sampling is recommended as the best way to get a true representative sample of the population;

- **Cluster random sampling:** Cluster random sampling is a technique in which the population is divided into clusters and representatives of the sample are selected randomly from the clusters. In other words, simple random sampling is conducted by clusters;

- **Stratified random sampling:** Stratified random sampling requires the population to be divided into strata or layers according to certain criteria, for example, age groups, and simple random sampling is conducted on the strata;

- **Systematic sampling:** Systematic sampling is a technique where the sample is made by selecting every nth person in the population until the required sample is found. Normally n is found by dividing the whole population by the required sample size;

- **Multistage sampling:** Multistage sampling involves a hybrid of any number of the above techniques.

b. **Non-probabilistic sampling:** Non-probabilistic sampling is a sampling technique that does not apply any probability for a representative of the general population to be included into the sample (Kothari, 2009; Daniel, 2011; Edmonds and Kennedy, 2012; SocialResearchMethods, 2012). Two main techniques under non-probabilistic sampling are:
• **Accidental/convenience/haphazard sampling:** Accidental sampling is a non-probabilistic sampling technique in which representatives are selected based on availability and willingness to participate in the survey;

• **Purposive sampling:** Purposive sampling is a non-probabilistic technique in which representatives of the sample are selected based on certain specific criteria that are presumed to have an influence on the goals and objectives set in the research.

Purposive sampling will be utilised in this research where a selection of only people with prior experience of the existing system will be asked to complete the questionnaires (Sections 1.4.3 and 2.3.3). Thirty small-scale traders with prior experience with the mobile e-procurement system that will be used to incorporate the model were identified in Limpopo Province. The criterion for a participant to be included in the sample is previous knowledge of the existing system. Such participants are believed to be able to provide the necessary feedback to be utilised to assess the usability improvement of the system when the context-aware model is utilised.

**2.3.3.2 Pilot Study**

A pilot study is a small experiment, conducted prior to the main study, designed to test logistics, validity of the data collection instruments and gather information that can be utilised to improve the latter’s quality and efficiency (Sharp, Rogers and Preece, 2011). The benefits of conducting pilot studies in research range from revealing deficiencies in the design of a proposed experiment, problems with evaluation procedures and sources of confusion in instructions to the participants. Identified challenges revealed by the pilot study can then be addressed before the actual study takes place, thereby saving time and resources.

The objectives of conducting a pilot study in this research will be:

• To identify and fix bugs and other problems in the model as well as with the integrated m-commerce application;

• To identify any usability issues with the application that could have a potential impact on the main evaluation results;

• To identify and resolve any ambiguity that may exist in the evaluation and data collection instruments such as questionnaires;

• To ensure the system’s readiness for the main end user evaluation.
The pilot study will be conducted in the laboratory by a sample of domain experts who will be able to identify usability issues as well as sources of confusion in the evaluation instruction and procedure. These participants will not form part of the main evaluation sample.

The main limitation of the proposed laboratory pilot study in this research is the lack of exposure to various context of use for the pilot participants. For example, all the participants will interact with the application in almost the same context and therefore system adaptation, based on context, will be limited. Furthermore, no previous history that has been used in retrieving a subset of the product catalogue will be available for these users and this may further affect the number of products retrieved and presented on the mobile phone.

2.3.3.3 Data Collection and Analysis

Data in research is defined as pieces of information that are gathered as evidence in order to explore a phenomenon under investigation (Quinlan, 2011). Data collection can be defined as the process of gathering specific pieces information to support research findings. There are two main types of data that can be collected in research: primary data and secondary data (Kumar, 2011). Primary data is data that is generated during the research process, for example, data that is generated through survey questionnaires and recordings. Secondary data is data that has already been generated and is gathered from sources such as the census.

There are many data collection techniques that can be utilised in information systems research, for example, questionnaires, observations, interviews and focus groups (Figure 2-4) (Oates, 2008; Olivier, 2009; Quinlan, 2011; Edmonds and Kennedy, 2012). The main data collection techniques that will be utilised in this research will be end user questionnaires that will be supported by user observations.

The end user evaluation will be a field study rather than a laboratory experiment in which the researcher will go to the participants A within-subjects technique in which the same sample is presented with different tests will be utilised in this research as opposed to between-subjects in which different samples are used for different tests (Edmonds and Kennedy, 2012; Tullis and Albert, 2013).
Data analysis is a follow up process to data collection in which the collected data is examined with the aim of discovering meaning for recommendations and conclusions of a phenomenon under investigation. Recommendations and conclusion normally mark the end of the research and introduce a significant contribution to the body of knowledge. This indicates that data collection and analysis play additional critical roles in a research process.

Descriptive and inferential statistics will be performed on the collected data in order to present the statistical validity of the results in addressing the research questions. The results will be used to draw conclusions and make recommendations about the research. Statistical expertise will be acquired from a consultant who will assist with statistical data analysis. The following section discusses ethical considerations.

2.4 ETHICAL CONSIDERATIONS

Ethics in research refers to the appropriateness of a researcher’s behaviour in relation to the rights of those who become the subjects or are affected by the research (Bryman and Bell, 2007; Saunders et al., 2009; Quinlan, 2011). The following are the main ethical issues in this research and how they will be addressed (Bryman and Bell, 2007; SocialResearchMethods, 2012):

1. Informed consent: Informed consent means that participants in the research be given all rights with regard to participating in the research. Participants must be told the scope and aims of the research and that they have a right to opt out of the survey as research is normally conducted on voluntary basis;

2. Invasion of privacy: Invasion of privacy means that the researchers must respect the right of participants to privacy;

3. Deception: Deception refers to the actions of researchers with regard to providing misleading information to other parties in the research process, for example, the researcher’s dishonesty in reporting the findings of the research may mislead other users of the research results.

Other additional ethical considerations include: data protection which refers to how the researcher will store the collected information after the research is complete, and conflict of interests which refers to parties, for example employers, that may have some other interest in the research.
The external party who might be affected by this research is the group of small-scale traders that will conduct the end user evaluation studies. Because of them, an ethical clearance application was submitted to the Nelson Mandela Metropolitan University Research Ethics Committee: Human (REC-H). Ethical clearance reference number: H11-Sci-CS-010 (Appendix A) was granted. During the survey, participants will be briefed about the survey and its aims and objectives. An informed consent form will be signed by each participant and the rights of participants will be explained in the consent form as well as by verbal description which will be provided. SAP Research gave the researcher permission to utilise its resources, such as space, to host the application on the server and have access to backend implementation of the existing application. Details of contact persons for the Sekhukhune Living Lab in Kgautswane village, Limpopo Province in which evaluations will be conducted were also given to the researcher by SAP Research. The next section discusses the limitations of the techniques and methodologies discussed in this chapter.

2.5 LIMITATIONS

The major limitation of the selected research techniques and methodologies include:

- *Researcher’s limited knowledge of statistics*: Quantitative data to be collected in this research will be statistically analysed in order to draw conclusions and verify the results. The researcher however does not possess thorough statistical knowledge to conduct such detailed analyses. As a remedy, the NMMU statistical consultant was asked for assistance with questionnaire construction and statistical analysis.

2.6 CONCLUSION

The objective of the chapter was to present the research design of this study. As defined in Section 2.1 research design presents the entire plan of how a researcher will proceed to get answers to research question. Research design is regarded as a tool that outlines specific research techniques and methods that can be employed during the research process. This chapter first defined and discussed different terms that are utilised in research (Section 2.2.1) in order to avoid confusion and specify which terms will be utilised in this research. Different research techniques were discussed and motivations were presented for selecting some techniques over others. The research philosophy is Positivist (Section 2.2.2). Both inductive and deductive research approaches will be utilised in this research (Section 2.2.3).
Quantitative and qualitative research methods will also be utilised in this research (Section 2.2.4).

The chapter has also presented the research process that discusses the main activities to be carried out in this study, including literature study (Section 2.3.1), prototyping as the selected development methodology (Section 2.3.2) and how evaluation of the study will be conducted (Section 2.3.3). Conclusions from this chapter will be used to guide various activities that will be carried out in this research in an effort to address the research objectives and get answers to questions from the research. The main deliverable of the chapter is the research process that discussed how the research will be conducted. The next chapter discusses literature on online businesses. The focus of this chapter is to discuss the state of the art with regard to online business and how this research fits.
CHAPTER 3: ONLINE BUSINESS

3.1 Introduction

3.2 Online Business Overview

3.3 Consumer Behaviour-Conventional vs. Online Purchasing

3.4 Conclusion

3.2.1 Introduction
3.2.2 Definitions (e-commerce and m-commerce)
3.2.3 Categories of Online Business
3.2.4 Benefits for Conducting Business Online
3.2.5 Challenges for Conducting Business Online
3.2.6 Online Shopping Systems Architecture
3.2.7 Components of an E-commerce Website
3.2.8 Online Business Overview Summary

3.3.1 Consumer Behaviour Processes
3.3.2 Information Retrieval (IR)
3.3.3 Decision Making
3.3.4 Consumer Behaviour-Conventional vs. Online Summary

Deliverable: General analysis and understanding of online business

Research Objective (RO)
Research Questions (RQ)

RO1: Understanding of Online Business and Consumer Behaviour
RO2a: Exploring Usability Challenges in Catalogues Browsing on a Mobile Device
RO2b: Gaps in Existing Solutions to Address Identified Usability Challenges
RO4: Conceptual Context-Aware Model and POC Prototype
RO5: Usability of the Context-Aware Model in Addressing Usability Challenges with Browsing a Catalogue on a Mobile Device
RO6: Research Findings, Contributions and Recommendations

A Context-Aware Model to Improve Usability of Information Presented on Mobile Devices

Figure 3-1: Chapter 3 context
3.1 INTRODUCTION

Chapter 2 discussed research design in which two main topics were covered; firstly, background to research theory (Section 2.2) that explained the general theories in research and motivation for selecting various methods over others. Secondly, the chapter explored the research process (Section 2.3) that explained how this research will actually be conducted. The objective of Chapter 2 was to present an outline of how the research will be conducted in line with the accepted procedures of conducting research. Outcomes of Chapter 2 will be applied to accomplish various activities which will be carried out in this research to address research objectives and questions outlined in the subsequent chapters of the thesis.

This chapter discusses online business and a background overview for online businesses is presented (Section 3.2). Section 3.2.1 introduces the concept of online businesses in which various general forms of online businesses are covered. Section 3.2.2 provides a distinction between e-commerce and m-commerce and demonstrates the focus of online business of this research. Technical architecture and components of B2C e-commerce (and m-commerce) systems are presented and a product catalogue is discussed as a key feature of any online store (Sections 3.2.6 and 3.2.7).

The chapter also discusses consumer behaviour that focuses on how customers make purchasing decisions (Section 3.3.1). Two important sub-processes within the consumer behaviour process, namely information gathering and decision making, are explored in Sections 3.3.2 and 3.3.3 respectively. The influence of product catalogues on consumer behaviour (and its associated sub-processes namely, information retrieval and decision making) have been discussed.

This chapter addresses the following research objective and question (Table 1-1):

\( RO_1 \): Understand the state of the art in online business with regard to development and online consumer behaviour;

\( RQ_1 \): What is the state of the art in online business with regard to development and consumer behaviour?
3.2 ONLINE BUSINESS OVERVIEW

The Internet and its related technologies have introduced many changes from the way business used to be conducted. Most importantly, the Internet has enabled businesses to implement e-commerce systems (virtual market places) that enable customers to purchase products online anytime, anywhere. This section discusses specifically e-commerce and m-commerce by defining the terms, exploring the categories of online business, and the benefits and challenges of online business. The section aims at providing an overview of online business understanding of the problem domain, which is usability in m-commerce with regard to browsing a product catalogue. Usability challenges when browsing a catalogue on a mobile device have been discussed in Section 4.5.

3.2.1 Introduction

The increase in the use of the Internet and its related technologies continues to significantly change the way business is conducted (Bai, Chou, Yen and Lin, 2005; Tiwari et al., 2008). Businesses are now taking advantage of the Internet and the latest innovations in technology to streamline business activities and also to facilitate communication with multitudes of potential customers online. The Internet has provided businesses with an opportunity to virtualise market places such that customers can browse and purchase products online at their convenience (Bai et al., 2005; Rose et al., 2011; Turban et al., 2011; Schneider, 2013).

This type of online or electronic communication between a customer and a virtual online store has been termed e-commerce. The increase in the use of mobile phones and consumer demand for ubiquitous services has seen e-commerce extending into m-commerce where sales-related transactions are conducted via wireless networks using mobile devices, anytime, anywhere (Tiwari et al., 2008; Turban et al., 2011; Gallego and Huecas, 2012). Formal definitions of e-commerce and m-commerce are discussed in Section 3.2.2.

The term online business (e-business) is often used interchangeably with e-commerce. Some authors, however, argue that the terms are slightly different as follows (Tiwari et al., 2008; Laudon and Traver, 2011); e-business refers to the overall online activities carried out by an enterprise in order to have stock for sale. These activities may include procurement, production, customer relationship management and sales. In a nutshell, e-commerce on the other hand refers to the online activities that are only related to the buying and selling of
goods, and after sales services, for example, marketing and customer support. E-commerce activities are business endeavours that directly bring revenue into the business (Laudon and Traver, 2011).

The preceding difference between e-business and e-commerce indicates that e-commerce can be regarded as a subset of e-business. M-commerce, which is an extension of e-commerce, is the main focus in this research. Figure 3-2 clarifies the relationship between e-business, m-business, e-commerce and m-commerce (Tiwari et al., 2008). The figure shows the relative sizes of transaction volumes for each type of online business as well as the relationships that exist between these types of online business. The main differences lie in the services that are available in m-business and m-commerce, but not available in e-business and e-commerce, the main one being mobility.

Figure 3-2: Overview of electronic and mobile business and commerce

Source: Adapted from Tiwari, Buse and Herstatt (2008)

3.2.2 Definitions (e-commerce and m-commerce)

E-commerce is defined as the buying and selling of goods and services, over the Internet by using stationary computers. E-commerce has enabled businesses to extend to a global market, thereby increasing the number of customers and consequently profits (Turban et al., 2011). The increase in the use of Internet-enabled mobile devices and recent innovations in wireless
Internet technologies have given businesses an opportunity to extend e-commerce initiatives into m-commerce (Bai et al., 2005; Jahanshahi et al., 2011; Gallego and Huecas, 2012). Businesses are now able to provide customers with interfaces on mobile devices on which customers can interact with established virtual stores, anytime, anywhere.

A broad definition of m-commerce is the conduct of business transactions with a monetary value by using mobile devices (Tarasewich, Nickerson and Warkentin, 2002; Chen, 2009; Min, Li and Zhong, 2009; Xining et al., 2010). Mobile devices include laptops, however, in this research the focus is on the conduct of business transactions using Internet-enabled handheld mobile devices such as mobile phones, tablets and personal digital assistants (PDA) (Tarasewich et al., 2002; Zenebe, Ozok and Norcio, 2005; Orjuela-Parra et al., 2009; Zhang and Lai, 2011). Figure 3-3 shows an example of recent mobile devices available on the market that are being targeted in this research.

![Figure 3-3: Examples of mobile devices](image)

The market share of m-commerce is quickly growing because of the rapid increase in the adoption of e-commerce and the increased use of Internet-enabled handheld mobile devices (Koukia et al., 2006; Kim et al., 2007; Min et al., 2009; Xining et al., 2010; BizReport, 2011). Additional factors contributing to m-commerce popularity include: convenience, easy connection, ubiquity and decreasing costs of the hardware (Koukia et al., 2006; Xining et al., 2010).
E-commerce and m-commerce share a number of similar objectives, for example, the use of the Internet (and wireless networks) to improve efficiency in business transactions. The major difference between e-commerce and m-commerce is in technologies that are utilised to access the online stores. For example, in m-commerce, mobile devices are utilised to access the online stores via wireless Internet protocols such as Wireless Application Protocol (WAP) while in e-commerce, similar stores are basically accessed by using stationary desktop computers that are usually connected to cable networks (Chen, 2009; Min et al., 2009). Table 3-1 summarises the characteristics of technologies used in e-commerce and m-commerce. The table outlines similarities and differences between e-commerce and m-commerce from a number of technology perspectives.

<table>
<thead>
<tr>
<th>Technology</th>
<th>E-Commerce</th>
<th>M-Commerce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access devices</td>
<td>Desktop computers (PC)</td>
<td>Smartphones, tablets, PDAs</td>
</tr>
<tr>
<td>Operating system</td>
<td>Windows, Unix, Linux</td>
<td>Symbian, iOS, Pocket PC, proprietary platforms, e.g. blackberry browser</td>
</tr>
<tr>
<td>Presentation standard</td>
<td>HTML</td>
<td>HTML, WML, HDML, i-Mode</td>
</tr>
<tr>
<td>Browser</td>
<td>Windows explorer, Mozilla, Google Chrome</td>
<td>Micro browsers, e.g. Opera Mini</td>
</tr>
<tr>
<td>Network Protocol</td>
<td>TCP/IP, Fixed wire networks</td>
<td>GSM/GPRS, EDGE, CDMA</td>
</tr>
</tbody>
</table>

Table 3-1: Comparison between e-commerce and m-commerce

3.2.3 Categories of Online Business

Online shopping is classified into a number of categories according to the main players involved in the transaction chain. The following are the three fundamental categories of online business (Laudon and Traver, 2011; Turban et al., 2011; Schneider, 2013):

1. Business-to-Business (B2B): B2B involves transactions that occur between businesses. For example, companies that specialise in online marketing and advertising offer their services to other businesses;
2. Business-to-Consumer (B2C): B2C is when businesses interact with end users in the transaction or supply chain. An example of B2C is when a customer purchases products online from an e-commerce or m-commerce site such as Amazon.com (Amazon, 2013a);
3. Transactions/business processes: This is a category of e-commerce where organisations use Internet technologies to support purchasing and selling activities.
There are other categories of online shopping that emanate from these three fundamental categories. Two common additional categories of e-commerce are Consumer-to-Consumer (C2C) and Business-to-Government (B2G) (Turban et al., 2011; Schneider, 2013). C2C extends from B2C when a business selling the product is also a consumer. E-bay is one popular global example of C2C (Ebay, 2012). Recently e-commerce platforms are being implemented where both businesses and customers are allowed to advertise and sell products to other customers, essentially combining B2C and C2C on one platform. A famous example is Bid or Buy, an e-commerce company based in South Africa that auctions various products for businesses and customers (BidorBuy, 2013). Figure 3-4 shows an example page from Bid or Buy.

![Bid or buy c2c website](http://www.bidorbuy.co.za/)

Figure 3-4: Bid or buy c2c website

Source: http://www.bidorbuy.co.za/ (March, 2013)
B2G extends from either B2B or B2C when a customer is Government. This research focuses on B2C m-commerce. Figure 3-5 summarises the connections between various categories of online shopping (Turban et al., 2011).

![Diagram of E-commerce (m-commerce) categories]

**Figure 3-5: E-commerce (m-commerce) categories**

### 3.2.4 Benefits for Conducting Business Online

There are a number of benefits for conducting business online to both the customer and the business as follows (Laudon and Traver, 2011; Turban et al., 2011; Schneider, 2013):

**Benefits to the business:**

- Increased customer base and market;
- Internet transactions are efficient and cost-effective, consequently, leading to improved overall business efficiency;
- Provides competitive business advantage;
- Reduced capital cost. For example, establishing an e-commerce store is quicker and cheaper than establishing a brick and mortar store.
Benefits to the customer:

- Easy comparison between various suppliers ensures value for money;
- Convenience, since business can be conducted anytime, anywhere;
- Recommender systems (when implemented) help customers in decision making;
- Delivery is fast at lower cost for some products, for example, when purchasing downloadable products, such as music.

3.2.5 Challenges for Conducting Business Online

There are a number of challenges to conducting online business especially for a business. Challenges online businesses face include (Chang, Changchien and Huang, 2006; Schneider, 2013; Turban et al., 2011):

- **Competition**: Online business, e-commerce and m-commerce have low entrance barriers for new players and so level the playing field, thus enabling new businesses to compete with existing and well established ones. This can result in loss or lack of potential customers for the online businesses;
- **Security (and trust)**: These are two commonly mentioned challenges that affect both customers and businesses in online transactions. Online businesses are susceptible to hackers and other malicious attempts to tap into servers. Along with security and trust also come ethical issues. E-commerce is open to the global market but ethics differ from place to place, for example, there are no established acceptable standards for online shopping practices (Turban et al., 2011). This means certain practices that an online business can implement but are deemed wrong by a certain society, organisation or group of people can damage a company’s reputation and affect sales within the specific society, organisation or group of people;
- **Lack of technological skills**: This involves the lack of skilled personnel who can implement and support e-commerce activities. For example, skills to integrate useful (business critical) existing legacy systems into e-commerce pose a great challenge for many businesses;
- **Implementation cost**: Implementation cost can be exorbitant and result in businesses not venturing into e-commerce initiatives. For example, huge costs are normally
associated with purchasing special web servers, hiring of programmers and other technical personnel in order to successfully establish an online store.

E-commerce customers also face a variety of challenges and these often lead to customers’ reluctance to embracing or partaking in online business activities. The following are the main challenges customers face in e-commerce (Turban et al., 2011):

- **Security, trust and privacy**: These issues have topped the list of customers’ concerns in e-commerce for a number of years (Schneider, 2013). Many customers still feel it is not safe to provide their personal information, including credit card details, on a website. Various techniques have been put in place to assure customers of safety and privacy in e-commerce, but there are still reports of little customer satisfaction with regard to online security, trust and privacy even in the face of such technologies;

- **Information saturation**: There is a lot of information, stores and products on the web. This information overload presents a challenge for customers to get what they really want. Recommender systems that suggest items users might be interested in have been implemented to address this challenge. However, not all e-commerce websites have effective recommender systems in place (Xiaohui and Murata, 2011; Asif and Krogstie, 2012). This implies that customers find it difficult to interact with e-commerce websites that do not use recommender systems. For example, literature shows that implementation of recommender systems in m-commerce websites has not been explored much and as a consequence users find it difficult to interact with most m-commerce websites (Ricci and Nguyen, 2005; Guan and Tay, 2007; Maheswari and Reddy, 2009).

### 3.2.6 Online Shopping Systems Architecture

Online shopping systems are normally implemented on $n$-tier client-server architectures. Businesses invest in infrastructure, such as backend servers, middleware and user interface software for implementing e-commerce systems (Schneider, 2013). Figure 3-6 shows the architecture of an e-commerce system with the server and client side (user interface) connected via the Internet. Online shopping systems (both e-commerce and m-commerce) can be implemented on the same infrastructure with the only difference being in the
techniques utilised for designing user interface, information delivery and access modes (Table 3-1).

Backend databases in e-commerce systems architecture normally store information such as product catalogue information, customer information and other information that need long term storage (Turban et al., 2011; Schneider, 2013). E-commerce systems databases can be implemented by using popular database management systems, such as MySQL, Oracle Database and Microsoft SQL Server (Turban et al., 2011). Web or application servers have programs that manipulate the data stored in the backend databases and display information to the user via the Internet. Microsoft’s Active Server Pages (ASP).NET and Sun Microsystems’ Java Server Pages (JSP) are among the most commonly used programming languages utilised to implement e-commerce application programs and user interfaces.

Firewalls are normally implemented by online businesses in order to limit and control access to backend servers. In other words, firewalls are implemented for security purposes in an e-commerce system. E-commerce systems can be accessed by using a mobile device or a desktop computer. The architecture shown in Figure 3-6 is for B2C online business which deals with real end users (consumers) in the supply or transaction chain. The advent of new web technologies, simplified web development, for example, Web 2.0, have led to an increase in e-commerce stores.

Figure 3-6: Online business systems architecture
Source: Adapted from Turban et al. (2011) and Schneider (2013)
### 3.2.7 Components of an E-commerce Website

An e-commerce website (or system) can be regarded as a system that integrates particular functionalities to enable the conduct of business online. In order to fulfill this purpose, any e-commerce website (or system) contains the three fundamental components that perform specific functionalities designed to facilitate online shopping as follows (Turban et al., 2011; Schneider, 2013):

1. **Product catalogue:** This is the most important feature of any B2C or C2C e-commerce website. An online product catalogue displays products a business is selling and enables customers to search and identify items to purchase. This is the first reference point for customers when they visit an online store. Literature reviewed thus far indicates that online product catalogue management has not been explored much although e-commerce has been in existence for over a decade and a half. For example, very few product catalogue management systems exist and are often costly. Furthermore, not much literature can be found that discusses usability of online product catalogues or the use of context to improve usability. Sections 4.2 and 4.3 discuss product catalogues and usability respectively.

2. **Shopping cart:** Also called a shopping basket is a component of an e-commerce website that enables customers to virtually drop (choose) selected items to purchase online before proceeding with payment. A shopping cart is an American English term meaning a four-wheeled cart (trolley) that conventional shops provide for customers to drop physical items into the cart while traversing through the shelves in conventional shopping. A shopping cart is used analogously in e-commerce websites to provide a virtual basket in which customers can add, view, edit and remove items to purchase. Recently, e-commerce websites’ shopping carts perform real-time calculation of items in the cart as well as additional costs, for example, associated tax, handling and shipping costs. There are companies that have specialised in the development of both proprietary and open source shopping cart components of e-commerce websites, for example, Avactis (Avactis, 2013).

3. **Transaction processing:** This is a component of an e-commerce website that handles or processes the whole online transaction, that is, the buying and selling transaction and after-sales services. Usually a transaction processing component of e-commerce
website interfaces with various other systems located within or outside the boundaries of the online store. For example, internal systems can be sales, stock management and customer relationship management while external systems include a banking system that processes payment online.

3.2.8 Online Business Overview Summary

The objective of this section was to present the outline and foundation of online business in order to demonstrate motivation for the focus of the research. Online business exists in various forms as depicted in Figure 3-2 and this section presented the form or type of online business to be covered in this research as B2C m-commerce. An outline of the B2C online systems architecture presented in Section 3.2.6 that has an impact on the actual implementation of the solution proposed in this research has been presented. Section 3.2.7 discusses the major components of an online consumer to business website in which a product catalogue is singled out as the key feature that can influence the success of an online store. Efficient browsing of a product catalogue impacts the customers’ purchasing decisions and sales. These factors motivate the selection of the m-commerce domain and product catalogues as the type of information to be utilised in this research (Sections 1.1.1 and 1.2). The next section covers consumer behaviour for conventional vs. online purchasing.

3.3 CONSUMER BEHAVIOUR-CONVENTIONAL VS. ONLINE PURCHASING

Trade has been in existence for centuries and it is one major activity that people around the world participate in. Consumer or buyer activities in trade have been extensively researched in a field called consumer behaviour that deals with understanding the processes buyers undertake in determining or realising the need, selecting, acquiring and disposing of products or services that satisfy needs (Kardes, Cronley and Cline, 2010; Turban et al., 2011). Consumer behaviour also looks at the impacts that these processes have on the consumer and the society as a whole. In a nutshell, consumer behaviour can be stated as an attempt to understand the decision making processes of buyers, both individually and in groups.

In order to fully understand these processes, consumer behaviour includes elements from other fields such as psychology, sociology, social anthropology and economics. Various consumer behaviour models have been devised that aim at describing what drives consumers
to make purchasing decisions. These models are often utilised by sellers in developing marketing strategies for their products and items. This section highlights steps consumers take in order to acquire a product or service in conventional and e-commerce. Information retrieval and decision making topics will also be briefly discussed in this section. It has to be noted, however, that topics discussed in this section are major fields of study on their own and fall outside the scope of this research. The goal for briefly including these topics in this section is to position the contribution of the envisaged research outcome in the entire process of influencing efficient purchasing and decision making by online customers.

3.3.1 Consumer Behaviour Processes

Consumer behaviour deals with the processes undertaken by consumers when purchasing a product, either online or in conventional commerce. The processes discussed in this section were originally introduced for conventional trade and later adapted to online commerce. The purchase decision making process in conventional commerce involves the consumer in following main steps (ManagementStudyGuide, 2013):

1. Recognition of the need: The need to acquire a product or service is a catalyst for the consumer in the decision making process to purchase. At this stage the consumer realises the need or the solution to a problem that can be solved by acquiring a certain product or item.

2. Information gathering: This step follows the recognition of the need by the consumer and the consumer tries to gather as much information to help in the decision making process. Information sources include external sources, from family and friends, commercial adverts, sales people, public newspapers or internal sources such as personal experience with the product. Information gathering maps directly into information retrieval (Section 3.3.2) which is a field in computing that deals with organising and extracting information to assist users in decision making.

3. Evaluating alternatives: This involves the use of the gathered information to evaluate the various alternatives available in the market. The goal for the consumer is to make the best possible purchasing decision. This involves a process popularly known as the decision making process that is defined as a mental process undertaken to determine a better course of action from a number of choices. The decision
making process has been an active area for research in various fields of study including management and Computer Science. Section 3.3.3 briefly discusses decision making and its relevance to this research.

4. Purchasing: After going through all the above stages, the customer finally decides whether to purchase the product or not;

5. Post purchase evaluation: Post purchase evaluation refers to a customer’s analysis whether the product was useful or not, whether the product fulfilled the need or not.

Contrary to conventional commerce that has been in existence for centuries, online shopping has only been in existence for a little over two decades and no specific online consumer behaviour models exist. Accordingly, online consumer behaviour research is still young and consumer behaviour models for conventional commerce are being widely utilised to discuss the processes online consumers follow in order to purchase a product (Chun-Xia and Zhen-Fa, 2010). The main distinguishing factor for the activities carried out during a conventional purchase as compared to those when purchasing online are interaction between the consumer and three main components of an e-commerce system, namely product catalogue, shopping cart and transaction processing and after sales services (Chun-Xia and Zhen-Fa, 2010; Yuan and Fernandez, 2011; Schneider, 2013). Table 3-2 shows the activities and related components of an e-commerce system responsible for handling particular activities during an online purchasing process (Callahan and Koenemann, 2000; Tarasewich et al., 2002; Li and Li, 2011). The first step in this process (omitted in the table) is when the customer discovers a need to acquire or purchase a particular product.

<table>
<thead>
<tr>
<th>Activity No.</th>
<th>Description</th>
<th>E-commerce System Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Browsing a catalogue and comparing offers from different suppliers</td>
<td>Product catalogue</td>
</tr>
<tr>
<td>3</td>
<td>Selecting a desired product from a catalogue</td>
<td>Product catalogue and shopping cart</td>
</tr>
<tr>
<td>4</td>
<td>Payment of the selected item/s</td>
<td>Transaction processing and after sales services</td>
</tr>
<tr>
<td>5</td>
<td>Shipping and delivery</td>
<td></td>
</tr>
</tbody>
</table>

Table 3-2: Customer activities when purchasing products online
Source: Tarasewich, Nickerson and Warkentin (2005: 42) and Li and Li (2011: 5300)
Organisations implement e-commerce websites (or online virtual stores) in order to guide consumers through the whole online purchase decision making process (Botha, Bothma and Geldenhuys, 2008). This implies that for every step in the purchasing process provision has to be made on the website that will assist the consumer to effectively and efficiently perform a particular activity. This research focuses on utilising a context-aware model to improve the usability of the product catalogue presented on mobile devices. Improved usability affects the purchasing decision of the customer and therefore, effectively sales and profits for an online business.

This research aims at improving usability of interfaces in the first two steps in Table 3-2 that involves browsing a product catalogue and partly the second step that involves selecting the intended items to purchase. The next two sections briefly discuss two selected consumer behaviour processes relevant to this research; namely information gathering (that has been discussed in a broader view as information retrieval) and decision making.

3.3.2 Information Retrieval (IR)

Information is a vital tool utilised by users, such as managers, in order to gather clues and take an appropriate course of action. This process of taking a certain course of action is also known as the decision making process. Techniques employed to gather relevant information for decision making are grouped under information retrieval. This section briefly discusses the technicalities involved in information retrieval.

3.3.2.1 Definition

Formally, information retrieval is defined as a field in computing that deals with the structuring, storage, searching and extracting of information from repositories (Allan et al., 2003). Information retrieval has been an active area of study for many years and has recently grown because of developments in storage hardware that is capable of keeping huge volumes of data (Manning, Raghavan and Schutze, 2009). Information retrieval can also be defined as a process that deals with searching and retrieving information from repositories (Manning et al., 2009). In this research, information retrieval is discussed from a process perspective.

The following is the general structure of any information retrieval system (Allan et al., 2003; Croft and Schek, 2008; Manning et al., 2009):
1. Representation of the content of the data items (data source): This is sometimes called indexing, cataloguing or simply the creation of a data source;

2. Representation of the user’s information need: This is also called query formulation by which the user (requestor) of a particular piece of information is allowed to present what type of information has to be extracted from the data source;

3. Comparison of the above two representations: This is the final step in which the contents of the data source are matched with the users’ query in order to determine what information should be extracted and presented to the user.

Figure 3-7 further elaborated on the basic structure in information retrieval and how information is retrieved from repositories. The information retrieval process is triggered by the users’ request for a particular piece of information (Manning et al., 2009). The user’s request is transformed into a query that can interpreted by the machine and the data store. A comparison is then performed between the query and the organised information in the data store. Results are obtained when the query and the data store match, or in other words, retrieved data is the set that meets the conditions set by the query.
3.3.2.2 Information Retrieval Techniques

There are a number of techniques that are utilised during information retrieval in order to retrieve only the relevant data that meets the user’s requirements from repositories. There is a number of models that are utilised to retrieve data in information retrieval, however, the following are three common techniques used to perform information retrieval from repositories (Barber, 2009; Manning et al., 2009):

- **Boolean Search**: A Boolean search strategy retrieves items from a data source which matches or returns true to the user’s query, that is all items that satisfy the query condition are retrieved (Manning et al., 2009). This is the simplest information retrieval technique. The basic query for the Boolean search consists of keywords and logical connectives such as AND, OR, and NOT. Execution of Boolean queries only considers the outcome of the logical connections and the content of the information repository in order to determine what items to extract and present to the user;

- **Vector Space Model Search (VSM)**: This is one of the most widely used information retrieval models. The VSM model creates a space in which both data items and queries are represented as vectors (Barber, 2009). Any data item can be represented by a vector in a dimensional space. If a term exists within the data set, it gets a non-zero value in the data-vector along the dimension corresponding to the term. During a retrieval operation, data items are ranked according to the similarity between the data-vector and the query-vector, and those with the greatest similarity are returned. This model adds an advantage over Boolean search in that the retrieved items have assigned priority, which means results can be sorted according to relevance (Barber, 2009);

- **Probabilistic Model Search**: This family of information retrieval models is based on the general principle that data items in a collection should be ranked by decreasing probability of their relevance to a query. Probabilistic information retrieval models estimate the probability of relevance of data items for a query. That is, retrieved data items are based on the degree of estimated relevance to the user query.

3.3.2.3 Information Retrieval Data Sources

These techniques are performed to retrieve different types of data that is stored in various data sources. Early information retrieval systems concentrated on unstructured data
repositories such as electronic library catalogues and the Internet (after its invention). Recently, information retrieval systems include the searching of information from structured data repositories. Examples of information repositories where information retrieval can be performed include:

- **Databases**: Databases refer to an organised collection of data items stored in one place and managed by Database Management Systems (DBMS). Databases used to store only structured data such as in relational databases, for example, in a MySQL database. Recent developments in databases have extended the capabilities of databases and DBMs to store and manage unstructured data. Examples of such databases include enterprise products such as SAP HANA and open source database products such as CouchDB;

- **World Wide Web (WWW) or simply the web**: The web is the collection of interlinked hypertext files (web pages) that can be accessed via the Internet through a browser interface (Manning *et al.*, 2009). The WWW provides a huge source of information that can be used for various purposes such as learning and decision making. Worldwidewebsize.com estimates that there are about 14.33 billion web pages available on the web as at 24th April 2013 (WorldWideWebSize, 2013). Various systems have been implemented to help users search for information on the web with Google being the most commonly used web information retrieval system (Google, 2012);

- **Text**: Text can be described as content within a written document such as a PDF or word processing document from which valuable information for decision making can be derived;

- **Miscellaneous sources**: These include all other sources that cannot be classified into the above classes of repositories. For example, social networking data sources that contain special content such as blogs, user profiles, photos and videos (Boyd and Ellison, 2007; Jain, 2012), Internet of Things (IoT) which is the collection of devices capable of communicating with people and other devices through the Internet, Machine to Machine (M2M) where machines communicate and share information (Chui, Loffler and Roberts, 2010; Gartner, 2011). These sources are proving to be
valuable sources from which information retrieval for decision making can be conducted and they are collectively being referred to as the Deep Web category.

3.3.2.4 State of the Art in Information Retrieval

A number of recent developments is taking place in the field of information retrieval in addition to the inclusion of structured data sources. The most notable are as follows:

1. Contextual Information Retrieval: Contextual information retrieval is a special type of information retrieval technique that combines search techniques, the user query and knowledge of the current user context into a single framework to perform information retrieval in order to provide the most appropriate answer for a user’s information needs (Allan et al., 2003; Wen, Lao and Ma, 2004; Sungrim and Kwon, 2009; Bouramoul, Kholladi and Doan, 2011). The use of context in order to improve usability of various mobile and desktop applications including information retrieval systems is gaining popularity (Wen et al., 2004). Examples of recent work in contextual retrieval include:
   - Location-aware search: This is a technique gaining popularity in which location information is used to provide services or search results that are within the vicinity of the user (Ismail et al., 2009);
   - Contextual content delivery: This is a technique used to deliver content on web and mobile applications based on a user’s current context, that is small sets or parameters of information describing the user’s environment (Sathish and Pettay, 2006; Coppola et al., 2009).

2. Mobile Information Retrieval: Mobile information retrieval can be defined as the indexing and retrieval of information such as text, images, animation, sound, speech and video for the purpose of presentation on a mobile device (Wen et al., 2004; Tsai, Etoh, Xie, Lee and Yang, 2010). This is a subcategory of traditional information retrieval that is lately attracting more attention and becoming important due to the ever-increasing usage of mobile devices. Mobile information retrieval enables users to search and acquire information from various sources while on-the-go.

During an online purchase, consumers lack sensory factors such as sense of smell, feel and touch for the item, that usually assist buyers in conventional commerce to make decisions
(Jovic, Milutinovic, Kos and Tomazic, 2012). Consumers therefore interact with a number of online information retrieval systems in order to gather information that can help to make a suitable purchase decision. This implies that information presented to buyers online plays a critical role in helping them make purchase decisions and compensate for the lack of other, usually present factors (Jovic et al., 2012). Various systems with specific search algorithms have been implemented in order to retrieve and present information to the online consumer with the purpose of easing consumer efforts during online purchase decision making. Examples of such systems include Price Check in South Africa that collects and presents comparative prices from various suppliers to the user and CNET reviews that present various reviews as well as price ranges on electronic products (CNetReviews, 2013; PriceCheck, 2013). The next section briefly discusses the general overview of the decision making process.

3.3.3 Decision Making

Human beings generally make many decisions every day, some decisions are easier to make while others are difficult and complex. Decision making is a multi-faceted phenomenon involving mental or cognitive processes that result in human beings selecting one or more courses of actions from a number of available alternatives (Van der Heijden, Kotsis and Kronsteiner, 2005; Harris, 2012). Decision making is usually influenced by a number of factors such as experience, available information and cost-benefit analysis of the decision. Some authors equate decision making to problem solving, in this research, however, a distinction is being made that problem solving can be one technique that can enable a person to make a decision.

Decision making as a subject is broad and has been studied extensively in different fields, for example, decision theory in Economics. In computing, there is a category of systems called Decision Support Systems (DSS) that deals with the development of applications where the goal is to assist users during the decision making process. A DSS is a computer based application that supports users in decision making activities. E-commerce websites can be regarded as a DSS because online shopping systems strive to provide the necessary information that can assist buyers in making suitable online purchasing decisions (Momin, Nirantar, Zagade and Deshmukh, 2012). This section and Section 3.3 aimed at outlining the
foundations of consumer behaviour in online purchasing by highlighting aspects of the decision making process that relate to the areas covered within the scope of this research.

### 3.3.4 Consumer Behaviour - Conventional vs. Online Summary

Consumer behaviour has been explored in a number of fields related to business, such as economics, in order to understand the consumer purchasing decision making process. Consumer behaviour models have origins from conventional commerce and evidence of consumer behaviour models for online consumers could not be found in literature. As a result this section makes no distinction between conventional consumer behaviour models and online consumer behaviour models (Section 3.3.1). Within the consumer behaviour models, information gathering and decision making have been highlighted as critical steps that consumers undertake during a purchasing decision (Section 3.3.1). In an online environment, a product catalogue has been presented as one key feature that influences consumers to make purchasing decision online. Therefore an efficient product catalogue would improve consumer behaviour process in an online environment.

This section discussed the processes of information retrieval that relate to online product catalogues. Online stores usually stock much more information compared to conventional stores that are constrained by the availability of space. For example, Amazon boasts that it has over 20 million books in its online store, a number that cannot be accommodated in a conventional store. The numerous product items that are stored in an online store’s product catalogue makes IR techniques more relevant in order to streamline retrieval of a relevant product catalogue item. The retrieved information is utilised by consumers to make a purchasing decision. The next section presents a summary of the chapter.

### 3.4 CONCLUSION

Purchasing of goods and services online through m-commerce initiatives is becoming more popular because of factors such as convenience, mobility, the cheaper cost of devices and widespread availability of affordable wireless connections. The objective of this chapter was to discuss the literature relating to the foundations of the research, which is the area of online business. The chapter achieved its objective by discussing the overview of online business including definitions of m-commerce and e-commerce (Section 3.2). Fundamental categories of online shopping such as B2B, B2C and transaction processing, and other additional
categories, for example, C2C and B2G were discussed (Section 3.2.3). The chapter also outlined the fundamental components of online shopping systems including product catalogues as a major component for any online store (Section 3.2.7). Online consumer behaviour was also discussed as well as brief overview of information retrieval and the decision making process (Sections 3.3.2 and 3.3.3).

The overall contribution of this chapter to the thesis is the exploration of the background to online business, specifically for transactions conducted via mobile devices (m-commerce). In addition, the chapter presented the influence which product catalogues have on consumer behaviour in online environments. Usable or efficient browsing of product catalogues can therefore influence the consumer decision making process. The next chapter builds on the work presented in this chapter and discusses the usability of product catalogues in m-commerce.
CHAPTER 4: USABILITY OF ONLINE PRODUCT CATALOGUES

Figure 4-1: Chapter 4 context
4.1 INTRODUCTION

Chapter 3 provided an overview of online business (Section 3.2). The chapter discussed types of online businesses and specifically covered e-commerce and m-commerce in detail (Sections 3.2.1 and 3.2.2). The architecture and components of B2C online shopping systems were presented, and a product catalogue was mentioned as one major component for any online store (Sections 3.2.6 and 3.2.7). Chapter 3 further discussed consumer behaviour which deals with the process consumers undertake in order to acquire a product (Section 3.3.1). Two important processes in consumer behaviour, namely information gathering and decision making, were also discussed Sections 3.3.2 and 3.3.3. The chapter showed how product catalogues can influence consumer purchasing decision making.

This chapter builds on the literature discussed in Chapter 3 to cover the usability of product catalogue, specifically in B2C m-commerce where consumers browse product catalogues by using a mobile device. The chapter presents an overview of product catalogues, various types of product catalogues and singles out online electronic product catalogues as the focus of this research (Section 4.2). The concept of usability and what has been done with regard to evaluating and improving usability of online product catalogues especially in m-commerce for the purpose of this research (Sections 4.3 and 4.4) are explored.

The objectives of this chapter are to highlight the challenges that customers encounter when browsing a product catalogue on a mobile phone and also to discuss existing techniques that have been implemented as remedies for any challenges (Sections 4.5 and 4.6). Two main topics of this chapter: product catalogues (Section 4.2) and usability (Section 4.3) have been presented in order to provide an understanding of the chapter’s objective. Overall, the research aims at utilising context information to address challenges in browsing a catalogue online when using a mobile device (Section 1.2). This chapter addresses the following research objectives and research questions (Table 1-1):

\textit{RO2a:} Investigate usability problems experienced by customers when browsing product catalogues using a mobile phone.

\textit{RO2b:} Explore and analyse gaps in current techniques designed to address usability problems identified in \textit{RO2a}.
RQ2a: What usability problems are experienced when browsing a product catalogue in m-commerce when using a mobile device?

RQ2b: How are the problems identified in RQ2a addressed?

The main deliverable of the chapter is discussion of how actual challenges can be addressed by the proposed solution.

4.2 PRODUCT CATALOGUES

Product catalogues play an important role in both conventional and e-commerce by disseminating information about products a business offers on the market (Jianyou, Ying and Shusheng, 2009). Research shows that efficient browsing of the product catalogue increases traffic and sales in B2C online shopping (Callahan and Koenemann, 2000; Mao Lin et al., 2009). Businesses utilise product catalogues to ensure that information about their products reaches potential customers. Traditionally, product catalogues have been printed on paper in magazines and brochures (Turban et al., 2011). Technology penetration has resulted in businesses distributing product catalogues electronically, for example, through CD/DVDs and on the Internet (Jianyou et al., 2009). Product catalogues that are distributed through electronic means are called electronic catalogues.

An electronic product catalogue is referred to as the backbone of an online store because it is the first point of interaction between an online customer and an e-commerce website (Turban et al., 2011; Schneider, 2013) (Section 3.2.7). Product catalogues present information for a wide range of items from ticket-selling e-commerce websites to accommodation websites (Turban et al., 2011). This section discusses product catalogues, however, the focus is on usability of electronic product catalogues that are utilised in m-commerce. The section will cover definitions of a product catalogue, types of product catalogues and the benefits of utilising online product catalogues.

4.2.1 Definition

A product catalogue is defined as a collection of items and a corresponding description of products a business is offering on the market (Callahan and Koenemann, 2000; Ho and Kwok, 2003; Hadzic and O'Sullivan, 2008; Yuan and Fernandez, 2011). Each item in a
product catalogue describes the specific characteristics of the item. For example, an item “television” can have the following as a set of its attributes (Chalakov, 2007):

- **Technical information**: This information can provide specific details about the television, for example, brand, screen size and signal type;
- **Selling information**: This information can provide details about the cost and how the buyer can possess the television, for example, price, delivery method and stock availability;
- **Other information**: This can include additional information that does not directly relate to the buying or selling of a product, for example, the seller’s contact details.

The main usage of product catalogues is to provide a platform for businesses to showcase the product range on offer in the market in one place, in a structured and concise manner. A product catalogue is the first reference point for a customer to look for products and as indicated in Section 3.3, product catalogue information influences customers’ decisions to purchase online (Hadzic and O'Sullivan, 2008; Yuan and Fernandez, 2011).

### 4.2.2 Types of Product Catalogues

There are two basic types of product catalogues that are defined according to the format and mode in which the actual product catalogue information is disseminated to potential customers (Turban *et al*., 2011). This section discusses the two types of product catalogues that are utilised in business, namely paper-based product catalogues and electronic product catalogues.

#### 4.2.2.1 Paper-Based Product Catalogues

Paper-based product catalogues (also called manual product catalogues) are product catalogues that contain static information normally printed on paper in brochures and magazines. The items in a manual product catalogue are described by using text and images. Printing product catalogues on paper has been a tradition in business for a long time (Turban *et al*., 2011). Paper-based product catalogues are distributed as hard copies either by post or physical distribution.

A paper-based product catalogue can also be generated electronically as a document file such as in a Portable Document Format (PDF) or word processing document and distributed via
electronic means, for example email, to be printed or read online on a digital interface (Chalakov, 2007). Accessing a manual product catalogue is much easier as customers can clearly see the products on the paper brochures (or on digital interfaces) and select the ones they are interested in. There is, however, a number of disadvantages for utilising a manual catalogue, for example, limitation in terms of the amount of product information that can be printed on paper and distribution can also be difficult. Furthermore paper-based product catalogues cannot be linked to other online shopping system functionalities such as purchasing.

### 4.2.2.2 Electronic Product Catalogues

Electronic product catalogues (e-catalogue) are product catalogues in which dynamic product information is presented in electronic media format and distributed via electronic means. Dynamic in this context means that the customer has some degree of freedom to request additional information or minimise the amount of product information to view in real-time. The dynamic nature of electronic product catalogues differentiates them from paper-based or manual product catalogues that are available as document files and accessed on a digital interface (Section 4.2.2.1).

The term e-catalogue is often interchangeably used with the term online product catalogue. In this research however; a distinction is being made in that online product catalogues is a subcategory of e-catalogue that is widely used by businesses in e-commerce and m-commerce initiatives to showcase products that can be accessed on digital interfaces via the web. The following example aims at demonstrating this difference between an e-catalogue and an online catalogue: an e-catalogue can be a catalogue in which information is stored in a structured way and distributed on CD/DVDs. The product catalogue information contained in the CD/DVD can be accessed offline on a computer. While an online catalogue can be one that is implemented in the backend in a form of a repository or web files containing product information and can be accessed in real-time via the Internet (Turban et al., 2011).

An online electronic catalogue is usually implemented as a web-based application and it is one important aspect of online shopping websites (Section 3.2.6) (Govedarova, Stoyanov and Popchev, 2008; Turban et al., 2011; Schneider, 2013). In advanced cases, online product catalogue data is stored in a repository such as a database. The product catalogue information
is retrieved and presented on web pages in a dynamic way upon request by an online customer. Product catalogue information stored in databases is made up of the following two main website content files (Yu, Wang and Manner, 2010; Jovic et al., 2012):

- **Plain text files**: These are files that contain information in text form such as html and cascading style sheets;
- **Multimedia files**: These are files that contain additional product description or information that is not in text form such as image files, sound and videos.

Figure 4-2 shows an example of an electronic product catalogue from Amazon.com (e-commerce version of Amazon) which is one of the famous B2C online store based in the United States of America (USA) (Amazon, 2013a). A similar page is presented in Figure 4-3 from Amazon.mobi (m-commerce version). The diagrams indicate the difference in presentations and highlight the challenges m-commerce customers face when browsing catalogues in m-commerce that are discussed later in Section 4.5 (Amazon, 2013b).

![Figure 4-2: Electronic product catalogue on e-commerce version of Amazon](http://www.amazon.com/ (March, 2013))

Source: http://www.amazon.com/ (March, 2013)

63
The increase in e-commerce adoption has resulted in increased need for more research in implementing and displaying product catalogue information on Internet storefronts (Callahan and Koenemann, 2000; Min et al., 2009). This research focuses on improving usability of online product catalogues in B2C m-commerce and for the rest of the thesis, reference to product catalogue will mean online product catalogue.

There are many advantages of using an online product catalogue as opposed to manual or paper-based catalogues and other forms of electronic catalogues. The following are some benefits of using online product catalogues in business (Callahan and Koenemann, 2000; Turban et al., 2011):
• Cut costs through easy distribution and updating;
• Can include much more detailed product information than can be accessed in real-time;
• Can be easily linked to other e-commerce functionalities, such as shopping cart, order processing and payment;
• Can provide an easy product search (information retrieval) mechanism to customers.

The main disadvantage of utilising online product catalogues in business is the limitation of access or browsing challenges that come along with the limited features inherent in digital devices. Product catalogue browsing challenges escalate in a mobile environment because mobile devices naturally have limited resources and features compared to desktop computers. Mobile devices, for example, have limited memory and processing power, small screen sizes and limited user input modes (Ho and Kwok, 2003; Glissmann et al., 2005; Issel and Mrozik, 2008). Specific challenges encountered by an m-commerce customer when browsing the catalogue are discussed in Section 4.4. The next section introduces the topic of usability.

4.2.3 Product Catalogues Summary

Online product catalogues are essential for any online shopping website. This research focuses on product catalogue presentation on m-commerce store fronts. The purpose of this section is to provide an overview and understanding of product catalogue background. The section’s main focus is on online product catalogues presented on online storefronts. The next section discusses usability. The section will link usability to product catalogues and discusses the usability challenges which users encounter when browsing a catalogue on a mobile device.

4.3 Usability

Computer applications are designed to perform specific functions to assist users or a group of users to achieve certain goals. Usability is a term in computing that refers to of the extent to which a computer application is able to assist users to achieve their intended goals during and after interaction. This section discusses usability by looking at the formal definition, the process of assessing the usability of an application and usability in B2C m-commerce.
4.3.1 Definition

A number of definitions of usability exist in literature; most of these are adapted from the International Standard Organisation (ISO) definition (Min et al., 2009; Safavi, 2009; Moritz and Meinel, 2010; Garrido, Rossi and Distante, 2011; Kokini, Lee, Koubek and Moon, 2011). According to standard ISO9241-11, usability is described as a process-oriented standard which states that a piece of software is usable when it allows the user to perform tasks effectively, efficiently and with satisfaction in a specified context of use (Min et al., 2009; Tullis and Albert, 2013). Standard ISO9241-11 of systems usability consists of the following three main elements (Usabilitynet, 2006):

1. **Effectiveness**: Refers to the accuracy and completeness with which specified users achieved specified goals while interacting with the system in a particular environment. In other words effectiveness in usability answers the questions: Does the system perform what it is supposed to do and does the user achieve the intended goal through the use of the system?

2. **Efficiency**: Refers to the extent to which a software product enables tasks to be performed in a quick, effective and economical manner. Efficiency in usability answers the following question: Did the user achieve the goal within the acceptable minimum time possible?

3. **Satisfaction**: Refers to the degree to which a software product is giving contentment or making the user satisfied during and after interacting with it. Satisfaction answers the question: Is the user happy or satisfied with the effectiveness and efficiency of achieving the goal?

The terms usability and user experience are sometimes used interchangeably. However, literature differentiates usability from user experience by defining user experience as the user’s general feelings, thoughts and perceptions during and after interacting with a specific product system, or object (Roto and Kaasinen, 2008; Sharp et al., 2011; Tullis and Albert, 2013). User experience, differs from usability in that it takes a broader view and it is subjective (Kokini et al., 2011). Usability focuses only on the extent to which a system, product or object can be used by its intended users to achieve a goal with effectiveness, efficiency and satisfaction in a particular context of use (Min et al., 2009; Obrist, Roto and Vaananen-Vainio-Mattila, 2009). As specified in Section 1.4.3, user experience with regard
to browsing a product catalogue on a mobile phone falls outside the scope of this research. Figure 4-4 adapted from Morville (2004) and Poole (2012), further clarifies the difference between usability and user experience (Morville, 2004; Poole, 2012). The figure shows that usability forms some components of user experience such as usefulness and usable.

Figure 4-4: User experience honeycomb
Source: Adapted from Morville (2004) and Poole (2012)

4.3.2 Usability Evaluation Methods
Usability evaluation is a systematic process undertaken by computer software developers or usability experts in order to assess usability or practicability of a system or an item (Moritz and Meinel, 2010). The goal for conducting a usability evaluation of a system is to find possible areas of the system that can cause usability problems, confusions or errors and ultimately find ways to avert such possible problems (Kaikkonen, Kekäläinen, Cankar and Kallio, 2008; Balagtas-Fernandez and Hussmann, 2009; Trivedi and Khanum, 2012).

The usability evaluation process often crosses paths with Software Engineering, for example, some metrics that are utilised to test usability, such as number of errors are also utilised in Software Engineering (Sommerville, 2011; Tullis and Albert, 2013). This research, however, makes a distinction that even if usability and Software Engineering cross paths, the terms mean two different things that aim at delivering different results during a software
development process. Usability as introduced in Section 4.3.1 focuses mainly on user tasks in three main dimensions: effectiveness, efficiency and satisfaction.

Software Engineering on the other hand is an engineering discipline that focuses on the whole software development lifecycle in order to determine software applications that meet acceptable criteria such as cost, maintainability, dependability (reliability and security), efficiency and requirements (Lauesen, 1997; Sommerville, 2011). During development of a software application Software Engineering principles are applied throughout the lifecycle starting with description of requirements up to software or product maintenance, support and evolution (Sommerville, 2011). Just like user experience, Software Engineering covers a number of areas such as project management, development, and testing, therefore overall usability of an application can be regarded as a metric in Software Engineering (Lauesen, 1997). Selected Software Engineering principles will be followed during the development of the POC prototype for this research (for example development methodology, Section 2.3.2); however, Software Engineering does not form part of the evaluation process of this research.

Experts utilise a number of usability evaluation methods and associated techniques in order to conduct a usability evaluation. The following sub-sections discuss the three main usability evaluation methods and example techniques for each method (Ji, Park, Lee and Yun, 2006; Min et al., 2009; Moritz and Meinel, 2010; Li and Li, 2011).

4.3.2.1 User-Based Usability Evaluation

User-based evaluation methods involve the use of real end users (or a representative sample of the users) to evaluate a system (Garrido et al., 2011). Specific techniques under user-based evaluations allow users to perform a set of carefully pre-determined tasks that are generally considered to yield the most reliable and valid estimate of an application's usability (Min et al., 2009). The test is conducted either in a controlled usability laboratory where a sample of users are invited into the lab to conduct the evaluation, or the test is taken to the users’ environment in the field (Trivedi and Khanum, 2012). Upon completion of the tasks, follow-up questionnaires are usually administered to the users in order to collect additional information concerning usability of the system from the user’s perspective (Tullis and Albert, 2013).
Usability testing is the common user-based evaluation technique where designers invite prospective users of the system or a representative sample of the users to conduct an evaluation of a system by completing a number of tasks (Min and Li, 2009; Min et al., 2009). The goal for user-based usability evaluation is to ensure that the users will be able to interact with the system effectively, efficiently and with satisfaction. For example, the usability testing technique can measure user performance on real tasks (Sharp, Rogers and Preece, 2007). Figure 4-5 shows the usability lab at the Nelson Mandela Metropolitan University that is utilised to conduct user-based software evaluation (Ntawanga, Calitz and Barnard, 2010). The figure shows equipment in the lab including the Tobii eye tracking computer (right), microphone, recorders and other computers with data analysis software that are utilised for conducting user evaluations.

![Figure 4-5: Usability evaluation lab](Source: NMMU Department of Computing Sciences Usability Lab (2010))

User-based evaluation methods have proven to deliver tangible and reliable usability results when utilised in an evaluation process than expert oriented evaluation (discussed next) (Moritz and Meinel, 2010). The only setbacks of user-based evaluation methods are that they are expensive to conduct and sometimes it is difficult to recruit users that can provide useful feedback for the evaluation.

4.3.2.2 Expert Oriented Usability Evaluation

Expert oriented (or analytical) evaluation is a process in which usability experts are recruited to evaluate a system based on their field experience and (or) heuristics (Ji et al., 2006; Moritz and Meinel, 2010; Trivedi and Khanum, 2012). Two common examples of expert oriented usability techniques include: heuristic evaluation and cognitive walkthrough.
• Heuristics evaluation is an expert oriented or analytical usability evaluation technique that aims at finding faults or usability issues with the system (Trivedi and Khanum, 2012). The technique was developed by Jacob Nielsen and his colleagues (Sharp et al., 2007) (www.useit.com). The process involves a small number of experts that interact with a system (sometimes no interaction is required), normally before the system is shown to or tested by the actual users of the system by using a set of heuristics that the system must conform to (Sharp et al., 2007; Min and Li, 2009; Min et al., 2009). Heuristics can be regarded as set of rules a system has to conform to and they are based on common knowledge, usability expertise and design guidelines (Sharp et al., 2007). The heuristics help evaluators identify usability problems or possible areas that can cause usability problems with the system being evaluated.

• Cognitive walkthroughs are task-focused analytical usability evaluation methods in which experts go through the system in order to identify the system errors and evaluate how easily users can perform tasks on the system. Experts perform specified tasks on the system just like a typical user and record any problems with the system while they interact with the system (Trivedi and Khanum, 2012). The technique is different from a heuristic evaluation in that it does not take a holistic approach to the usability of the system and also does not use heuristics.

Specific techniques under expert oriented usability evaluation, such as heuristic evaluation, are cheaper and require fewer resources to conduct than user-based techniques. The main disadvantage of expert oriented usability evaluation is the lack of user input and context of use during the evaluation.

4.3.2.3 Model-Based Usability Evaluation
Model-based evaluation methods involve matching the user roles in completing a task and those from a model in order to calculate the usability index. Usability index measures the percentage of how close a system feature rates when compared to generally accepted guidelines defined in the model. Goals Objectives Methods and Selections rules (GOMS) introduced by Card, Moran and Newell (Card, Moran and Newell, 1986) is one of the most popular model-based usability evaluation techniques that is used to predict the time and effort
required for users to learn to use a new system (Card et al., 1986; Drury, Scholtz and Kieras, 2007; Sharp et al., 2011).

GOMS was developed based on human information processing abilities acquired from various fields such as psychology that analyses human perception, cognition, and memory systems. The GOMS family includes other models, such as the Card, Moran, and Newell-GOMS (CMN-GOMS), Keystroke-Level Model (KLM), Natural GOMS Language (NGOMSL) and Cognitive, Perceptual, and Motor GOMS (CPM-GOMS) (Jokela, Koivumaa, Pirkola, Salminen and Kantola, 2006; Drury et al., 2007). There is a number of models within the GOMS family models that have the following fundamental concepts:

1. **Goals:** This is a goal that the user intends to accomplish;
2. **Operators:** These are actual actions to be performed by the user in order to get to the desired goal;
3. **Methods:** These are steps as sequence of operators that the user needs to undertake to reach a goal;
4. **Selections:** These are rules a user may follow to select one method over the other in order to reach a goal. Selection is normally used in cases where there is more than one method to reach a desired goal.

Table 4-1 summarises the usability evaluation methods, specific techniques under each method as well as advantages and disadvantages of each method.

<table>
<thead>
<tr>
<th>Usability Evaluation Method</th>
<th>Examples of Specific Techniques</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>User-based</td>
<td>User testing</td>
<td>Provide the most realistic estimate of usability and can point out problems with the system</td>
<td>Time consuming and costly especially when it is a field study</td>
</tr>
<tr>
<td>Expert-based (Analytical)</td>
<td>Heuristics evaluation</td>
<td>Cheap and fast</td>
<td>Experts may overlook pertinent issues</td>
</tr>
<tr>
<td></td>
<td>Cognitive walkthrough</td>
<td></td>
<td>May overestimate or underestimate true number of usability problems</td>
</tr>
<tr>
<td>Model-based</td>
<td>GOMS Keystroke-Level Model (KLM)</td>
<td>Provides rigorous estimate of usability criterion</td>
<td>Measures only one component of usability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can be performed on interface specification</td>
<td>Limited task applicability</td>
</tr>
</tbody>
</table>

Table 4-1: Comparison of usability evaluation methods
Developers usually consider a number of factors in order to determine a suitable usability evaluation method and specific technique(s) to use during a usability evaluation. Examples of such factors include: budget, time to complete the evaluation and the stage in development of the system. For example, during early stages in development expert oriented usability evaluations are frequently used (sometimes called formative evaluation, since the evaluation then plays a role in forming the final product) and user-based evaluations are generally used after the product has been finalised (sometimes classified as summative evaluation since the purpose is to determine if the final product does what it is supposed to do) (Drury et al., 2007). The following sections discuss usability metrics and data collection methods that are utilised during usability evaluations.

4.3.3 Usability Metrics
Usability metrics are measuring instruments that give an indication of the extent to which a system is usable by its intended users (Tullis and Albert, 2013). Usability metrics, like any other metrics, must conform to certain properties, for example, metrics must be quantifiable and observable. There are several metrics that can be used to measure usability of an application. Task completion rate, task completion times and error rates are some of the commonly used usability evaluation metrics. Usability experts would normally utilise field experience and specific usability evaluation goals in order to select suitable metrics to be utilised in a usability evaluation scenario (Tullis and Albert, 2013).

4.3.4 Tools for Collecting Usability Evaluation Data
A number of tools are used to collect usability data during a usability evaluation. These tools collect usability data that is used by usability experts, designers and developers to evaluate the usability of a system (or prototype) by its intended users. An evaluation method and its associated technique can determine the type of data collection tool to be used to gather usability evaluation metrics data.

Common tools utilised to collect data in a usability evaluation include:

- **Questionnaires:** Questionnaires are the most reliable tool for collecting research data, and in usability they are used to collect data about how users feel about a particular system. Examples of questionnaires used to collect usability data include:
Computer System Usability Questionnaire, System Usability Scale and Questionnaire for User Interface Satisfaction (Tullis and Albert, 2013);

- **Observations:** This is a tool by which developers or evaluation experts observe users while performing tasks on a prototype or a system. The evaluators make notes on any observation while the users are completing the evaluation. An example of this technique is eye tracking in which the users’ eye movements on the screen and actions are recorded;

- **Interviews:** This is when evaluation experts ask users their opinion about the system or the system’s functionalities in a one-to-one meeting;

- **Logging:** This a tool in which computers automatically record the user’s interaction with the system. An example of logging is the eye tracking technique.

- **Expert reviews:** This is a technique by which usability experts collect or record usability issues they find on a system;

- **Task performance:** This is a technique by which the task performance of users is used to collect the data about the usability of an application.

### 4.4 USABILITY EVALUATION IN MOBILE COMPUTING

The popularity of mobile applications (and mobile devices) comes with complexities that have a direct impact on general usability of such applications (Wesson, Singh and Tonder, 2010; Nayebi et al., 2012; Baharuddin, Singh and Razali, 2013). Examples of usability issues in mobile computing include information overload, screen clutter, lack of task support and limited interaction mechanisms (Wesson et al., 2010). Such usability issues have prompted an increase in mobile human computer interaction (mobile HCI) research that focuses on developing usable mobile applications with minimal usability issues (Coursaris and Kim, 2006; Alshehri and Freeman, 2012; Tullis and Albert, 2013).

This section discusses usability evaluation in mobile computing by highlighting the factors that differentiate usability for desktop application from mobile applications. The section further discusses mobile computing usability evaluation methods and challenges in mobile usability evaluation.
4.4.1 Factors that Influence Usability in Mobile Computing

Usability of mobile applications is influenced by several unique factors that distinguish it from usability evaluation of desktop applications. These factors include technology, device capabilities and the environment in which mobile applications operate. (Brewster, Dunlop, Kallio and Kekäläinen, 2004):

- **Mobile technology:** The competitive nature of mobile technology has a profound influence on the usability of mobile applications. For example, the highly competitive nature of the mobile market provokes frequent changes and shorter life span for mobile devices and associated technologies as compared to the life span of desktop computers (Jokela *et al.*, 2006; Nayebi *et al.*, 2012). For example, to maintain competitiveness, mobile device manufacturers continually develop and release new device models that run new technologies, different from previous models, such as Samsung devices with the associated Android platform (Android, 2013; Samsung, 2013). In addition, manufacturers enforce their product specific design guidelines that impact usability. One such an example is that of Apple Inc. where the design paradigm for iPhone applications must be followed by iPhone application developers (Nayebi *et al.*, 2012). These rapid changes and shorter life span, and manufacturer usability or design guidelines pose a challenge for developers in that mobile applications have to survive the changes in both device models and technology. In other words, when new models are introduced onto the market, existing applications have to be able to adapt without the need for redesigning. Furthermore applications developed for one platform might need major changes in order to be ported to another platform.

- **Mobile device:** Limited features and capabilities inherent in mobile devices affect usability of both native and web applications that run on such an interface. Specific examples of mobile device limitations that affect usability include (Issel and Mrozik, 2008; Balagtas-Fernandez and Hussmann, 2009; Stanescu, Hamza-lup and Tuncay, 2009) limited user input and output modes, such as a small screen and keyboard that affect how information is entered and output is relayed to the user, limited resources, such as shorter battery life and small memory capacity, that affect how much and how long a device can be used to run an application (Harrison, Flood and Duce,
These limitations pose a challenge for developers to develop usable applications that can provide seamless user interactions within such limitations:

- **Operating environment:** Mobile applications give the user the freedom and flexibility to interact with applications in various, often unpredictable environments. Such environments may pose different types of challenges that impact the usability of an application accessed within a particular environment. By virtue of being unpredictable, these factors pose additional challenges for application developers to design applications that will provide users with seamless interaction regardless of environmental changes. Examples of specific environmental factors developers need to address in mobile computing include the following:
  - Social presence, which means mobile applications can be accessed and utilised anytime, anywhere and as such developers have to consider the effects of the presence of other entities on usability during interaction when developing mobile applications;
  - Bandwidth fluctuations, which is an additional challenge that mobile web applications face. Bandwidth fluctuation tops the list of environmental challenges in mobile web applications and developers need to consider the effects of bandwidth fluctuation when developing mobile web applications.

The collection of these specific factors that influence usability of mobile applications (and to a lesser extent desktop applications) is what has recently been termed as context. Context is covered in Chapter 5. This research specifically looks at context in m-commerce environment.

**4.4.2 Mobile Computing Usability Evaluation Methods**

To date, limited research has been conducted to produce usability guidelines for mobile applications (Baharuddin *et al.*, 2013). The few existing usability evaluation methods that have been introduced by researchers to evaluate usability of mobile applications remain unproven and disintegrated (Baharuddin *et al.*, 2013). This makes usability evaluation for mobile applications difficult and many researchers tend to use desktop application usability guidelines instead and few consider the additional factors discussed in Section 4.4.1.
4.4.3 Challenges in Mobile Computing Usability Evaluation and Methods

General usability evaluation was discussed in Section 4.3.2 and focused on evaluating applications designed to run on desktop computers. As shown in previous sections of this chapter, usability evaluation for desktop applications is an established discipline that offers flexibility in that many existing methods and techniques can be utilised and are capable of producing reliable results. For example, field study and laboratory usability evaluation in desktop applications has proven to produce almost similar reliable results. However, usability evaluation methods and techniques are less developed in mobile computing and this renders a number of challenges when it comes to conducting usability evaluation for applications developed to run on mobile devices.

The following are specific challenges encountered by usability experts when evaluating mobile applications:

- To date, no clear, established usability guidelines have been published for mobile applications. As discussed in Section 4.4.2, a few usability guidelines and methods evaluating usability of mobile applications exist but their existence and use are in isolation and disintegrated;
- Researchers have not agreed on suitable usability evaluation methods in mobile computing, as is the case in desktop application usability. For example, some authors argue that laboratory evaluation cannot provide reliable usability results in mobile computing because the laboratory does not represent the real environment (Ji, Park, Lee and Yun, 2006; Schmiedl, Blumenstein and Seidl, 2011), while other authors claim that laboratory and field evaluation studies for mobile applications provide the same results (Kaikkonen et al., 2008).

Simulated environments are often utilised for usability evaluation in e-commerce and desktop applications and are capable of producing reliable results. A mobile environment, on the other hand, cannot be easily simulated and as a result assumptions are used in most cases. Therefore, techniques such as a cognitive walk through and heuristic evaluation have proved ineffective in mobile environments because there is no inclusion of the dynamic user environment that is key to the mobile domain.
4.5 USABILITY WITH REGARD TO BROWSING ONLINE PRODUCT CATALOGUES ON MOBILE DEVICES

Section 4.2.2.2 discusses the benefits of using an online product catalogue. Electronic devices utilised to browse online electronic product catalogues are governed by a number of inherent constraints. This section discusses specific challenges that customers face when interacting with an online electronic product catalogue in both e-commerce and m-commerce. The challenges escalate in m-commerce generally because there are more constraints in an m-commerce environment as compared to an e-commerce environment. The following is a list of notable problems that users experience when browsing a catalogue on a mobile phone, most of which are as a result of the limitations of the device (Allan et al., 2003; Coppola et al., 2009; Chang and Wang, 2010):

- **Limited space on digital interfaces to present many items:** Unlike physical stores which only display a few products because of space limitation, online stores are not limited in terms of product items they can keep in their databases. For example, a website such as Amazon.com can have millions of books and other items in a product catalogue database. Unlike in a physical store, all these items can potentially be presented to the user. However, limited space on digital devices limits the number of products that can be presented to the user at a time. Categorisation and menus are usually utilised to present the products at different levels as a remedy to the presentation problems (Ji et al., 2006; Amazon, 2013a). These methods however, have proved not as efficient as the customers need to go through a number of menu items to get to the required product or item. These menu items are normally hidden under main menu items because of limited space and customers have to go through a number of steps before getting to the actual product catalogue subset they require (Ji et al., 2006).

- **Product selection and decision making is problematic as there are many choices presented on small screens for customers to process:** Limited recommendations in online stores affect the number of products that can be presented to the user at one time. This directly follows the previous challenge and users are left with cognitive overload to search and find the particular product they are interested in. Section 3.3
discusses the processes of consumer behaviour and decision making that shows the steps consumers take in order to make a purchasing decision.

In a mobile environment (m-commerce), product catalogue presentation and browsing are major challenges as there are other factors that already affect mobile interactivity, for example, limited screen space, slow connection speed and low memory and processing power to efficiently conduct such tasks (Ho and Kwok, 2003; Issel and Mrozik, 2008; Min et al., 2009). The product catalogue presentation challenge negatively impacts usability, adoption of m-commerce applications and effectively sales and profits (Min et al., 2009). The next section discusses the various techniques that are utilised to resolve challenges customers face when browsing a catalogue in both e-commerce and m-commerce.

4.6 TECHNIQUES USED TO IMPROVE USABILITY OF ONLINE BUSINESS APPLICATIONS

There are several techniques that are implemented in online shopping websites in order to improve usability of the information presented on the online store. Online businesses make investment for such techniques because research has shown that a usable online store eases and supports consumer behaviour and purchasing decision making. This section covers the three main techniques utilised in online stores to improve usability and to support consumers’ decision making. The development of these techniques has been more apparent and effective in e-commerce than on m-commerce websites (Ricci and Nguyen, 2005).

4.6.1 Examples of Specific Techniques

- Recommender System: Recommender systems are systems that perform intelligent information filtering of information or products based on available user information and suggest products that might be of interest to a particular online customer. These systems have been utilised in e-commerce to improve the online customer’s experience, however, similar approaches have not been investigated much in m-commerce (Ricci and Nguyen, 2005; Maheswari and Reddy, 2009). Recommender systems employ a number of methods in order to determine the list of items to present to a particular user. The three basic methods are:
  - Collaborative filtering: Collaborative filtering determines the contents to be presented to a particular user or customer based on the customer’s profile
(Section 5.3.1.1 discusses customer profiles in more detail) and reference is made to other customers with similar profiles. The system does the filtering and presentation based on analysing similarities in other customers (Kim and Lee, 2005), and tries to offer recommendations on items the customer has not yet rated.

- **Content-based filtering:** The content-based filtering technique is done based on the customer’s profile created from what the customer has done in the past (Kim and Lee, 2005). Some of the customer actions that can be used to create the profile are purchasing behaviour and items a customer has rated in the past.

- **Knowledge-based or Hybrid filtering:** The knowledge-based filtering technique is a combination of content-based filtering and collaborative filtering techniques (Adomavicius and Tuzhilin, 2005). One way to implement the knowledge-based filtering technique is to implement the content-based filtering and collaborative filtering techniques separately and then to combine the results.

- **Personalisation:** Personalisation is defined as the use of technology and available customer information to tailor e-commerce interactions between a business and each individual customer (Adomavicius and Tuzhilin, 2005; Kim and Lee, 2005). Personalisation, in this case, can help to make products offered online more suited to the unique and individual needs of each user.

- **Customisation:** Customisation is a method that is used to remove the burden of information overload on the part of the user, especially the online user (Kim and Lee, 2005). In a customisation process, end users are given an opportunity to select their requirements from a set of comprehensive options and the businesses provide products and services based on users’ explicitly selected requirements (Zhang and Jiao, 2007).

The literature reviewed thus far indicates that the abovementioned techniques are widely utilised in e-commerce applications but not as widely in m-commerce (Tran, 2006). Often researchers utilise user profiles (models) to implement the above techniques rather than other context parameters that exist within the whole environment in which the user interacts with the mobile application (Section 4.4.1, Figure 5-2). In addition, evidence could not be found of
existing specific techniques that are utilised to present the filtered product catalogue information according to the mobile device and other context information.

4.6.2 Determining User Similarities in Recommendation Techniques

Many techniques are utilised to determine similarities between users that form the basis for recommendation in e-commerce and other systems. Most authors, however, do not dwell on the technical details of the recommender system. Examples of such similarity calculations include: Jaccard Index, Sørensen-Dice, Cosine Index (or difference) and Overlap Similarity. For the purposes of proving the concept of this research only two similarity calculations were analysed: Jaccard Index and Cosine Difference. Butgereit and Botha (2013) analysed four similarity calculations that were used to determine the correct word when users entered a wrong word in instant messaging for Mathematical vocabulary. Results indicated that the Jaccard Index produced more accurate results and Cosine and Sørensen-Dice produced more similar results (Butgereit and Botha, 2013). This observation further influenced the decision to limit the similarity indexes for this research only to two. The two selected similarity calculations are performed as follows:

a. **Jaccard Index:** Jaccard Index was named after its inventor Paul Jaccard (Jaccard, 1912). The Jaccard Index is calculated as follows:

Given two sets $A$ and $B$, the similarity between the elements in the set can be determined by using the following formula:

$$ \frac{|A \cap B|}{|A \cup B|} $$

The higher the index obtained from this formula the greater the similarity.

b. **Cosine Index:** Cosine Index is a measure of similarity that is calculated by determining the cosine of the angle between two vectors. Given two sets $A$ and $B$ the Cosine Index is found by using the following formula:

$$ \frac{|A \cap B|}{\sqrt{|A||B|}} $$
As in the Jaccard Index, the higher the cosine index obtained from this formula the greater the similarity.

Similarity indexes in this research will be utilised to determine a comprehensive list of products to be retrieved from a data repository for a particular user by analysing similarities between the users. Section 6.4.2.2 discusses how this was conducted.

4.6.3 Usability Summary
The usability of product catalogue influences consumer purchasing decisions that can have an impact on sales and growth of an online business. Presenting and browsing product catalogue in a m-commerce environment is challenging because of inherent challenges in mobile devices, for example, small screen size and small keyboard. This chapter aimed at presenting the challenges experienced when customers browse product catalogues online when using a mobile device, and existing techniques utilised to address the challenges. This section highlighted a number of techniques that are utilised to improve usability with regard to information presentation on digital device interfaces. Not many technicalities could be found in literature about how the techniques are implemented, for example, how similarities are calculated between users. Furthermore, very little literature could be found on the application of these techniques in mobile web environment. This research will utilise the existing techniques and add details of techniques, such as similarity calculations between users and also the research emphasises on mobile web environment.

4.7 CONCLUSION
Product catalogues are a critical component of any online store and improved usability can have a direct impact on sales and profits (Section 3.2.7). Product catalogue presentation in m-commerce is challenging because of the various factors that are inherent in mobile technology. These challenges affect usability, adoption of m-commerce applications and effectively sales and profits for m-commerce businesses. The objective of this chapter was to discuss the literature surrounding usability with regard to browsing a product catalogue on a mobile device (in m-commerce).

The chapter achieved the objective by presenting an overview of product catalogues (Section 4.2). The chapter also discussed the concept of usability evaluation, usability in mobile
computing and usability problems that are experienced during browsing of online product catalogues in an m-commerce environment (Section 4.3). The overall contribution of this chapter to the research was to address research objectives and questions 2a and 2b. Discussion in Sections 4.4 and 4.5 comprises the main deliverable of the chapter by outlining the usability challenges customers face when browsing a product catalogue in m-commerce when using a mobile device and how they are currently addressed. The output from this chapter will be utilised as input to the proposed solution that is discussed in Chapter 6 and as well as the basis for conducting evaluation of the proposed model discussed in Chapter 7. The next chapter discusses context-awareness.
CHAPTER 5: CONTEXT-AWARENESS

5.1 Introduction
5.2 Context and Context-Awareness
5.3 Context in M-commerce Environment
5.4 Context-Aware Model Examples
5.5 Conclusion

5.2.1 Definition
5.2.2 Types of Context Information
5.2.3 Categories of Context Information
5.2.4 Acquisition of Context Information
5.2.5 Model of Context Information - Context-Awareness
5.2.6 Types of Context-Aware Adaptations
5.2.7 Challenges in Context-Aware Computing
5.2.8 Context and Context-Aware Computing Summary

5.3.1 Types of Context Information in M-commerce
5.3.2 Uses of Context in M-commerce
5.3.3 Summary of Context in M-commerce Environment

5.4.1 General Context-Aware Model Examples
5.4.2 Specific M-commerce Context-Aware Model Examples
5.4.3 Context-Aware Model Examples Summary

Deliverable: Analysis of Context Parameters for M-commerce Context-Aware Model

Deliverables

A Context-Aware Model to Improve Usability of Information Presented on Mobile Devices

Figure 5-1: Chapter 5 context
Chapter 4 discussed usability with specific focus on accessing product catalogue in m-commerce. The chapter outlined product catalogue presentation challenges on mobile devices and their impact on usability that effectively influence the decision making process for m-commerce customers (Sections 4.5). The overall goal of the research was to address the usability challenges experienced when browsing a product catalogue when using a mobile device through the use of a context-aware model. This chapter discusses the concept of context-awareness that is gaining popularity in computing.

Context-awareness is a relatively new field in computing that is proving to have a significant impact on the way applications are being developed (Pushpa and Venkataram, 2011). Being a new field, many gaps exist in context-aware literature with regard to acquisition, interpretation and use of context information in areas such as mobile computing and specifically m-commerce. This chapter aims to explore how context information is utilised in mobile computing, especially during presentation of information on mobile devices.

The chapter first discusses context and context information. Types of context information and acquisition will be discussed followed by usage of context information in developing context-aware applications (Section 5.2). The chapter will also discuss the context available in m-commerce environment and how adaptation based on context information is currently performed in m-commerce (Section 5.3). The goal of the chapter is to seek evidence and demonstrate how context information can be utilised to improve usability of m-commerce applications with regard to product catalogue data presentation.

This chapter addresses the following research objective and question (Table 1-1):

\[ RO_3: \] Explore the state of the art in context-aware computing with regard to background and implementation building blocks in m-commerce;

\[ RQ_3: \] What is the state of the art in context-aware computing with regard to background and implementation building blocks?
5.2 CONTEXT AND CONTEXT-AWARENESS

The term context (and context-awareness) emerged in computer applications development from the early 90s. Since then incorporation of various pieces of context information into application development and runtime has proven to have a significant impact on usability and the way end user computer and mobile applications are developed. Incorporation of context information into application development and runtime is what has been termed as context-awareness or context-aware computing (Schilit et al., 1994; Dey, 2001; Tao, Pung and Da Qing, 2004; Orjuela-Parra et al., 2009; Zhang and Wang, 2010; Chin-Chih and Shih-Tsung, 2012). This section will discuss the definitions, classification and uses of context and context information in developing adaptive mobile and desktop applications.

5.2.1 Definition

Literature reviewed thus far on context in computing indicates that researchers have not come to agreement on one definition for context (Trivedi and Khanum, 2012). For example, Poulcheria and Costas (2012) define context in m-commerce as the set of all possible conditions and states surrounding an electronic operation, while Bohmer et al. (2010) defined context in computing as any other relevant factors that can influence interaction and usability of an application apart from the system itself. Many more definitions exist in literature for the term context (Keidl and Kemper, 2004).

However, one definition for the term context that was proposed by Dey (2001) has been extensively cited (Schmidt, Aidoo, Takaluoma, Tuomela, Laerhoven and Velde, 1999; Dey, 2001; Bohmer et al., 2010; Zhang and Wang, 2010; Asif and Krogstie, 2012; Lowe et al., 2012; Poulcheria and Costas, 2012). Dey (2001: 5) defined context as:

“Any piece of information that can be used to characterise a situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves”.

Dey’s definition is close to the dictionary definition of context which can be rephrased as the set of facts or circumstances that surround a situation or event (OxfordDictionary, 2013). The definition of context in computing, however, relies upon the word “relevant” which entails

85
that any context information that can be derived for use in an application has to be relevant for that particular situation (Bohmer *et al.*, 2010; Asif and Krogstie, 2012). Context information in this case refers to the set of data elements that constitute, define and provide characteristics of a context entity (Poulcheria and Costas, 2012). For example, context information for an entity user can include features such as name, age, gender, race and preferences. The implication is that a context entity (or simply context) only becomes meaningful when context information is available. Examples of common context information developers used to improve usability include: location, device characteristics and user preferences (Keidl and Kemper, 2004; Tao *et al.*, 2004; Orjuela-Parra *et al.*, 2009; Asif and Krogstie, 2012).

### 5.2.2 Types of Context Information

There are basically two types of context information namely, dynamic and static (Bouramoul *et al.*, 2011). The type of context information is determined based on the time interval that elapses before the value of a piece of information changes (Adomavicius and Tuzhilin, 1999; Poulcheria and Costas, 2011; Vieira, Caldas and Salgado, 2011). Context information is static information when its value does not change during interaction between the user and the application. A typical example is the user’s mobile device (and its features) which remains static for the period of interaction (Table 5-1).

Dynamic context information is information where the value can change a number of times during interaction. A device’s Internet connection strength or bandwidth is a typical example of dynamic context information in a mobile web environment because connectivity strength usually fluctuates during interaction (Yao, Kanhere and Hassan, 2008). The mobile environment is generally considered as dynamic because of the fact that there is huge diversity in terms of users and devices used to interact with mobile applications.

### 5.2.3 Categories of Context Information

Context information is classified into various categories depending on the source where the information is acquired from. For example, context information that originates from or relates to the user falls into its own category. Literature reviewed thus far indicates that there is no agreement on classification of context information. For example, Woerndl and Groh (2007) and Schmidt (2013) classified context into two categories: social and physical context, and
human and physical environment respectively, while Gallego and Huecas (2012) classified context into social, location and user. Schmidt et al. (1999) proposed three categories of context information, namely, environment, user and activity.

This research adopts a three-tier context classification that has been widely utilised by other researchers as follows (Kim, Kim and Lee, 2005; Ryan and Gonsalves, 2005; Barnard et al., 2007; Coursaris and Kim, 2007; Poulcheria and Costas, 2012):

1. **User specific:** This is context information that is directly related to the user. This information provides characteristics about the user. User models (customer profiles) are usually used as a source of such information in mobile and desktop applications. User specific context information can be further classified into two groups: external and internal information. External information includes features of the user that can be perceived from outside, for example, physical appearances and disabilities. Internal information includes features of the user that are held within the user and cannot be ordinarily perceived by another person, for example, a user’s previous experience with using the application, emotions, feelings and age;

2. **Device (or technology specific):** This is context information that is related to the device being utilised by the user during interaction with an application. Device specific context information is also classified into two groups: input and output characteristics. Device input contextual information includes features of the device that capture input information from the user into the application. Examples include: keyboard (touch vs. keypad), camera and microphone. Device output contextual information includes features of the device that relay output from the system to the user. Examples include screen size and speakers. An additional group of device contextual information deals with the internal composition of the device that assists and/or processes the user input and produces output. This group is usually omitted during classification of device specific context information;

3. **Environment specific:** This is context information that is available in the environment in which the user can be found during interaction with an application. Environmental context information relates neither to the user nor the device in use. Common examples of environmental specific context information include: weather,
time, availability of other individuals, activities happening around the user or activities the user is involved in and bandwidth, when it comes to web applications.

Figure 5-2, adapted from Kim et al. (2005) and Coursaris and Kim (2006), shows context categories and specific examples of context information that fall into each of the identified categories. The figure illustrates the general components of context information in a mobile web environment as well as specific context parameters such as bandwidth. Section 5.3 filters context information shown in Figure 5-2 and presents specific context information that is relevant in an m-commerce environment for the purpose of this research.

Figure 5-2: Context classification
Source: Adapted from Kim, Kim and Lee (2005: 176)

5.2.4 Acquisition of Context Information

Context information is acquired through different sensors that gather pieces of context information and supply the information for interpretation and utilisation in an application (Chin-Chih and Shih-Tsong, 2012). Two types of sensors exist: physical and logical sensors (Schmidt et al., 1999; Tao et al., 2004; Santos et al., 2010; Poulcheria and Costas, 2011; Gallego and Huecas, 2012). Physical sensors are sensors that detect (or collect) context information through the use of some form of a physical electronic device (Schmidt et al., 1999; Tao et al., 2004). A well-known example is the Global Positioning System (GPS)
sensors (or receiver) installed in some devices that can be utilised to detect the current location and guide travellers with directions such as the Satellite Navigation System (SATNAV) (Schmidt, 2013).

Logical sensors are sensors that utilise some form of software in order to detect (or collect) context information (Tao et al., 2004; Poulcheria and Costas, 2011). For example, some software plugins and Application Programming Interfaces (APIs) are able to determine mobile phone device parameters; one example is the Wireless Universal Resource File (WURFL) which is an Extensible Mark-up Language (XML) file that contains specific features of all known handheld mobile devices (Scientiamobile, 2013).

Context sensors perform their tasks of collecting context information in two main ways namely, explicit and implicit (Zenebe et al., 2005; Bohmer et al., 2010). In explicit context information acquisition the user is aware that context information is being collected for use by an application and usually gives consent for the information to be collected (Adomavicius and Tuzhilin, 2005; Bohmer et al., 2010). For example, GPS (location) sensors in many web browsers usually ask the user to consent to sharing current location information with the application. The user may decide to accept or decline to share the location details.

Another common example is when users are requested to register on websites and provide their initial preferences such as what products, items or news they are interested in viewing. This form of explicit acquisition of context information is extensively utilised by e-commerce websites such as Amazon.com and Kalahari.com to acquire customer profiles (Ntawanga, Calitz and Barnard, 2008; Amazon, 2013a; Kalahari, 2013).

In implicit context information acquisition the user is unaware that context information is being collected for use by an application (Adomavicius and Tuzhilin, 2005; Lim, Dey and Avrahami, 2009). For example, when the application uses an accelerometer to determine the speed at which the user is travelling while accessing the application. This is done implicitly and the application responds by giving relevant output. Further examples of implicit context information acquisition include recording of the user’s previous interaction with the system for use to improve future interactions (Adomavicius and Tuzhilin, 2005; Ntawanga et al., 2008).
The acquired context information is utilised by the application to streamline the interaction between the user and an application in order to improve the usability of the application (Figure 5-3). Applications that utilise some sort of context information for the purpose of improving usability fall under context-aware systems. The next section discusses the use of context information in achieving the goal of improving usability.

5.2.5 Uses of Context Information - Context-Awareness

The main use of context in computing is for designing context-aware applications. Gartner predicts that by 2015 context will be very influential in delivering mobile consumer services (Pettey and Stevens, 2009; Pettey, 2011). Context information such as location has proven to improve usability of many desktop and mobile applications in providing location-aware services to users, that is, services that provide information adapted or suited to the current user location (Keidl and Kemper, 2004; Ismail et al., 2009; Pettey and Stevens, 2009). For instance, Google search provides an option to narrow results based on the user’s location by using specific localised web addresses such as www.google.co.za that searches and prioritises web addresses within the .co.za (Republic of South Africa) domain (Google, 2012).

Context-awareness can be defined as the system’s ability to utilise context information (or generally context) in order to interpret features and conditions within the user’s current environment and provide relevant feedback (response or output) to the user, depending on the context with the aim of improving usability or quality of interaction (Keidl and Kemper, 2004; Pettey and Stevens, 2009; Vieira et al., 2011). Relevancy in this case depends on the task the user aims to accomplish by using the system (Poulcheria and Costas, 2012).

Parameters which context-aware applications utilise in order to streamline interaction between the user and the applications for improving usability include gathering and utilising information relating to answers to questions such as (Dey, 2001; Church and Smyth, 2008):

- Who is the user?
- Where is the user?
- What device is the user using to access the application?
- What time is it? and
- What activities are going on?
A context-aware system aims to leverage information collected by sensors as responses to the above questions plus user input to provide users with relevant feedback in order to improve the quality of interaction and usability. Researchers have developed a number of different adaptation frameworks which provide understanding and guidelines for implementing various adaptations. One recent framework is the Generic Adaptation Framework (GAF) which was proposed by Knutov (2012). GAF aims at consolidating work in AHS by combining state of the art and redefining classification of the adaption process in AHS as initially proposed by Brusilovsky (1996). The framework is defined by layers of component models that addresses specific item or question in the adaptation process (Knutov, 2011; 2012; Brusilovsky, 1996; 2001). Adaptation does not form a core component of this research and therefore it will not discussed in detail.

Researchers argue that the concept of context-aware computing (also referred to as context-sensitive by other authors) was first introduced by Mark Weiser in the early 90’s who introduced the idea of the ubiquitous computing paradigm (Weiser, 1991; Dey and Hakkila, 2008; Dargie, 2011; Lowe et al., 2012; Schmidt, 2013). Weiser (1991) described ubiquitous computing as a then future computing paradigm that takes into account the natural human environment and allows the computers themselves to vanish into the background. Over the years the concept has evolved and different terms such as pervasive and ambient computing have emerged that are often confused with context-awareness (Keidl and Kemper, 2004; Vieira et al., 2011; Alshehri and Freeman, 2012).

This research distinguishes pervasive (or ubiquitous) computing from context-aware computing in that pervasive computing is more broad in scope and covers all aspects of computing including hardware and software, while context-aware computing is narrower and often deals with manipulating interaction between the user and the system through an interface (Weiser, 1991; Cook and Das, 2012; Ye, Dobson and McKeever, 2012). Context-aware computing can be described as one of the various enablers and a component of pervasive computing.

Figure 5-3 shows the model for acquiring and utilising context in context-aware applications adapted from Lowe et al. and Poulcheria and Costas (Lowe et al., 2012; Poulcheria and Costas, 2012; Schmidt, 2013). The figure shows how context is acquired through sensors,
either explicitly or implicitly, context interpretation which usually involves validating context information before being finally utilised in an application (Lowe et al., 2012; Poulcheria and Costas, 2012). Usually a significant amount of context information is collected by various sensors and only relevant context information is utilised for a particular task. Context information that is not relevant for a particular task is stored for future use (or discarded, if not required).

Gartner (2009) stated that at the moment, context-aware computing currently stands where search engines and web were in the early 90s, meaning that it is still in its infant stages. There are a number of challenges being encountered in context-aware computing (Section 5.2.7) and active research is currently underway in various areas of computing in order to leverage the claimed full benefits of context-aware computing.

**Figure 5-3: Architecture for context-aware applications**

Source: Adapted from Lowe, Mandl and Weber (2012), Poulcheria and Costas (2012) and Schmidt (2013)

### 5.2.6 Types of Context-Aware Adaptations

There are four main types of adaptation that are used in context-aware applications during interaction with the user in order to assist the users to achieve their goals and improve usability. The four adaptation types are (Tao et al., 2004; Sathish and Pettay, 2006; Poulcheria and Costas, 2012):

1. **User interface**: User interface adaptation refers to the system’s ability to alter the application’s user interface based on the user’s current context information. This is the most common adaptation in applications (Wesson et al., 2010; Baharuddin et al., 2013). Wesson et al. (2010) in their paper concluded that user interface adaptation
has enormous potential to improve usability of applications, especially mobile applications;

2. **Content**: Content adaptation refers to a system’s ability to select relevant content for processing and presentation. Based on the available context information, context-aware systems adapt content to meet the user’s goals for interacting with the system. For example, in most recommender systems, content that the user indicated in his or her preferences is brought first on the interface with an option given to ask for more information or context when required (Amazon, 2013a; Kalahari, 2013);

3. **Functionality**: Functionality adaptation refers to the selection of relevant functions that have to be performed by the system in order to meet the specific user requirements. For example, in an integrated enterprise resource planning system depending on the user’s role some functionalities can be hidden;

4. **Device**: Device adaptation is a relatively new addition to adaptation techniques that adapts the above adaptations according to the device being utilised during interaction. The increase in the use of diverse mobile devices and applications has resulted in more focus on device adaptation recently.

The above types of adaptations in context-aware systems can be performed either actively or passively (Schmidt, 2013). Active adaptations in context-aware applications are performed without the user’s intervention. For example, re-routing mobile device users to a mobile version of a website is usually done without the user’s intervention. However, oftentimes users are given an option to revert to the desktop version of the website. Examples of websites that implement such adaptations include Amazon.com and Kalahari.com (Amazon, 2013a; Kalahari, 2013). Passive adaptations in context-aware applications ask for the user’s intervention before presenting the user with the adapted version of the system.

Specific examples of terms utilised in context-aware systems include: adaptive systems, personalisation, recommenders systems and customisation. These have been discussed in Section 4.6. The recent increase in the use of mobile applications has encouraged increased attention towards context-awareness in mobile and mobile web application as compared to desktop applications. Some authors have argued that the reason for this bias towards more apparent use of context in mobile computing is because the mobile environment is dynamic as compared to a more static environment for desktop applications (Dey and Hakkila, 2008;
Poulcheria and Costas, 2011; Schmidt, 2013). This research primarily aims to model context that can be utilised to improve content and presentation of product catalogue data in m-commerce.

5.2.7 Challenges in Context-Aware Computing

Developing context-aware applications is hindered by a number of challenges. This was confirmed by Tao et al. (2004) who indicated that context-aware computing is complex. Recent developments have aimed to simplify context-aware computing, for example, the use of Service-Oriented Computing (SOC). SOC enables various context information resources to be accessed and utilised in applications as services in context-aware computing (Erl, 2008; Scientiamobile, 2013). A number of challenges still remain unresolved in context-aware computing and the following are notable:

- **Defining useful/relevant context information:** This involves identification of relevant context information that can be incorporated into an application with the aim of improving usability. The fundamental question in this challenge can be what information is relevant and how can this information be applied in an application (Lowe et al., 2012);

- **Quality of context (QoC):** Lack of techniques to collect quality of context information has been highlighted as a critical challenge to the advancement of context-aware computing by a number of authors (Brgulja, Kusber, David and Baumgarten, 2009; Asif and Krogstie, 2012). The quality of context information is affected by issues such as accuracy and completeness;

- **Disparities in context information:** Context information is collected in different formats through various sensors. For example, a location is usually determined by a GPS by coordinates, latitude and longitude real values, while user preferences can be collected from a user profile with values consisting of integers and string values. The challenge in this regard is to integrate various sensors and interpret various data formats of context for use during adaptation (Lawton, 2010);

- **Security and privacy:** This is another challenge that is hampering the growth of context-aware computing (Lawton, 2010). For example, to perform effective adaptation, a context-aware application may require characteristics of the user such as location and other personal information. Research, however, has shown that users
usually are not willing to share such information with applications for safety and security reasons (Turban et al., 2011).

5.2.8 Context and Context-Aware Computing Summary

This section has discussed the general literature on the present understanding of context. As discussed in Section 5.2 context-awareness is a relatively new field in computing and many gaps exist. The goal of this section was to analyse existing literature and present suitable terms and techniques that can be utilised in this research. For example, the definition of the term context is still elusive and this section analysed several definitions in order to present a suitable definition for the purpose of this research (Section 5.2.1). Various other concepts with regard to context-aware computing were presented in this section for the purposes of this research as well as for the benefit of other researchers who may build on this work. Examples include acquisition of context (Section 5.2.4), uses of context information (Section 5.2.5) and known challenges in context-aware computing (Section 5.2.7). The next section takes a further step to discuss context in m-commerce.

5.3 CONTEXT IN M-COMMERCE ENVIRONMENT

Early context-aware research and applications predominantly utilised location as the only context information for use during adaptation (Schilit et al., 1994; Dey and Hakkila, 2008; Xining et al., 2010; Schmidt, 2013). This was due to lack of advanced technologies able to acquire additional context information. Recently introduced technologies have enabled the acquisition of a variety of context information for use during adaptation in addition to location information. Examples of such technologies include the accelerometer that senses the speed at which the device is moving in a mobile environment.

An m-commerce environment can be described as an interaction environment in which business transactions take place using mobile devices that connect to the Internet via wireless networks anytime, anywhere (Poulcheria and Costas, 2012). An overview of m-commerce was discussed in Section 3.2. M-commerce is set to become the greatest, promising market because of the rapid increase in the use of Internet-enabled handheld mobile devices to conduct business transactions (Koukia et al., 2006; Su, Yeh, Yu and Tseng, 2010; Jahanshahi et al., 2011).
M-commerce applications suffer from a number of usability problems that impact future success, if left unresolved. For example, with the increasing amount of information available on virtual markets, it is difficult for online customers, especially m-commerce customers, to get what they are looking for without the assistance of intelligent systems such as recommender systems running in the background (Ricci and Nguyen, 2005; Koukia et al., 2006). Various remedies have been developed to resolve the challenges by the use of context information, such as user profiles to implement personalisation.

However; only little progress has been achieved with regard to resolving usability challenges in m-commerce, especially with regard to browsing a product catalogue (Section 4.5). For example, literature reviewed thus far lacks a clear focus on the use of context to improve usability in m-commerce with regard to presenting catalogue information on a mobile device interface, despite the evidence of some research that has been conducted on the use of context in improving usability of general computer and mobile applications (Anagnostopoulos et al., 2007; Barnard et al., 2007; Dey and Hakkila, 2008).

The m-commerce interaction environment, just like any other mobile web environment, is characterised by factors, such as diversity of devices, profile of users and other context of use (Koukia et al., 2006; Kim et al., 2007). A number of context parameters are utilised in developing context-aware computer and mobile applications (Figure 5-2). This section aims at presenting a selection of context components that can apply in m-commerce for the purpose of improving usability with regard to browsing a product catalogue. The challenge in delivering mobile web applications lies mainly in managing the dynamic nature of the mentioned components that form context in the mobile web (Figure 5-2) (Sohn, Li, Griswold and Hollan, 2008). Context components discussed in this section are a selection from the overall context information that is utilised in general computer and mobile application development.

5.3.1 Types of Context Information in M-commerce
As discussed in Section 5.2.1 context only becomes useful when context information is relevant or suitable to explain a particular situation or environment. Many context parameters exist in various situations and environments, however not all can be relevant or suitable for use in an m-commerce environment. The following sub-sections discuss the different types of
context components or characteristics relevant or suitable for an m-commerce environment and for each context, component examples, sources, and gathering means (explicit or implicit) are discussed.

5.3.1.1 Customer (User) Profile

A customer profile is defined as a collection of information that describes the customer (Adomavicius and Tuzhilin, 1999). The term user profile is also frequently used, especially in applications that fall outside online business circles. Orjuela-Parra et al. (2009) and Adomavicius and Tuzhilin (1999) extend the concept of customer profiles to include mobile customers and introduce a concept called a mobile customer profile. A mobile customer profile is simply a customer profile with additional information that describes an m-commerce customer.

Customer profiles contain two sets of information, static (or factual) and dynamic (or behavioural) information (Adomavicius and Tuzhilin, 2005; Zenebe et al., 2005; Jong-Hyuk and Seunghun, 2012). Static information, just like static context information, describes customer information that takes a long time to change. Examples of static customer profile information include customer demographic information, for example, name, date of birth and gender.

Figure 5-4 shows an example of a page utilised to collect static customer profile at Kalahari.com (Kalahari, 2013). The page shows fields that customers are required to complete when they register on the website. An option is provided to register additional static information such as billing addresses and contact numbers.
Dynamic customer profile on the other hand is customer information that frequently changes. Examples of dynamic customer profile information include:

- Interests and preferences, for example, a particular brand of products;
- Purchasing and browsing history, for example, the user’s previous purchases.
Mobile customer profile information can be collected using the two main ways of acquiring context information, implicitly and explicitly (Adomavicius and Tuzhilin, 2005). Explicit acquisition of customer profile information is usually done by requesting the customers to register on websites and in most cases customers are further requested to indicate initial preferences (Ntawanga et al., 2008; Amazon, 2013a). In this way both static and dynamic customer profile information is collected.

This list of initial preferences and other static customer profile information acquired explicitly is then mostly updated implicitly. This usually takes place as users continue to use the system. Information such as initial preferences can be updated by adding to the preference list items the customer has purchased in the past or items customers with similar profiles have purchased. For example, in a study conducted by Ntawanga et al. (2008) a method for creating and updating initial customer profiles based on user clickstreams and browsing history was validated. The method proved efficient in creating initial profiles for new customers and the initial profiles were accurately adjusted to match variance in the users’ preferences over time.

Figure 5-5 shows an example of how customer preferences can be acquired while registering on an e-commerce website (Ntawanga et al., 2008). The example shown in Figure 5-5 is a questionnaire that was set for the user to complete upon registration. The collected responses were utilised to rate the user’s levels of knowledge on various products that constituted the user’s initial profile. This rating was utilised during personalisation in order to present users with relevant levels of information based on their rating levels (Ntawanga et al., 2008). Similar techniques are utilised in e-commerce websites such as Amazon.com and Kalahari.com where customers are requested to explicitly select categories they are interested in such as books, movies and electronics during registration (Amazon, 2013a; Kalahari, 2013).
The main sources of gathering user profile information are the users themselves either explicitly providing information through methods such as user registration or implicitly where systems collect different pieces of information about the user. In both explicit and implicit methods of gathering user profile information, users play a major role in providing such information, knowingly or unknowingly. For example, in research conducted by Ntawanga et al. (2008), users created their own profiles (explicitly) and later on the system was able to update the profile based on interaction history and clickstreams (implicitly). This enabled the application to provide users with specific customised information depending on their up-to-date customer profiles.

Security and privacy issues discussed in Section 3.2.5 hamper the accuracy of customer profiles. The creation of accurate customer profiles depends on the users’ participation, however, as discussed in Section 3.2.5 online customers still feel unsafe to share specific categories of information online. This affects the quality of customer profile information collected that in turn affects the quality of its use during adaptation. For example, if the
customer profile is not accurate, then adaptation based on an inaccurate profile will also be ineffective and can affect overall usability and user experience of the application.

5.3.1.2 Mobile Device Profile
A mobile device profile can be defined as a description of the characteristics of a particular mobile device being utilised by a specific user to access an m-commerce application. The diversity of mobile devices demands that content and presentation adaptation have to be designed and implemented to fit within the current device’s capabilities that can be provided by a profile (Sathish and Pettay, 2006; Barnard et al., 2007).

Mobile device profile can be defined by parameters that fall into two groups: hardware and software (Orjuela-Parra et al., 2009). These parameters are basically static (do not change during the course of interaction) and those that influence presentation of information on the mobile phone. Table 5-1 shows these parameters, the class for each parameter, behaviour and the level of influence on presentation on a mobile user interface.

<table>
<thead>
<tr>
<th>Phone Feature</th>
<th>Class</th>
<th>Behaviour</th>
<th>Influence on presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>Hardware</td>
<td>Static</td>
<td>Low</td>
</tr>
<tr>
<td>Screen size</td>
<td>Hardware</td>
<td>Static</td>
<td>High</td>
</tr>
<tr>
<td>Resolution</td>
<td>Hardware</td>
<td>Static</td>
<td>High</td>
</tr>
<tr>
<td>Processor</td>
<td>Hardware</td>
<td>Static</td>
<td>Low</td>
</tr>
<tr>
<td>User input mode</td>
<td>Hardware</td>
<td>Static</td>
<td>Low</td>
</tr>
<tr>
<td>Operating system</td>
<td>Software</td>
<td>Static</td>
<td>Low</td>
</tr>
<tr>
<td>Installed software</td>
<td>Software</td>
<td>Static</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 5-1: Generic mobile device features

Mobile device profiles can be acquired explicitly by asking the user the type of device in use, or implicitly by using a number of logical sensors that determine the type and characteristics (features) of the mobile device (Scientiamobile, 2013). When explicit means of acquiring a mobile device profile are utilised, users are responsible for identifying the devices, and applications perform adaptations based on the provided information. In implicit acquisition, mobile devices themselves are responsible for exposing and providing properties of the device to applications in order to perform adaptations. Many device property databases have been developed in order to put in one place all the properties of known devices. An example
of such a database is WURFL which is an open source XML file that developers can use to query device properties (Scientiamobile, 2013).

5.3.1.3 Environment Factors

A number of context factors within the m-commerce (or general mobile web) environment can have an impact on the usability of an application. A number of research attempts are currently under way to incorporate such context information into applications in order to improve usability. This section highlights the most notable environmental context parameters that are relevant and utilised in m-commerce, including location, user activities and other factors.

Location: One distinguishing feature of mobile applications is their ability to provide flexibility in terms of access location, generally termed as mobility (other authors refer to this term as ubiquity) (Tiwari et al., 2008). Unlike localised applications, mobile applications can be accessed at different places and the provision of services that suit a particular location can play a crucial role for the mobile application’s usability and user acceptance. Literature defines three types of mobility as follows (Barnard et al., 2007; Tiwari et al., 2008):

1. Wandering: Movement within a place;
2. Travelling: Movement between places;
3. Visiting: The act of being in one place for some time and then moving to another.

Mobile application designers have to consider all three mobility aspects, especially wandering and travelling, as visiting is static for a certain period of time (Barnard et al., 2007).

Location in mobile applications can be determined implicitly or explicitly. However, for security and privacy purposes, web application users are always requested to consent sharing location information for use within the application (w3schools, 2013). The application can then either implicitly determine location through the use of techniques such as the GPS system or explicitly by asking the user to specify (or choose) the correct location information.

Activities: Refers to the general actions the user is currently undertaking while interacting with the application. For example, a user can be in the middle of a conversation with
colleagues while interacting with the application. This context can be acquired by an application in order to improve usability of the application during that particular context.

Other context: In a mobile environment, users access applications in different places with different factors surrounding them, for example, varying bandwidth, connection costs, light and sound levels, among others (Bellavista et al., 2006; Barnard et al., 2007). These factors pose a great challenge in developing mobile applications that suit the ever-changing context that is naturally embedded in mobility (Bohmer et al., 2010). Additional context information can also be determined implicitly or explicitly (Bohmer et al., 2010). For example, an application can detect the time of the day without asking the user (implicitly), users can indicate whether they are using the application in the presence of other people (explicitly).

5.3.2 Uses of Context in M-commerce

Literature provides evidence that context information can improve usability of both desktop and mobile web applications. Sections 4.6 and 5.2.6 present examples of specific work that has been done with regard to the use of context in improving usability of m-commerce applications such as personalisation and recommendation. Literature, however, indicates that such techniques have been more extensively explored and effectively implemented in e-commerce as compared to m-commerce.

5.3.3 Summary of Context in M-Commerce Environment

There exist a number of different types of context information that can be utilised in developing context-aware web applications. This research, however, focuses only on the m-commerce environment and therefore there was a need to present a narrow set of relevant context parameters and a discussion that focuses on meeting the goals of the research. This section has outlined and discussed what context parameters are relevant in a m-commerce environment, namely, user profile, mobile device profile, location and other context. The discussion of context parameters in the m-commerce environment aims at providing thorough understanding of the parameters and how they fit into this research. Context identified in this section will be utilised in the context-aware model presented in Chapter 6, in which a specific set of parameters are utilised. The next section discusses examples of existing context-aware models. The section highlights the main components of existing models that can be utilised as a basis for designing the context-aware model proposed in this research.
5.4 CONTEXT-AWARE MODEL EXAMPLES

The increasing attention in context-aware computing stimulated the rise in development of context-aware models that aim at easing implementation of context-aware applications. Over the past decade and half, a number of context-aware models similar to the model being proposed in this research have been implemented by other researchers. This section discusses selected examples of similar models. The goal of this section is to highlight core functionalities in existing models as well as highlight deficiencies that compel the requirements for the proposed model. Four models were identified and analysed from two groups of context-aware models, namely, general and specific context-aware models.

5.4.1 General Context-Aware Model Examples

The general models provide broad understanding of context-awareness and foundations for implementing wide-ranging context-aware applications. The purpose of general models was a motivation for including them in the analysis of context-aware models. The following subsections discuss examples of general context-aware models identified and analysed in this research.

5.4.1.1 The Context Toolkit

A context toolkit was developed by Anind Dey in 2001 (Dey, 2001; Dey and Abowd, 2001a; Dey and Abowd, 2001b). The context toolkit is an architecture that can be utilised by developers and researchers to build and deploy context-aware applications (Dey and Abowd, 2001a). The context toolkit aims at facilitating the development and deployment of context-aware applications. Distributed sensor units (called widgets), interpreters and aggregators register themselves to the centralized discoverer to ascertain if they are discoverable by the client applications (Dey and Abowd, 2001a; Dey and Abowd, 2001b). The architecture is middleware-based and oriented to sensor-based applications.

Services provided by the context toolkit include (Dey, 2001; Dey and Abowd, 2001a):

- Encapsulation of context sensors;
- Access to context data through a network API;
- Abstraction of context data through interpreters;
- Sharing of context data through a distributed infrastructure;
- Storage of context data, including history for future use and reference;
- Basic access control for privacy protection.

Dey’s work on context and context awareness has been extensively cited by other authors and seemingly is one of the first comprehensive research efforts on context-awareness (Brgulja et al., 2009; Zhang and Wang, 2010; Poulcheria and Costas, 2011; Asif and Krogstie, 2012; Lowe et al., 2012; Poulcheria and Costas, 2012). This observation was an additional motivation to selecting Dey’s model for analysis.

5.4.1.2 Context Directory: A Context-Aware Service for Mobile Context-Aware Computing Application by the Example of Google Android

Lowe et al. (2012) developed a context directory that facilitates context acquisition and dissemination in a mobile computing space. The model proposed by Lowe et al. was similar to Dey’s context toolkit in general terms, with its only unique feature being the focus on mobile computing. The goal for the context directory architecture is to create a reasonable (scaled down) set of context models, parameters, associated interpretation methods and adaptation possibilities that could facilitate development of context-aware applications. Lowe et al.’s context directory had the following main components:

- **Context client:** This component connects with the context sensors of a mobile device. The interaction between the mobile device and context client was many-to-many, that is, a number of context clients could collect context information from different mobile devices;
- **Context-aware API:** This is the component that enabled easy development of context-aware application to run on mobile devices by exposing the context information in a useful format via an API. Further context information, however, can be acquired on demand from the context client;
- **Context directory:** This acted as a server part in the architecture. Its main functionality was to receive and update context information from the context client.

A context-aware application example was developed using the Google-Android based platform.
Other additional examples of general context-aware models include work by Wagner, Reichle and Geihs (2011) who developed a context as a service platform and Hussein, Han and Colman (2011) who proposed a model-based development approach for context-aware adaptive systems.

### 5.4.1.3 Shortfalls in General Context-Aware Models

General models are useful in providing the basic foundation and understanding for development of context-aware applications, for example, background theory and general technicalities of context-aware computing. However, a number of shortfalls were identified that necessitated the development of specific context-aware models. The following were the deficiencies identified in general models:

- Literature shows that context is difficult to define unless there is enough domain knowledge (Lowe et al., 2012). This means context has to be defined within a specific domain in order to be meaningful. The generality of the models therefore made it difficult to adapt and utilise within a specific domain;
- The use of specific examples of context information in these models was sparsely clarified. This can be attributed the general nature of the models. The clear focus in both models (and other similar examples) was on acquisition and dissemination of context (Inverardi and Mori, 2010);
- The models do not provide techniques for determining QoC which is fundamental during development of effective context-aware applications.

### 5.4.2 Specific M-Commerce Context-Aware Model Examples

Two specific m-commerce context-aware models were identified and analysed. The goal for selecting m-commerce context-aware models was to align the analysis to the research objectives. Analysis of m-commerce context-aware models narrowed down functionalities of the general model and aimed at the analysis in the perspective of this research. The following were the criteria that were aligned with research objectives that influenced selection of the two specific m-commerce context-aware models:

1. **Mobility**: The model has to be developed for mobile computing, specifically mobile web computing. The selected models were designed for m-commerce which is often conducted via mobile web computing and hence qualified;
2. Retrieval and presentation of data: The model should be performing retrieval of information from a data repository. Both models had retrieval and presentation components and hence qualified.

The following sub-sections discuss the specific m-commerce context-aware models that were analysed in this research.

5.4.2.1 Context-Aware M-commerce Services: C-IOB Model Approach

Pushpa and Venkataram (2011) developed a context aware m-commerce service: Context-Information, Observation, Belief (C-IOB) model. Core to the model was defining context as consisting of three classes of information that exist in the user’s physical, system, application and social environments from which context can be acquired. The classes of context defined by Pushpa and Venkataram (2011) are:

- **Well-defined context information**: This class consists of well-defined, unambiguous context information, such as a place, object and person. It is associated with specific values such as time is 2:00 p.m., where time is a context parameter and 2.00 p.m. is an associated unambiguous value;

- **Qualitative context information**: This class consists of symbolic data that utilises distinct quantity spaces in a specific application-oriented domain. Examples include the festive time of the year (Nov-Dec);

- **Credible context information**: This class consists of information that qualifies an object and provides ill-posed or relevance-based values. Examples include conditions of the road as poor, fair and good.

The C-IOB context-aware model consists of the following elements:

- **Context information (C-I)**: This is the determined context information in various classes as discussed above;

- **Observations (O)**: This consists of the summary of observed context and makes a deduction about the meaning of the determined context. For example, the user can be searching for a particular product, based on context observation;

- **Beliefs (B)**: Beliefs are deduced from the observations.
The context aware model itself had three components:

- **Customer service analyser unit (CSU):** The CSU is used to analyse the customer and collect context information from the users’ environment;
- **Central service provider (CSP):** The CSP interfaces with the customer and the Vendor Selection Unit (VSU). It makes a decision on which vendor presents the customer with based-on-context information;
- **Vendor selection unit (VSU):** This component stores the list of vendors.

The context-aware architecture is used to recommend m-commerce services and credible product vendors to customers based on their context. The research claims that simulation results indicate that the context-aware m-commerce application eases selection of services and reduces the time needed to provide recommendations to the user.

### 5.4.2.2 A Context Management Architecture for M-Commerce Applications

Poulcheria and Costas (2012) developed a context management architecture for m-commerce applications. An example m-commerce web context-aware application was developed using ASP.NET in order to demonstrate the usefulness of the model. The model was implemented to conduct general recommendations and adaptation with the following main requirements:

1. **Capture:** This involves the acquisition of context information from various sources using logical and physical sensors;
2. **Store context:** This involves storage of context information for future uses;
3. **Interpret:** This involves interpretation and transformation of context information into meaningful and usable formats that can easily be utilised within a context-aware application;
4. **Transit:** This consists of actual utilisation of context information within an application.

Figure 5-6 shows the context management architecture that was developed by Poulcheria and Costas (2012). The figure shows the main components of the architecture in line with the requirements outlined above.
Figure 5-6: Context manager
Source: Poulcheria and Costas (2012)

Additional examples of specific mobile context-aware models include: SMMART: using context-awareness in m-commerce (Kurkovsky, Zanev and Kurkovsky, 2005) and the conceptual model of context for mobile commerce applications (Poulcheria and Costas, 2010).

5.4.2.3 Shortfalls in Specific M-Commerce Context-Aware Models
Specific m-commerce context-aware models are useful in providing the basis for the development of context-aware m-commerce applications. However, a number of shortfalls were identified in the analysed models that necessitated the development of a completely new model in this research. The following were deficiencies identified in the analysed specific m-commerce context-aware models:

- The models were found to be more general within the m-commerce domain. For example, there is a number of services and components within an m-commerce application (Section 3.2.7) and as such the analysed models fall short of addressing a particular service or component;
- The models lacked the use of existing tried and tested methods that enable efficient use of scarce resources associated with mobile web environment;
- Various specific context parameters were defined in the model, however, an analysis of usage of each context parameter during development of the context-aware applications was missing in that research.

An additional common deficiency in the analysed models (both general and specific) was that evaluations that were conducted on the models only went as far as the model’s functionalities. Little empirical evidence, obtained mainly from simulations, was presented
on the applicability, usefulness and effectiveness of the models when utilised in a context-aware application.

5.4.3 Context-Aware Model Examples Summary

Context-aware computing has been discussed as an emerging field within computing that is exerting significant influence on the way end user computer applications are developed. Various models have been developed in order to clarify and aid development of context-aware application over the years since the first literature on context-aware computing emerged. This section has presented a selection of existing context-aware models. The purpose of the section was to highlight the strengths and weaknesses of the existing models that necessitated the development of the proposed model. During this process, best practices for developing context-aware models were discovered.

Generalisation has been identified as the main limitation in the existing models. For example, the general models were found to be more general and lacked clarity that is critical to develop a context-aware application within a specific domain. The specific m-commerce context-aware models analysed in this section attempted to address this limitation. However, they have also been found to be too general within the m-commerce space itself. For example, no clarity was given on what context parameters are useful and how can the parameters be utilised within a context-aware application. Furthermore, the models did not utilise tried and tested techniques that could have improved clarity on core functionalities of the models.

These limitations were a motivation to develop a context-aware model proposed in this research from scratch. Useful core components of the proposed model were borrowed from existing models, however, technical specification and implementation were different. The proposed model aims to be more specific and provide a possibility for improvement and generalisation in order to be utilised in solving other similar challenges across different domains. Furthermore, several factors of the models such as their applicability (usefulness), effectiveness and efficiency will be empirically evaluated with a sample of real end users.

5.5 CONCLUSION

Since its emergence in early 90s, context-awareness research has increased and projections by major IT research firms indicate that context-aware applications are becoming a basis for
numerous innovative business models. Various research studies have been conducted in context-aware computing; however there are many gaps in understanding context, its acquisition and utilisation in computing. The objective of this chapter was to review what had been done in the field of context-awareness in order to create a setting for the understanding of how context can be utilised to improve usability with regard to browsing a product catalogue on a mobile device (Chapter 6).

The chapter achieved the objective by discussing definition of context and context-awareness, types of context information, general methods of how context information can be acquired and utilised in both desktop and mobile applications (Section 5.2). The chapter further looked at the types of context that are suitable and relevant in an m-commerce for the purposes of this research. Existing challenges in context-aware computing have also been discussed (Section 5.2.7). This chapter has addressed research objective 3 and research question 3 (Table 1-1). The main deliverable of the chapter is the outlined best practices in context-aware computing that can be utilised during the design and implementation of the model proposed in this research (Figure 5-1). The next chapter discusses conceptualisation of a generic context-aware model for improving using usability of information presented on mobile devices.
6.1 INTRODUCTION

Model Based Software Engineering (MBSE) is becoming a reliable way for simplifying presentation and communicating ideas to stakeholders involved in a SDLC to solve problems caused by the ever increasingly complexity in software systems. Models are fundamental components in MBSE that are usually developed from various viewpoints such as requirements and runtime environment during the SDLC. The main purpose of models in the Software Engineering process is to present various proposed functions or components of software systems to various stakeholders in a simple and understandable way (Mohagheghi and Aagedal, 2007). The purpose of this chapter is to use the work discussed in the previous chapters and to present the context-aware model developed in this research.

Chapter 5 discussed context-awareness in which literature on context and context-awareness was analysed and presented. The chapter defined context and context-awareness (Section 5.2.1). Types of context information and classes of context information were also analysed (Section 5.2.2). The chapter further discussed the acquisition of context information, uses of context information and challenges in context-aware computing (Sections 5.2.4 and 5.2.5). Context in an m-commerce environment was presented in Section 5.3 and a selection of context parameters relevant to this research comprises part of the chapter’s main deliverable. Chapter 5 laid a foundation for understanding context parameters to be utilised in this research.

This chapter builds on discussions in Chapters 3 to 5 and discusses the context-aware model that constitutes the core deliverable of the research. The chapter first explores literature related to the conceptualisation and development of the context-aware model, including Model Driven Engineering (MDE) (where MBSE emanates from), mathematical optimisation and mobile information presentation techniques (Section 6.2). The chapter further discusses how the context-aware model was derived (Section 6.3). Detailed components of the context-aware model and the function of each component within the model to achieve the model’s objective are also discussed (Section 6.4). In addition the chapter explains Figure 3-6 by discussing mobile web application implementation options such as mobile application frontend and backend development tools and specifically m-commerce application development tools (Section 6.5).
The chapter also discusses implementation tools that were utilised to develop the POC prototype of the context-aware model that was utilised during the evaluation of the research (Section 6.7.4). The purpose of the context-aware model was to exploit the current context within the user’s environment in order to optimise retrieval and presentation of product catalogue data on a mobile device interface in m-commerce.

This chapter addresses the following research objective and question (Table 1-1):

- **RO4**: Conceptualise, design and implement a POC prototype of a context-aware model to be utilised for optimising retrieval of personalised product catalogue and presentation thereof on a mobile device in m-commerce.

- **RQ4**: How can a context-aware model for optimal retrieval and presentation of product catalogue information on a mobile device be implemented?

The main outcome of the chapter is a detailed description of how a context-aware model was implemented for an m-commerce application.

6.2 BACKGROUND

The focus of this section is to provide background related to the conceptual design and practical development of the context-aware model. The model discussed in this chapter was developed by utilising a number of theories and techniques in order to achieve success. Theories and techniques utilised to develop the model include MDE (Section 6.2.1), mathematical optimisation (Section 6.2.2) and mobile information visualisation (Section 6.2.3). MBSE is the underlying paradigm that was utilised to create the context-aware model which is the overall deliverable of the research (Section 1.1.4).

6.2.1 Model Driven Engineering

Model Driven Engineering (MDE) (also known by terms such as Model Based Engineering (MBE), Model Based Design and Model Driven Design (or Development) (MDD)) is a general engineering principle that involves the use of models during the process of creating an artefact (Brown, 2004; Ramos, Ferreira and Barcelo, 2012). MDE continues to be utilised in many engineering fields during the process of inventing or solving problems where the solution is an artefact (Brown, 2004; France and Rumpe, 2007; Mohagheghi and Aagedal,
It is a common method utilised by professionals such as manufacturers, designers and architects involved in creating artefacts to present and communicate solution specifications beforehand to other stakeholders involved in the solution or in the process of creating an artefact. The stakeholders may include end users, domain experts and project sponsors.

MDE is recently gaining wide recognition in the Software Engineering field (Brown, 2004; Ramos et al., 2012). Software Engineering researchers have derived terms such as MDD and MBSE to specifically associate MDE in Software Engineering (France and Rumpe, 2007; Jubai, Salman and Mohammed, 2012; Ramos et al., 2012). Additional terms that appear in MBSE literature include: Model Driven Software Development (MDSD) and Model Driven Architecture (MDA). MDSD is regarded as very specific to software development, while MDA is a standardised way to realise MBSE that was developed by the Object Management Group (OMG). MDA is covered in Section 6.2.1.4. MBSE is not regarded as a methodology, but rather a formalised way of utilising models in all phases of SDLC (MBSE, 2011; Ramos et al., 2012).

Figure 6-2 adapted from Brown (2004) shows how the concept of MBSE has progressed and gained recognition in the Software Engineering field over the years. The figure shows that software development is shifting from code dependent development to model dependent development. Previously, software code was the only presentation of software solutions. Recently however there has been a transition from this trend as a consequence of increased recognition of MBSE in which models started appearing in the software development process. Models were initially derived from code, but recently the tendency is a process where models generate code. The following sub-section covers model definition, model elements or components and applicability. The section motivates why a model was chosen to represent the core deliverable of the research.
Since models are the core components and output of an MDE process, it is essential to provide a definition that can be utilised in this research. The term model is derived from a Latin word “modulus” that means measure, rule, pattern or an example to be followed (Collins, 2013). The term has been defined differently in MDE by authors because of the term’s diverse use in various fields. For example Ramos et al. (2012) and Rumbaugh et al. (2004) defined a model as a representation of a selected part of the world or domain of interest that captures the important aspects from a certain point of view, simplifying or omitting the irrelevant features (Rumbaugh, Jacobson and Booch, 2004; Ramos et al., 2012). Collins online dictionary has several definitions for the word model (Collins, 2013). The first definition of a model is a simplified version of something complex that is used to analyse and solve problems or make prediction. Collins’ dictionary definition and other definitions of a model implies that it is an example that can be imitated (Collins, 2013).

The above explanations show that definition for the term model has to be carefully chosen with regard to the intended audience as well as the field in which the model is being discussed or utilised. There are two core words that constitute these definitions: representation and simplification which entail the main functions of a particular model within
a specific field. This research falls within the Software Engineering domain and the definition for model is restricted to models in the SDLC. The intended audience includes stakeholders involved in software development, such as, systems analysts, designers, developers and researchers within context-aware systems.

This research defines a model in computing as a representation of a system or part of a software system which includes only the essential details of its structure, processes and the runtime environment (Rumbaugh et al., 2004; Booch, Rumbaugh and Jacobson, 2005; Den Haan, 2008; Olivier, 2009). The main purpose of utilising models in computing is to display or show essential components of a solution or system and ignores the non-essential components (Booch et al., 2005; Wu, 2006; Mohagheghi and Aagedal, 2007; Oates, 2008). Essential components of the system displayed in a model include: processes with their associated inputs and outputs, while examples of non-essential details that are excluded can include data types (for example, integer or Boolean) for process input and output. In addition, models focus on activities rather than on the actual algorithm of the software solution. For example, how input is captured and computed within the process to produce a particular piece of output.

Models are often confused with frameworks in literature. This research differentiates a framework from a model by defining a framework as a set of beliefs, ideas or rules that are used as a basis for making judgements or decisions, or an underlying structure of a particular system (Wu, 2006; Oxford, 2009). Frameworks are more general, for example, a framework can set out guidelines of a particular concept, while models are specific to a solution that produces a tangible artefact. Examples of frameworks in computing can include the Microsoft .NET framework while an example of a model includes a data flow diagram that shows how data flows in and out, and changes form as it passes through various stages or processes in a system (Olivier, 2009).

6.2.1.2 Realisation of Models in MBSE

Models in MBSE are developed as drawings with specific standard elements representing an entire system or its components (Rumbaugh et al., 2004; Ramos et al., 2012). The elements in a model diagram are connected by using arrows and lines that run from one element to another representing the flow of some form of parametric such as input and output. The
model elements are usually drawn by using a modelling language to represent the systems’ requirements, structure, behaviour and parametric such as input and output (Ramos et al., 2012). The next sub-section covers model development using a modelling language, in particular the OMG’s Unified Modelling Language (UML) which is regarded as a de facto modelling language in MBSE (Poulcheria and Costas, 2010; Ramos et al., 2012).

6.2.1.3 Modelling Languages (UML)

OMG invented the UML as a modelling language and for over the past 20 years since its inception UML has evolved into one of the most successful modelling languages in MBSE (OMG, 2013a). UML is a general purpose visual or graphical modelling language that is utilised to draw components of a software artefact for visualising, specifying, constructing, and documenting a software system (Rumbaugh et al., 2004; Rouse, 2010; UML-diagrams, 2012; OMG, 2013a; SparxSystems, 2013). UML offers a standard way to write a system's blueprints, including concepts such as business processes and system functions as well as concrete things such as programming language statements, database schemas, and reusable software components. The elements in a UML diagram are connected by using arrows and lines that run from one element (or component in a system) to another representing the flow of some form of parametric such as input and output.

The term unified in UML signifies the language’s amalgamation of different aspects from various authors whose inventions were incorporated into UML. The main contributors who began the UML efforts were: Grady Booch with his Booch Method, Ivar Jacobson with his Object-Oriented Software Engineering (OOSE) and James Rumbaugh with his Object Modeling Technique (OMT) (Rumbaugh et al., 2004; Booch et al., 2005). UML can be used to derive models at different stages during a SDLC. Furthermore UML can be used to design models across different domains and it is implementation-independent (Rumbaugh et al., 2004). Figure 6-6 shows some of the domains in which UML can be utilised.

There are two groups of UML model diagrams that can be used during the SDLC process: structural and behaviour UML diagrams (Rumbaugh et al., 2004; Booch et al., 2005; UML-diagrams, 2012). Structural diagrams present the visual static aspects of the system and the elements in a structure diagram represent the meaningful concepts of a system. In addition, structural diagrams may include abstract, real world and implementation concepts
(Rumbaugh et al., 2004; UML-diagrams, 2012). Examples of structural UML diagrams include (Bell, 2004; Booch et al., 2005; UML-diagrams, 2012; SparxSystems, 2013):

- **Class diagrams**: These diagrams show the set of classes, interfaces, attributes and operations (or methods) that can be performed on a class and internal and external relationships of a class that exist;
- **Component diagrams**: These diagrams show the internal parts, connectors and ports that implement a component. Component diagrams offer a higher level abstraction than class diagrams and consist of one or more classes at runtime;
- **Composite diagrams**: These diagrams show the internal structure of a class as well as interaction points (class interfaces) with other parts of the system;
- **Object diagrams**: These diagrams show the set of objects and their relationships. Object diagrams are usually used to clarify issues in complex classes;
- **Deployment diagrams**: These diagrams show the set of nodes and their relationships in a run-time environment of a system.

Figure 6-3 shows examples of structural model diagram elements in UML including a class, component and deployment node diagrams. The example diagrams show the structure and labelling of the elements. For example, the class diagram has a class name at the top, class attributed in the middle section and operation that the class can assume in the lower section of the diagram (SparxSystems, 2013).

![Figure 6-3: Examples of UML structural diagrams](image)

UML behaviour diagrams depict the dynamic aspects of a system, that is aspects of a system that change over time within the system (UML-diagrams, 2012; SparxSystems, 2013). Examples of system’s dynamic aspects include the message inflow and outflow, and the physical movements of objects over a network (Booch et al., 2005). Examples of these
diagrams include (Rumbaugh et al., 2004; Booch et al., 2005; UML-diagrams, 2012; SparxSystems, 2013):

- **Use case diagrams:** Use case diagrams describe the boundary and interaction between the system and users. The use case diagram corresponds in many respects to a requirements model, that is, what the system intends to do;
- **State machine diagrams:** State machine diagrams describe the various sequence of conditions that classes (or objects) assume during its lifetime in a system in response to triggered events;
- **Communication diagrams:** Communication diagrams describe how objects in the system will interact with each other in order to achieve the goal of a system;
- **Sequence diagrams:** Sequence diagrams are utilised to show the step-by-step processing or interaction between components or elements in a UML behaviour diagram.

Figure 6-4 shows examples of behavioural model diagrams in UML including use case diagram, sequence diagram and activity diagram. The figure shows examples of behaviour exhibited by a system and how interaction between user and processes, and processes to process is depicted in a UML diagram (UML-diagrams, 2012; OMG, 2013a; SelectBusinessSolutions, 2013; SparxSystems, 2013).

![Figure 6-4: Example of UML behaviour diagrams](image)
Figure 6-5 summarises the set of UML diagrams as updated in November 2012 (UML-diagrams, 2012). The figure provides all the sets of diagrams or elements used in a UML including a set of structure and behaviour diagrams. The next section discusses OMG’s Model Driven Architecture (MDA).

**Figure 6-5: UML diagrams**

6.2.1.4 Model Driven Architecture (MDA)

OMG’s MDA is the most successful approach in developing model based software systems using MBSE. OMG describes MDA as a modern technique of developing applications and writing their specifications based on a platform-independent model (PIM) of the application (OMG, 2013b). MDA focuses on specifications of business functionality and behaviour rather than on implementation platforms (OMG, 2013b). MDA provides an open, vendor neutral approach to the challenge of meeting progressing business and technology change in Software Engineering (OMG, 2013b). MDA aims to separate business and applications from the underlying implementation platform. The separation provides flexibility in terms of implementation and runtime environment of the application developed from the models. MDA is applied in many software domains and Figure 6-6 illustrates some software domains in which MDA can be applied. The figure shows that MDA can be utilised during development of solutions for all software domains.

![Diagram of MDA in various software domains](http://www.omg.org/mda)

Figure 6-6: Application of MDA in various software domains

Source: http://www.omg.org/mda (April, 2013)
Models in MBSE should possess the following properties in order to realise the full benefits of modelling in MDE (Selic, 2003; Selic, 2006; Olivier, 2009; Jubai et al., 2012; Ramos et al., 2012):

- **Abstraction**: This is a core property that a model must possess. Abstraction helps stakeholders involved in the solution development process to cope with complexity of the solution while focusing on core functionalities;
- **Understandability**: Models must be easy to understand by all stakeholders involved. For example, in SDLC models should balance between technical detail and business requirements or specifications;
- **Accuracy**: Models must present the true-life representation of the solution;
- **Predictiveness**: Models must provide a consistent level of predictiveness of the proposed solution;
- **Inexpensive**: Models must be developed with simple and cheap materials in order to avoid substantial upfront investments.

One major advantage models bring into MBSE from MDE is simplification of complex solutions. Models enable stakeholders to understand a problem and its potential solutions before an implementation investment is made. Researchers in Software Engineering have identified a number of model advantages that are specific to MBSE including the following (Selic, 2003; Selic, 2006; Ramos et al., 2012):

- Models bring the proposed solution closer to the problem domain thereby limiting the possibility of run-away solutions (solutions that do not address the main problem);
- Models ease specification, maintenance, communication and understandability of complex software solutions by SDLC stakeholders. Examples of stakeholders include: end users, business and IT experts;
- Models are less bound to solution implementation platform and runtime environment which provide flexibility during code and platform implementation;
• Models give hope to non-technical domain experts to be actively involved in the software solution design process;
• Recent modelling languages have capabilities to automatically generate code from models which can make development easier;
• Models for software solutions can be verified upfront by various trusted methods such as formal methods to accurately determine factors such as usefulness and cost/budget implications;
• Standards such as MDA, SOAP, XML and UML in MBSE help to promote software component re-use and best practices.

6.2.1.7 Challenges in MBSE
Researchers who advocate MBSE as well as its critics have highlighted some challenges that are deemed to have a negative impact on successful adoption and future of MBSE in SDLC. The following are the main challenges in MBSE (Jubai et al., 2012; Zheng and Taylor, 2013):

• Multi-aspect modelling: The development of complex software requires describing the system from different angles or aspects such as structural, behaviour and non-functional properties. The challenge in this regard is to present simple and yet complete models from various angles that can be turned into code;
• Code generation: The premise of model based development is that models should be able to automatically generate code. Currently, however, there are limitations in terms of code generation capabilities. For example, currently there are no known code generators that can generate code for non-functional requirements;
• Model-code consistency: After code generation there are chances that code may need to be modified further. The implemented changes may affect the consistency between the developed model and the modified generated code.

6.2.1.8 MBSE Summary
The discussion in this section has highlighted the factors that are influencing the increasing adoption of MBSE. One characteristic of models that has been highlighted in this section is simplification of solutions and flexibility in terms of implementation options. Models are easy to understand, maintain and adapt. This research proposes a context-aware model that other researchers can utilise to implement or improve existing context-aware applications.
The discussion in this section justifies why a model is the most suitable means to represent the core deliverable of this research in order to achieve the research goals and objectives. The number of software development or programming languages and platforms available to develop mobile applications keeps on increasing. As such MBSE provides a suitable flexible option for a deliverable that can keep up with developments and can be extended rather than a program tightly coupled to a specific programming language.

MBSE was utilised in this research to present the underlying implementation technique (or methodology) of the proposed context-aware model. Properties of MBSE discussed in this section justify its suitability for presentation of the solution proposed in this research, for example, flexibility of MBSE model in terms of actual implementation technologies can help other researchers utilise the core idea presented by the proposed MBSE-based model and conduct actual implementation using tools of their choice. The MBSE presents the conceptualisation of the model while prototyping methodology (Section 2.3.2) presents the model’s actual implementation/developmental methodology using specific implementation tools. The next section discusses Mathematical optimisation.

6.2.2 Mathematical Optimisation

Optimisation is a term that means getting the best out of the situation, especially under some restrictions or limitations (Grotschel and Lovasz, 1995; Korte and Vygen, 2005). The mobile web environment is restricted in many ways and mathematical optimisation was explored in this research as one trusted way to ensure the most optimal results during interaction with the user. This section discusses the concept of mathematical optimisation and how it applies in this research. Mathematical optimisation will be used to address the information presentation challenge on mobile devices.

6.2.2.1 Definition

Optimisation is a term commonly used in Computer Science and Mathematics to refer to the selection of the best subset of elements from a set of available alternatives (Grotschel and Lovasz, 1995; Paquete, 2005). In optimisation the aim is either to maximise or minimise a function (Grotschel and Lovasz, 1995). Mathematically an optimisation problem can be represented as follows:
Given

a function \( f: A \rightarrow \mathbb{R} \) from some set \( A \) to the real numbers \( \mathbb{R} \)……..(i)

We would like to find an element \( x \) in \( A \) such that

\( f(x) \leq f(\bar{x}) \) for all \( x \) in \( A \) (minimisation) ……………………………..(ii)

or

\( f(x) \geq f(\bar{x}) \) for all \( x \) in \( A \) (maximisation)…………………………….(iii)

Mathematically results of equations (ii and iii) ensure optimal outcome for minimisation and maximisation problems respectively.

6.2.2.2 Types of Optimisation Problems

There are two main types of mathematical optimisation problems (Grotschel and Lovasz, 1995; Hoffman, 2000; Korte and Vygen, 2005; Paquete, 2005):

- **Continuous optimisation**: This is an optimisation problem in which the elements of the solution set are continuous, for example, a set of real numbers;

- **Combinatorial optimisation**: This is an optimisation problem in which the elements of the solution set are discrete, for example, a set of integers.

Mathematical optimisation problems are also further divided into two sub-classes, namely (Hoffman, 2000; Rayside and Estler, 2009):

- **Single-objective optimisation problem**: This is an optimisation problem in which the objective function aims at maximising (or minimising) a single variable;

- **Multi-objective optimisation problems**: These are optimisation problems in which the objective function aims at optimising two or more variables, often conflicting in nature. Most real world problems generally fall into the category of multi-objective optimisation where there is a need to optimise a number of variables.

This research falls within multi-objective combinatorial optimisation in which context parameters are discrete and the optimisation function may need to optimise a number of variables depending on values of currently determined context information.
6.2.2.3 Formulation of a Mathematical Optimisation Problem

Korte and Vygen (2005) and other researchers in Mathematical optimisation have concluded that the majority of real world problems are solvable using optimisation techniques (Hoffman, 2000; Korte and Vygen, 2005). Examples of such problems include: the travelling salesman, minimum cost flows and the knapsack problem (Korte and Vygen, 2005; Schrijver, 2013). An optimisation problem is defined by three main elements as follows (Rayside and Estler, 2009):

1. **Decision variables**: These are values in one or more sets from which we can select items to determine a solution or solution set. These sets are called domain sets (Formula i);

2. **Constraints**: These are limitations that selected items from the decision variables or domain set must abide by. Constraints cannot be manipulated in any way and they are only used as input for the decision variables;

3. **An objective function**: This is a function either to be maximised or minimised in an optimisation problem. It is also called a cost (mini) where the aim is to minimise cost or utility (maxi) where the aim is to get the most out of something.

6.2.2.4 Mathematical Optimisation Summary

This research is addressing two aspects, namely: retrieval and presentation of product catalogue data on a mobile phone. The mobile environment comprises a number of limitations that have to be managed during design and runtime of m-commerce applications in order to ensure optimal retrieval and presentation of product catalogue data on the mobile interface. The key to determining optimal values for these two aspects of this research is context determination that provides boundaries or constraints which the solution has to satisfy.

Section 5.3.1 discusses examples of context parameters within the m-commerce environment that will be utilised in the proposed context-aware model, namely: user profile, location, time, bandwidth and device properties. Section 6.4.4 discusses how optimisation was utilised during both retrieval and presentation of product catalogue information on a mobile device. Specifically combinatorial multi-objective optimisation techniques were found suitable to be utilised to achieve optimal presentation of product catalogue information on a mobile device in this research (Section 6.2.2.2) (Rayside and Estler, 2009; Schrijver, 2013). The objective
of this section was to bring perspective with regard to the use of context parameters during optimisation in order to determine the most suitable product catalogue subset and its optimal presentation on a mobile device interface. The next section discusses mobile information visualisation in which general techniques of presenting information on mobile devices are covered.

6.2.3 Mobile Information Visualisation

Mobile Information Visualisation aims to develop more efficient and satisfying user interfaces for searching, presenting and exploring large information spaces on small screens (Chittaro, 2006; Chittaro, 2009). The increase in the use of mobile devices to access various types of information and the challenges thereof has necessitated the need for more research in the field of Mobile Information Visualisation (Section 1.1) (Chittaro, 2006; Chittaro, 2009; Kohlbrecher, Hakobyan, Pickert and Grossmann, 2011). This section provides an overview of Mobile Information Visualisation and how this relates to this research.

6.2.3.1 Definition

Information visualisation can be defined as a methodology for representing a large amount of data by using various visual techniques to help people understand and analyse data in the most convenient manner (Chittaro, 2006; Chittaro, 2009). By using this information visualisation, users can easily understand and analyse large quantities of data. Examples of information that can be displayed using visualisation techniques include (Chittaro, 2006; Chittaro, 2009):

- **Text:** This is information that is available in large text format, for example, list of names, menus, e-books, and documents;
- **Multi-media information:** This is information that is available in multi-media format, such as images/pictures, maps, video and audio information;
- **Physical objects:** For example, models and interactive information;
- **Abstract Data:** For example time-oriented data such as calendars, medical records, stock market data.

A product catalogue can consist of several types of information, for example, text, images, audio and video. Therefore visualising this type of information is critical for efficient presentation and access especially in a mobile environment where devices and the setting are
limited in a number of ways. Information visualisation is closely related to user interface design which is one area in computing that has been widely explored in Human Computer Interaction research (Wesson et al., 2010). Terms such as Intelligent User Interface (IUI) and Adaptive User Interfaces (AUI) are very common in computing nowadays (Wesson et al., 2010). An IUI can be defined as an interface that has the capability to utilise some intelligence to adjust itself and assist users in efficiently achieving their goals and objectives when interacting with a system. An AUI can be referred to as one example of an IUI which is an interface that uses various knowledge-based techniques such as user models in order to determine how the interface should be presented to a particular user (Wesson et al., 2010). In an e-commerce context personalisation and customisation are considered to be forms of IUIs.

6.2.3.2 Mobile Information Visualisation Techniques

Information visualisation techniques have been successful in desktop applications or for information designed to be presented on desktop computers. Literature indicates that very little research has been conducted in mobile user interface adaptation and information visualisation techniques as compared to the desktop application. Mobile information visualisation remains a challenge because of limitations of the mobile devices and limitations of mobile devices will not go away anytime soon because of the objectives of the device, for example, smaller size and energy efficiency (Chittaro, 2009; Orjuela-Parra et al., 2009). Furthermore, most research studies that have been conducted in personalisation and customisation has been focusing on user profiles only to present an interface that suits a particular user's profile (Adomavicius and Tuzhilin, 2005; Woerndl and Groh, 2007; Bohmer et al., 2010).

This certainly works in e-commerce because most desktop computers have almost similar features and standard specifications, for example, screen sizes and user input mode (Jhangiani and Smith-Jackson, 2007). The challenge in m-commerce is that apart from customers having different profiles, mobile phones come in various types and shapes with no standard specifications (Tarasewich et al., 2002; Glissmann et al., 2005; Jhangiani and Smith-Jackson, 2007; Orjuela-Parra et al., 2009). For example some mobile phones have touch screen interfaces and slightly bigger screen sizes than others. As such, a one-size fits all approach for information presentation used in e-commerce has not been effective in m-commerce, hence a need arises to consider how information can be presented on a mobile phone taking
into consideration a specific mobile phone’s constraints as well as the customers’ profiles (Bellavista et al., 2006; Orjuela-Parra et al., 2009).

6.2.3.3 Mobile Information Visualisation Summary

In addition, literature indicates that when it comes to mobile web search information adaptation not much has been done. However numerous research efforts have been invested in mobile web search, rather than the actual presentation of the pieces of each result (Westlund, Gómez-Barroso, Compañó and Feijóo, 2011). For example, Church, Smyth, Bradley and Cotter (2007, 2008) conducted a variety of research regarding mobile search but none considered the effects of context on the actual presentation of the retrieved information (Church et al., 2007; Church et al., 2008; Church and Smyth, 2008).

This research takes a step further to determine how retrieved information can optimally be presented on the mobile device interface, depending on current context information (Section 5.3). Current context information within the user’s environment will be determined and utilised as constraints for optimisation technique (Section 6.2.2) in order to determine how efficiently the retrieved information can be transferred over the network and presented on a mobile device interface. Sections 6.4.4 and 6.4.5 discuss how this was conducted. The next section discusses design considerations for the context-aware model proposed in this research.

6.3 CONTEXT-AWARE MODEL DESIGN CONSIDERATIONS

Design is defined as a process of devising a plan or drawing produced to show the look and function or workings of an artefact such as a building, garment, or other object before it is actually made (OxfordDictionary, 2013). In Computing, design is a process in which solution developers determine components of a system derived from the requirements and portray its outlook of the system. Components included in design include core system modules or functions, running environment as well as software and hardware requirements. Design outcomes help the SDLC stakeholders to test the system’s structure, components and how the components will work together in order to achieve the intended goal long before the system is developed.

A number of design considerations were taken into account in this research that assisted in designing a context-aware model that can be generalised, extrapolated and utilised to retrieve
any type of information. The following are the main considerations that were taken into account during design of the proposed model:

- **Service-oriented computing (SOC):** SOC has its origin in Service-Oriented Architecture (SOA) which is defined as a set of patterns and guidelines for creating loosely coupled, standards-based and business-aligned services that provide a new level of flexibility in responsiveness to business threats and opportunities (Canfora, Fasolino, Frattolillo and Tramontana 2008; Erl, 2008; Sommerville, 2011). SOC promotes the use of services as a basic unit for a solution in order to solve organisation challenges. Services in SOC communicate by exchanging standard messages expressed in formats such as XML. The context-aware model was designed based on SOC in which its components were designed loosely as services that can be invoked by any service provided the calling service meets the communication standard. SOC has an impact on the extensibility of the model in that components can be utilised and extended without having to redesign the model. Standard communication within the model was achieved by using XML based standard message as input and output from one service to another. For example, the WURFL data repository was accessed by sending an XML string with the User Agent (UA) for a particular device. This information was used to map the characteristics of the device that was returned as another XML string.

![SOA Architecture Diagram](image-url)

**Figure 6-7: SOA architecture**  
Source: Sommerville (2011: 510)
• **System input and output:** Input and output were divided into two classes as follows: input and output that interfaces with the end user and input and output between different services within the model. Mobile devices generally have small keyboards and data entry is a challenge, furthermore the screen is small with a variety of display capabilities. Minimalistic design was utilised for interfaces between the user and the system in such a way that minimal input is required from the user only if necessary, otherwise the model should be able to determine context in the background. Mathematical optimisation was utilised in order to determine the optimal way to present output on the device screen. Input and output within the model were influenced by the SOC paradigm in which standard XML based messages were exchanged between services. Different techniques such as REST, SOAP and custom-made XML standards were utilised depending on the requirements and specification of each service (Figure 6-7).

• **Process/components specifications:** MBSE was utilised for specification and implementation of the model. UML class diagram and use case diagrams were utilised to show the core functions of the model’s components as well as user interaction with the context-aware application use case. All classes for the services were presented using UML class diagrams. The process specification distinguishes the conceptual model (Figure 6-9) from its implementation (UML and implementation tools). Figure 6-9 shows the conceptual model that was proposed in this research.

The next section introduces the context-aware model by discussing its components.

### 6.4 CONTEXT-AWARE MODEL COMPONENTS

This section discusses the main components and functions of the context-aware model that is proposed in this research. Conceptualisation of the model utilised background information discussed in Sections 6.2 and 6.3 as well as outcomes from the literature chapters (Chapters 3 to 5). A description of each component of the model incorporates the functional requirements and technical operation. The underlying SOC design paradigm that was utilised during design of the model enables each component of the model to act as a standalone service that can be invoked by any service requestor. Components of the model discussed in this section include:
This section presents work that forms part of the prototyping development methodology that was selected for use in this research (Section 2.3.2). The components provide a basis for the design and implementation of the POC prototype that will be utilised during evaluation of the research.

### 6.4.1 Context Sensor

A context sensor is one core component for all context-aware applications. This section discusses the context sensor component of the proposed model. The section introduces the component and provides details of its function.

#### 6.4.1.1 Introduction

The context sensor is the component of the model whose purpose is to determine context information from the user’s current environment to act as input for the model to determine what information should be retrieved and presented to the user. A logical context sensor was developed to perform this task. The logical context sensor utilises software-based techniques to determine context information as opposed to physical context sensors requiring a physical device that determines context information (Santos et al., 2010; Poulcheria and Costas, 2011; Poulcheria and Costas, 2012; Ntawanga et al., 2013).

The motive for implementing a logical context sensor to determine and provide contextual input for the model was that current physical context sensors are bulky and unfit for use, especially in mobile computing. There are efforts from mobile device hardware manufactures incorporating some physical sensors such as GPS sensors and gyroscopes into sophisticated mobile devices that are usually very expensive. Example of such a mobile device is Samsung Galaxy S4 smartphone that can cost anywhere between US$400-600.

The logical context sensor was developed by using a combination of various open source web application development tools and techniques (Ntawanga et al., 2013). The motive for using
open source was to ensure the sensor’s compatibility with a variety of other technologies running on different mobile devices. The selection of context information to be included in the sensor was determined by analysing the most commonly used context information in mobile web adaptation from a comprehensive list such as the one presented in Figure 5-2 (Ismail et al., 2009; Orjuela-Parra et al., 2009; Pettey and Stevens, 2009; Bohmer et al., 2010).

6.4.1.2 Function
The integrated logical context sensor was developed to determine the following context parameters: user profile, location, date and time, device profile (features) and bandwidth (Section 5.3 has discussed these context parameters). These context parameters were deemed a basis for which various adaptations can be implemented. This section discusses how each context parameter was determined including its implementation details. The parameters utilised in this research are: user profiles, location, time of the day, device properties and connection bandwidth.

- **User profiles**: The context sensor component is supposed to determine information about the user. Information about the user is usually modelled and stored in a data repository. The user profile component was able to create an initial profile for the user which was continuously updated with the users’ interaction history, for example, purchasing history (Ntawanga et al., 2008). Creation of the initial profile was a manual process in a method similar to how other online stores create their customers’ profiles (Ntawanga et al., 2008; Amazon, 2013a).

For purposes of this research and evaluation, the model utilised the already existing user profiles that were created by the users in the existing application that the model utilised to test its functionalities. All the participants who were involved in the evaluation of the model had experience in using the existing system in which the model was incorporated (Sections 1.1.4 and 6.7.1). The system had a rich profile of the users which would prove useful for determining recommendations. For example, the model relied on the user’s previous purchasing history in order to determine what items to retrieve and present to the user. Section 6.4.2.2 provides more details on how the model performed data retrieval based on user profiles. In addition the profile was utilised for authentication of users when performing the evaluation.
• **Location:** The location sensor utilised the HTML 5 Geolocation API to determine the location from which an application was accessed (w3schools, 2013). Location information in the sensor was presented as GPS coordinates, that is, latitude and longitude points. The motivation for using coordinates rather than a location name is to accurately determine the distance between points. For example, by using the Vincenty formula that uses trigonometry sine and cosine rules, and two sets of GPS coordinates, distance between the points can be calculated in Miles or Kilometres (Movabeltypescripts, 2013). For privacy and security purposes, during runtime the Geolocation sought the user’s approval to share location information (w3schools, 2013).

• **Time of the day:** The PhP DateTime function was utilised to determine the actual time of the day at which the application was accessed. PhP server localisation was used to inform the user’s browser where the server is located. The determined location from (as discussed in the point above) was utilised together with the PhP DateTime function and world clock to determine the location’s current time (PhP, 2013).

• **Device profile:** WURFL was used to determine the characteristics of the device being used by the user to access the application. WURFL determines device properties by mapping HTTP Request headers by using user agents (UA) to the profile of the HTTP client device, be it a desktop, mobile phone or tablet, that issued the request (Scientiamobile, 2013). The client UA is matched against the contents of the XML file. A match returns properties of the relevant device. Google and Facebook are examples of companies using WURFL in their websites (Scientiamobile, 2013). Other platforms that can be utilised to determine device features are: Open Device Description Repositories (OpenDDR) and 51 Degrees (51Degress, 2013; OpenDDR, 2013).

• **Bandwidth:** An existing software component to determine bandwidth or specific bandwidth sensor could not be found. A mathematical model was therefore developed to determine bandwidth for the purposes of this research. Formula 1 was derived to determine bandwidth:

\[ b = \frac{d}{t} \]  

(1)
Where:

- $b$ is bandwidth to be determined in Bytes/Second;
- $d$ is the predetermined amount of data to be transferred from the server to the client. (This can be any file with a known size in Bytes (or Kilobytes)); and
- $t$ is the amount of time in seconds taken between sending a request to the server and when the response or acknowledgement from the server is received by the client. This time is also called Round Trip Time (RTT) or ping time.

The context sensor component was implemented as a standalone application composed of various services. The service-based context sensor application enabled re-usability and platform independence. To ensure accuracy and real-timeliness of the determined context information, the context sensor was evaluated with a sample of 30 participants from across the world. The evaluation and results are discussed in Sections 7.3.2 and 7.4.1 respectively. The next section discusses the data retrieval component.

6.4.2 Data Retrieval

The data retrieval component of the context-aware model is an improved standard information retrieval (IR) (Figure 3-7) component responsible for extracting optimal context-dependent information from the repositories. One major challenge in the field of IR is information overload in which users are presented with too much information and users are required to perform filtering in order to find the specific piece of information that they are looking for (Ismail et al., 2009). A number of attempts have been implemented to automate the information filtering process in IR systems; however, most of them still fall short of determining a relevant subset of information to be retrieved from a source for a particular user. This section discusses the data retrieval component and how context was utilised to improve information filtering processes in order to determine a smaller and more relevant subset of the data set for a particular information user. Section 3.3.2 discusses the concept of IR. Figure 3-7 shows a basic IR system structure and Figure 6-8 is the improved context based IR system architecture proposed in this research.
6.4.2.1 Introduction

The core functionality of the data retrieval component is to extract a subset of the product catalogue based on determined context information within the user’s current environment. The data retrieval component was designed in a generalised way using SOC principles in order to capacitate it to perform its intended function on any set of information. In this research product catalogue data was utilised as a specific type of information to retrieve from the data repositories (Section 6.4.3). The data retrieval component has three sub-components that enables it to perform its function of retrieving a relevant smaller subset of information for a particular user based on context. The sub-components are as follows:

- **Read context**: This sub-component is responsible for getting context information from the context sensors for use in the actual data retrieval process. Any usable context sensors capable of delivering useful context can be utilised to provide context to this component. This means that the component is not tightly coupled to a specific context provider. A standard interface was designed using SOC principles to enable any context service provider to interact with the component regardless of the underlying implementation platform;

- **Retrieve data**: This sub-component is responsible for utilising context information in order to retrieve personalised or relevant information from the data repository. In this research an example of product catalogue data was utilised as a source of information on which the context-aware model can perform its functionalities. Based on current context information the component is able to retrieve only a relevant and useful subset of information;

- **Results ranking (Prioritisation)**: This sub-component was utilised to rank or prioritise the retrieved results based on context information. Specific weighting for ranking is determined for each retrieved item depending on the current context. Results are ranked based on the weightings. The ranking or prioritisation helped to determine how the retrieved information will be presented to a particular user. For example, during ranking, information with the highest ranking is deemed the most useful information to the user based on a particular determined context and will be presented first when the user is accessing the application.
6.4.2.2 Function

Out of the five determined context parameters, user profile and location were the main context parameters utilised to determine the optimal list of items to be retrieved from a data source. The popularity of location-aware services and the use of customer profiles in determining items to recommend to a customer in most well-known e-commerce websites were motivations for selecting these two parameters for use during retrieval of product catalogue (Ismail et al., 2009; Wan, 2009; Amazon, 2013a). The user’s purchase history component of the user profile was used as a basis for determining what items to retrieve from the data source. However, an additional list of items was determined by using collaborative filtering techniques to analyse the purchase history of other similar users (Butgereit and Botha, 2013). User preferences are also another source of information that online stores such as Amazon and Kalahari utilise to recommend items or present specific items to the user (Amazon, 2013a; Kalahari, 2013).

The model’s data retrieval component performed the following main tasks in order to generate a list of products for a particular customer based on the user’s current context information:

1. **Determining the users’ current context:** This included getting the user’s current context information such as location, preferences and previous interaction history;

2. **Determining a list of other users who purchased similar items that the current user purchased:** This process aimed to gather an additional list of users who purchased a product similar to the items the current user has also purchased;

3. **Utilise various similarity techniques to determine which items from the items determined in the above two steps should be presented to the current user:** This process involved the use of techniques such as Jaccard and Cosine Index to determine similarities between users.

4. **Ranking the results:** This process ranked the determined list depending on priority to the user. This means a prioritised list of items was presented to the current user.

The following sub-sections discusses two matrices that elaborate how steps above were conceptualised. The first 2-dimensional matrix was utilised to determine a list of products that can be presented to the user, based on context. The second matrix was utilised to rank the
results in order to assign priority such that items with higher priority deemed to be more critical to the user are presented first.

a. 2-Dimension User-Product Matrix

A user-product matrix is a two dimensional \((i \times j)\) matrix containing user ids and products ids. The entries in the \(i \times j\) matrix are presented as either 1 or 0, with 1 representing user \(i\) bought or prefer item \(j\) and 0 represents user \(i\) never preferred or bought item \(j\). The two dimensions of the user-product matrix are utilised to determine the similarities between users that are calculated collaboratively. This matrix was utilised to determine what products to retrieve from the data repository. Table 6-1 is an example of a user-item matrix that was created based on user purchasing history.

<table>
<thead>
<tr>
<th>Item_ID</th>
<th>User_ID</th>
<th>User_1</th>
<th>User_2</th>
<th>User_3</th>
<th>User_4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item_1</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Item_2</td>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Item_3</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Item_4</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6-1: \(i \times j\) user-item matrix

In order generate a comprehensive list of products to present to a particular user, additional items were collected from users with similar profiles to the current user. For example, if user \(A\) and \(B\) bought and prefered similar items such as \([1, 2, 3, ..., n]\) and \([1, 2, 3, ..., p]\) respectively, where \(n<p\), then user \(A\) will be presented with additional items including \((p-n)\) items. Large recommender systems such as those utilised by major e-commerce stores, for example Amazon, improve accuracy of the recommended list for a particular user by including more customer features to determine similarities between users. Additional features that are usually utilised include profile information such as age, gender and income levels.

For the purposes of proving the concept in this research, only the user’s purchasing history was utilised. The design of the model enables easy incorporation of the additional features.

User similarity indicators were determined by calculating various similarity indices using the Jaccard and Cosine Index (Butgereit and Botha, 2013). Jaccard and Cosine Indexes were discussed in Section 4.6.2.

The following steps were implemented for personalised catalogue retrieval from a data repository:
1. **Get current users preferences and previous purchases:** Users’ preferences and previous purchases were utilised as the main basis for determining future purchases. A list of all previous purchases the user had made were the departure point to determine the personalised product catalogue to be presented to the user.

2. **Get users with similar preferences and previous purchases:** A list of users with similar purchases to the current logged in user was determined. According to collaborative filtering, similar users have similar likes and therefore an assumption was made that the user who shared similar purchases with the current user has purchased items that the current user will be interested in. (The current model could be extended to include additional similar parameters between the user profiles such as age, gender, income, qualification and other user factors in order to generate a more accurate list of items to retrieve and present to the user.) (Adomavicius and Tuzhilin, 1999; Adomavicius and Tuzhilin, 2005; Amazon, 2013a; Kalahari, 2013).

3. **Generate and retrieve comprehensive personalised list of items that can be recommended to the current user:** This list is generated by collecting items similar users have purchased in the past. Various thresholds were utilised in order to determine a priority list to present to a user. The next sub-section discusses in detail how this was performed.

### b. 3-Dimensional User-Product-Frequency matrix

The user-product and frequency matrix is a 3-dimensional matrix \((i \times j \times k)\) utilised to determine ranking of specific products in the retrieved results. The matrix utilises the frequency with which a product has been purchased by a particular user and the last date the purchase was made in order to determine priority of items in the retrieved data. A joint query of user similarities, retrieved results and user product frequency matrix is utilised to determine which products are ranked higher, based on the frequencies of purchase. No evidence could be found for such a product ranking mechanism on popular e-commerce websites such as Amazon.com and Kalahari.com. However, news websites such as BBC News utilise other mechanisms to rate and recommended news, for example, the number of stars a news item receives from previous readers or the number of comments posted for a particular news item are utilised to determine whether to recommend an item to a reader or not.
A threshold is also utilised to determine how many products can be presented to the user at this level. For example, assume 1000 product items are initially retrieved, but based on the ranking algorithm it is found that half of the products have higher ranking while the other half has lower ranking. The algorithm would then cut down the number of initial products to half based on the ranking. Figure 6-8 shows the innovative component of the data retrieval as compared to traditional information retrieval process shown in Figure 3-6. Standard IR consists of only core components that perform information retrieval including the organised data and the user query. A match of the two is retrieved and no mechanisms of prioritising the results are available in such systems.

Figure 6-8 shows that prior to setting up the query, context is utilised to streamline the query such that only relevant information should be retrieved. Retrieved information is further filtered and prioritised based on available context information. This process results in a more relevant prioritised subset of data presented to the user.

Figure 6-8: Context based IR
6.4.3 Data Repositories

Data repositories are useful components in many applications to store and manage data in both web and native apps. In this model two main data repositories were proposed: product catalogue data repository and personalised catalogue cache (temporary repository). The product catalogue data repository is the main source of information from which the context-aware model should retrieve a relevant subset to present to the user based on specific context information. The SOC paradigm that was followed during the design and development of the model enables the data source to be substituted with any other source of data or information to be retrieved by the model. For example, the data repository can be made up of news articles. This SOC based plug ‘n’ play feature of the model makes it generalisable, extendable and usable across a variety of information retrieval and presentation domains.

The personalised catalogue cache is a temporary repository that stores optimised retrieved information for a particular user in order to eliminate repetitive backend calls to the data repositories in a limited connectivity environment such as the mobile web. The main function of the personalised catalogue cache repositories is to improve efficiency of the information presented on the mobile user interface in that calls for additional information are only made to the cache. Given enough resources, such as large screen space and unlimited bandwidth speed, information in the cache can be presented on the mobile user interface at a single goal. However due to resource limitation in the mobile computing environment, the cache is designed to be utilised for storing information that is sliced into smaller, manageable chunks to be optimally pushed and rendered on the mobile user interface.

In the event that the user requires additional information when the cache is completed, that is, all information stored in the cache has been presented to the user, only then a call to the backend repositories is made. This event can be minimised by utilising context information so that all the relevant information is retrieved into the cache for batch presentation based on user requests.

6.4.4 Optimisation Engine

This section discusses the optimisation engine whose purpose in the model is to utilise Mathematical models and current context to determine what type of content within a product
catalogue item can be rendered on the mobile user interface. The background to Mathematical optimisation has been discussed in Section 6.2.2.

6.4.4.1 Introduction

Section 6.2.2 discussed optimisation as a technique in Computing and Mathematics that is utilised to determine the best options from a given list of options, especially under some restrictions. The mobile environment is characterised by limited and sometimes insufficient resources, for example, small user input and output features (keyboard and screen) and fluctuations in bandwidth strength (Jiazao, Xining and Lian, 2010; Xining et al., 2010; Zhang and Lai, 2011). Such limitation necessitated the use of optimisation techniques in order to determine how best to present retrieved information in order to improve usability while managing the limitations in mobile web computing. In this research, mobile device characteristics and bandwidth were used to determine the optimal amount of data to be transferred and presented on a particular mobile phone. The combinatorial optimisation technique was selected as a suitable technique to solve this problem (Section 6.2.2.4).

The following will be used to optimise transfer and presentation of information on the mobile phone interface:

- **Data**: This is the retrieved subset of information that is based on the user profile;
- **Maximum waiting time**: This is the maximum time that the user of the retrieved information can wait for a page to fully load on the mobile phone without refreshing or abandoning the search;
- **Bandwidth**: The determined bandwidth in a particular environment. This is the download speed of the connection that a user is using;
- **Screen space**: This is the actual screen size of a mobile device that can be used to display the retrieved information.

6.4.4.2 Function

In order to utilise optimisation in this component of the model a proper optimisation problem was formulated (Section 6.2.2.3). The problem assisted in determining the variables to be optimised and also ways to manage other limitations. Formulation of the problem proceeded as follows:
• **Decision variables:** The decision variable for this problem was the subset of the retrieved data to be transferred and displayed on a mobile phone, and the time it will take to transfer that data to the user. Suppose $D$ is the maximum available data for presentation and $d$ is the optimised amount of data that can be selected for presentation depending on the phone features and bandwidth.

Therefore for the amount of data, $d$, should satisfy $d \leq D$, \(\text{(i)}\)

Likewise suppose $T$ is the maximum waiting time for a page to load on a mobile phone and $t$ is the optimised time for the data to reach the user’s mobile device interface.

Therefore for the user waiting time, $t$, should satisfy $t \leq T$, \(\text{(ii)}\)

Graphically these can be represented as follows, where $d, t > 0$: \(\text{(iii)}\)

\[D \xrightarrow{d \rightarrow t} T\]

$D$ and $T$ are decision variables (domains) from which we can select a maximum $d$ (utility) that can be transferred in minimum time $t$ (cost) that is within the maximum given waiting time $T$. Expression $d \rightarrow t$ implies the mapping of the decision variables to generate a solution set.

• **Constraints:** There are a number of constraints in a mobile environment. For example, device limitation such as small screen and keyboard, limited processing power and fluctuations in bandwidth strength (Jiazao et al., 2010; Xining et al., 2010). For the purposes of this research in this problem only two constraints were utilised, namely, bandwidth and screen size. These constraints are dynamic in a sense that they change for different users interacting with the application in different environments. The context sensor that was implemented will assist in determining the values for these constraints in real-time.

These constraints affect the decision variables directly. For example, bandwidth will affect the time $t$ for data $d$ to be transferred to the device, at the same time data $d$ will
also be affected by the screen size, that is \( d \) has to fit within a certain determined screen size.

Suppose the screen area of the determined device is \( y \) and the bandwidth is \( x \), therefore:

For presentation of data on the screen \( y \): \( d \leq y \leq D \) \hspace{1cm} (iv)

\( x > 0 \) \hspace{1cm} (v)

Maximum \( d = x \cdot T \) \hspace{1cm} (*)

As long as all conditions are met, that is conditions i, ii, iii, iv and v are satisfied.

- **Objective function:** The objective function for this problem can be stated as follows:

  The objective is to find the maximum amount of data that can be transferred to the mobile phone interface in a minimum time possible subject to constraints screen size and bandwidth.

- **Problem example:** What is the optimal amount of data \( d \) of \( D \) that can be transferred to device Z given that \( D \) is 20 items of 10MB each and \( T \) is 40 seconds?

- **Solution:** To simplify the solution, the following assumptions have been taken into consideration:
  i. There is no scrolling down on the mobile phone;
  ii. \( t = T \) (i.e. \( t \) is constant and pre-determined).

Using the proposed context sensor the following is determined:

Screen size \( y = 15 \) (the maximum number of items that can be presented on the phone)

Bandwidth \( x = 2 \text{MB}/s \)

Using (*) \( d = 2 \text{MB/s} \cdot 40 \text{s} = 80 \text{MB} \)

Since every item is 10MB, therefore 8 items will be transferred and all conditions hold. The next section discusses the UI Adaptation component which was responsible for actual presentation of product catalogue information on the user interface and as well as user interface controls.
6.4.5 UI Adaptation

UI adaptation is a component that is responsible for presenting personalised and optimised content on the user interface. There are four types of adaptation that can be performed in a system namely: user interface, content, functionality and device (Section 5.2.6). Previous components of the context-aware model performed adaptation on content and device, this component finalises the process by performing presentation of the personalised content shaped according to current context information on a specific mobile device interface.

6.4.5.1 Introduction

UI adaptation is the component that utilised a number of techniques and context information in order to determine how information should be presented on the mobile device interface. The main task of the UI adaptation component was to design the underlying UI layout design including positioning of UI controls and actual presentation of the optimised product catalogue information.

6.4.5.2 Function

The UI adaptation performed its function by determining the way UI control and information are presented on the device interface. Most web interface layouts are designed using Cascading Style Sheet (CSS) which is usually static during runtime. The UI adaptation component implemented a flexible control container that was capable of changing the positions of various UI controls depending on context such as device screen size. For example, for a wider screen device, the underlying CSS should be able to adapt not only in size but in control as well. This was achieved by utilising device feature values that were obtained from the WURFL to determine how components can be swapped around the user interface to improve usability of the application with regard to browsing the product catalogue (Scientiamobile, 2013).

Examples of flexible UI controls that were implemented include interaction controls such as buttons; static information controls for product catalogue information content; such as images, various texts (e.g. price and item description). Depending on determined context and device capabilities from the WURFL, the UI adaptation would determine where to place what on the mobile device interface. The mapping was achieved by prior knowledge of what type of information would be pushed to the interface by the optimisation engine. For example, if
the optimisation engine did not include an image for a product catalogue item, then the UI adaptation would not consider an image control container in its adaptation presentation of the product information.

6.4.6 Context-Aware Model Diagram

Figure 6-9 shows the context-aware model and the components discussed in this section. The diagram is divided into two main sections that correspond to the core functionalities of the model as well as the two subjects outlined in the main research question and objective of this research, namely, retrieval and presentation of product catalogue information on a mobile device. Each section of the figure has components that enable it to achieve the section’s goal or function in the model. Both sections possess the context sensor component. In the presentation section, however, the context sensor component is just a representation replica of the main context sensor as indicated by the component with a dotted border line. This means that only one context sensor was actually implemented and utilised by both sections, the replica representation shows the significance of the component to both sections.

Specific components in both sections clearly indicate the associated sub-components that are implemented in order for a particular component to achieve its goal. For example, the data retrieval component shows the following sub-components: read context, retrieve data and rank results that assist the parent component (data retrieval) to achieve its intended core task of retrieving an optimal subset of product catalogue data. Functionalities of all the sub-components were presented and discussed in Section 6.4. At the end of the entire process, the results, as well as the context parameters that influenced the results are stored in the data repository for learning purposes. The learning component was not explored much in this research because of the limited number of transactions during the evaluation of the model (Section 8.6). Figure 6-9 summarises and simplifies the core deliverable of the research. Practical implementation of the model utilised the discussed MBSE in which a number of UML model components were developed.
Figure 6-9: The context-aware model for product catalogue data retrieval and presentation
6.5 MOBILE SOFTWARE DEVELOPMENT

The objective of the section is to discuss the common mobile software development tools available on the market and also to make a selection of the tools to be utilised to implement the context-aware model prototype in this research. Discussion in this section will mainly focus on expounding Figure 3-6 by providing details of available options for implementing each component in the online shopping systems architecture. The section will briefly discuss the background to mobile software development, mobile software market share and implementation options available for each layer in the client-server architecture for mobile web applications.

6.5.1 Background

Computer hardware evolved through various developmental transitions, from the early room-size computers in the 1950s to recent handheld and pocket-size tablets and mobile phones (ComputerHistory, 2006). Software development has also followed suit, for example, in the early years software was developed using machine language in which software code was written in a language that can directly be translated by a machines’ Central Processing Units (CPU). Later on compilers were developed with an aim of simplifying software development, specifically with regard to enabling software code to be written using English-like commands.

The introduction of portable handheld mobile devices such as mobile phones and PDAs in the early to mid-80s compelled the need to develop software that can run on such small devices. Over the past 30 years since the first PDA was introduced on the market, portable mobile device market share has grown and it is estimated that by 2015 the mobile market share will surpass desktop population. This will mean continued growth in mobile software development and applications (Section 1.1).
Figure 6-10: Mobile device development

Figure 6-10 shows an example of the first handheld mobile device manufactured by Motorola in 1984 and also a range of recent mobile devices from various manufactures in 2012 (CBCNews, 2013). Recent mobile devices have computing power that sometimes compares with other computers, but with limitation associated with mobility objectives, for example, small sizes that impact input and output modes (keyboard and screen size) and limited battery power.

### 6.5.2 Mobile Operating Systems Market Share

A number of mobile device operating systems are available for use by various hardware manufactures to run on their products (Table 6-2). For example, Samsung devices often run Android on its devices while Nokia partnered with Microsoft to run Windows Mobile on its devices. The mobile device market share is usually determined by the operating system units shipped or sold to consumers as opposed to actual device types sold to consumers. For example, Android is the most common mobile operating system at present, but there are many devices that run Android such as Samsung, HTC and other smaller brands such as Huawei (Butler, 2011; IDC, 2013).
Table 6-2 shows the latest world wide mobile device market share as reported by IDC in August 2013 (IDC, 2013). The table shows that most devices sold on the market in Q2 2013 were Android devices followed by Apple iOS. Table 6-2 was determined based on the units of various mobile devices from different manufacturers shipped into the market. Currently 1 billion units of devices are shipped every year and the number is expected to grow by over 50% in the next 5 years. This means the mobile device market and its associated software applications are here to stay.

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Developer</th>
<th>Q2 2013 Units</th>
<th>Q2 2013 Share %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Android</td>
<td>Google (open source)</td>
<td>177,898.2</td>
<td>79</td>
</tr>
<tr>
<td>iOS</td>
<td>Apple</td>
<td>31,899.7</td>
<td>14.2</td>
</tr>
<tr>
<td>Windows Mobile</td>
<td>Microsoft</td>
<td>7,407.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Blackberry</td>
<td>Blackberry</td>
<td>6,180.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Bada</td>
<td>Samsung</td>
<td>838.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Symbian</td>
<td>Accenture</td>
<td>630.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Others</td>
<td>Others</td>
<td>471.7</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>225,326.2</strong></td>
<td></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 6-2: Mobile devices operating system market share Q2 2013

Source: http://www.idc.com (November, 2013)

6.5.3 Mobile Web Application Implementation

Mobile web applications are usually implemented on the same or similar client-server infrastructure as desktop web applications; the main differentiating feature is the frontend or user interface implementation (Hernandez, Viveros and Rubio, 2013). The client-server architecture usually contains the business logic that runs core application functionalities in the backend and a frontend that interfaces with the users. This section discusses possible implementation options that developers utilise to implement web applications (both mobile and desktop web), with a specific focus on online shopping applications. Implementation tools discussed in this section can also be utilised to implement the context-aware model proposed in this research and summarises of the tools that were actually utilised in this research to implement the POC prototype that was utilised for evaluation purposes of this research (Section 6.7.4).
6.5.3.1 Data Repository Implementation

A suitable database management system (DBMS) or data repository is vital for any online shopping application. Figure 3-6 indicates that the backend repositories for online shopping applications must be present for any online shopping website. There is a number of DBMS technologies that developers can utilise to implement data repositories for online shops. Examples include: Microsoft SQL Server, MySQL, Oracle, SAP Max/HANA DB and IBM. From the researcher’s point of view, most DBMS have similar capabilities that normally would serve the purpose of an average size online application. Therefore, the decision which DBMS to use can only depend on factors such as organisation policies, developers’ expertise, preferences and access to tools rather than functional specifications and capabilities of a specific tool. The researcher decided to utilise the term data repository as opposed to a database because recently data storage is not only being managed using data bases. Other data repository options have been introduced, for example, the NoSQL data stores that do not require the standard SQL statements to manipulate the data.

6.5.3.2 Application Logic Implementation

Application logic, also called business logic, consists of the rules that govern the execution of the system according to its specification in order to serve the requirements. For example, application logic determines how input is captured from the user through an interface, how it is processed, stored or returned to the user in the form of various outputs. Application logic can be implemented as part of the backend or middleware in an online shopping application or web application. Examples of common implementation tools for application logic include:

- **JavaScript (JS):** JS is a device independent scripting language that can be utilised to implement scripts that can run at the client-side or server-side. The main purpose of JS in web development is to create scripts to execute business rules;

- **PhP:** PhP is a multi-purpose language that can be utilised to implement both presentation logic as well as the business logic for an application (PhP, 2013);

- **Message exchange formats:** XML and JSON are two common techniques utilised to exchange messages between components of an application (JSON, 2013; XML, 2013).
6.5.3.3 Presentation Logic Implementation

Presentation logic is also called user interface (UI) or frontend implementation. Presentation logic deals with how objects are presented on the device screen during interaction with the user. For example, using pop-up screen or drop-down list objects on the interface. There is a number of technologies, both commercial and open source, that have been developed with regard to designing and implementation of presentation logic. For example, Microsoft’s ASP.NET is one famous example of presentation logic programming language used in web application. Others languages include JavaServer Pages (JSP), HTML5, PHP and PhoneGap (Pilgrim, 2010; w3schools, 2013). Cascading Style Sheet (CSS) has been recognised as the main method to create underlying layout designs for web applications.

Figure 6-11 shows a general architecture for a mobile web application that performs retrieval and presentation of information on a mobile frontend. The diagram shows the various available options for implementing different levels in the client-server web environment such as backend, middleware and frontend (Section 6.5.3). In relation to the main objective of this research (ROM), the figure shows the steps at which retrieval and presentation of information is performed. The figure was developed as a generalised, low level technical version of the context-aware model diagram proposed in this research shown in Figure 6-9. Components of the proposed model (Figure 6-9) can be integrated and implemented into specific levels outlined in Figure 6-11 in order to perform various functions aiming at addressing usability challenges with regards to retrieval and presentation of information on a mobile device.
6.6 UML CLASSES OF THE MODEL IMPLEMENTATION

Implementation of the model discussed in Section 6.4 followed the MBSE and Figure 6-12 shows the context-aware model class interfaces diagrams for the various classes or function modules of the model. The figure shows how the MBSE was applied to implement the conceptual context-aware model (Figure 6-9). Following MBSE the actual coding of the model is programming language independent. The class model interface diagram shows the general attribute of each class that can be implemented, operations that can be by a class as well as the name of the class. UML class diagrams have also been highlighted as a suitable way to represent context entities (Poulcheria and Costas, 2010).

Operations and attributes can be improved according to requirements. For example, if the model is to be implemented for a different solution domain to the case being investigated in this research, then different context parameters will be utilised with different data sets.
The figure further shows relationships how various classes within the model fit together and collaborate in order to perform various functions to accomplish the objective of the model. In addition, various extendable attributes for each class have been presented as well as operations that can be performed on each class.
Figure 6-12: Context-aware model UML class interfaces
6.7 M-COMMERCE APPLICATION

The context-aware model was incorporated into an existing m-commerce website in order to show the model’s applicability but also to implement a platform that could be utilised for end user evaluation. Sections 1.1.4 and 2.3.2 indicated that a suitable system would be utilised to test the model’s usefulness, applicability and its impact on improving usability. The Rustica system was found to be suitable for incorporating the model and to turn the system into a context-aware application (Section 5.2.5). This section discusses an outline of the Rustica system and motivations for selecting this system. Furthermore, the section discusses the context-aware Rustica system that was implemented including the changes that were made in the background of the Rustica system in order to achieve the objectives of the research.

6.7.1 Introduction to the Rustica System

The Rustica system is an application that was developed for small-scale traders in the Kgautswane community in order to address challenges in the stock procurement process. The system would enable small-scale retailers from a remote area to use the mobile web-based application to place orders with suppliers. A bulk delivery would be made in the area once a week. Motivations for selecting the Rustica system as the platform to incorporate the model and conduct evaluation, included the following:

1. The researcher was granted a rare access to the source code of the live Rustica application by the SAP Research management which enabled successful incorporation of the model into an existing application backend that was being utilised in reality by users to place orders online;

2. A sample population with prior experience with an existing system was a critical requirement in order to assess the usefulness and the impact of the model on usability. Participants in the Project Rustica provided a suitable real end user sample for this purpose;

3. Prior research conducted indicated that the Kgautswane community has reliable wireless data connectivity networks and the majority of the small-scale retailers own smartphones. Some of the retailers were provided with smartphones during the Rustica project (Ngassam, Ntwang and Kandie, 2010; Ngassam, Ntwang and Eloff, 2013). These factors were critical requirements for a participant to complete the evaluation;
4. The researcher worked with the community members in a number of initiatives and therefore there was high level of trust between the community members (including the sample) and the researcher which could ensure honesty and smooth running of the evaluation;

5. The sample in Kgautswane was unique in that no similar research in South Africa was conducted with a sample like the one used in this research. For example, in addition to the areas being remote and facing a number of challenges, the majority of the participants from Kgautswane community who participated in the evaluation had little if any prior computer experience. Most participants had reasonable experience in using low end smartphones for Internet access.

6.7.2 Functional Requirements
The Rustica system was implemented with very minimal requirements in order to achieve the objectives of the system as well as to enable it suit the environment in which the system was to be deployed. This section highlights the main functionalities of the Rustica system as follows:

1. *User authentication:* This module was responsible to authenticate users of the system upon login. Upon successful login the system would display a main menu where users can select an action they need to perform on the system. Figure 6-13 shows the user login and main menu screenshots of the Rustica system;
2. **Display catalogue:** All items in the catalogue were presented at once on the user interface. The catalogue was designed in such a way that different categories of products were represented by an accordion button that would expose various products in different tabs when expanded (by clicking). The catalogue component of the system would push all the contents of the product catalogue to the user interface, but hidden in the accordion view of the catalogue interface;

3. **Place an order:** This module would enable users to select items they need to order and place them into a shopping cart;

4. **Confirm order placement:** When customers were satisfied with their order they would confirm the order so that the order could be sent to the supplier. Figure 6-14 shows an expanded catalogue and an order confirmation page;
5. Edit or cancel order: This module enabled customers to manipulate the contents of the shopping basket by removing or adding items to order;
6. View previous orders: This was utilised to show shopping history for a particular customer.

The next section discusses the context-aware extension Rustica application that was implemented with the components discussed in this chapter including a context-aware model in the backend to assist with adaptation.

6.7.3 Context-Aware Rustica System
The context-aware Rustica system was developed by utilising the online shopping components of the original Rustica system (discussed in Section 6.7.2) and incorporating the context-aware model in the backend in order to improve usability, specifically with regard to the product catalogue presentation. No major changes were implemented on the user interface as the goal was to maintain the user experience between the two systems, with the only improvement happening in the backend processing. This can be attributed to content adaption with minimal user interface adaptation.
The main modification in the system was implemented in the second step in which the product catalogue was displayed. When users requested to view the product catalogue, the context-aware model functionalities were invoked in the following manner (Figure 6-12):

1. **Determining context information (context sensor):** Context information was determined in real-time. Various context sensors were called to determine and present context information in real-time to progressive components in order to enable optimal retrieval and presentation based on context;

2. **Data retrieval:** The context sensor would provide relevant context information in order to optimise data retrieval. Product catalogue data would be retrieved from the data repository based on determined context information. Prior to passing the information for presentation, the data retrieval component would prioritise the retrieved data in order to determine what information the user would be more interested in, based on current context. The prioritised list of product catalogue information would then be stored in a cache in XML format. This was done in order to limit calls to the backend data repositories when the users decide to access more information. The cache assisted in providing a temporary storage of a prioritised small subset of relevant product catalogue that could only be efficiently displayed in chunks (or slices) due to space limitations on the mobile screen device;

3. **Optimisation:** Information in the cache would be sliced and pushed on the screen in portions. The size of the cache slice would depend on the context information such as bandwidth and device features. Specific optimisation techniques carried out at this stage included determining what aspect of product catalogue information should be presented on the interface in order to improve usability. For example, the component could limit product catalogue information to text only depending on context such as device screen capability and bandwidth strength;

4. **UI adaptation:** This component would only do presentation of the information on the UI. Various techniques were utilised to enable flexibility of the underlying layout of the interface design. The UI adaptation component would swap around UI controls depending on context and available information. For example, due to bandwidth fluctuations the optimisation component could optimise and present catalogue information in different format (for example, first cache slice can contain images as well as text while the following slice can contain only text). The UI adaptation was able to deal with such dynamic changes in information to be
presented by determining how best the information could be presented without compromising usability in real-time.

Figure 6-15: Implemented context-aware application use case diagram

Figure 6-15 shows the use case diagram that summarises functionality of the model and interaction between the customer and the online context-aware mobile shopping web application. The figure shows the main interfaces between the user and the application and how the application utilised context and other functionalities in the background. The application’s main purpose was to present a platform on which the proposed and implemented context-aware model can be evaluated by end users.

6.7.4 Summary of POC Prototype Implementation Tools

A number of implementation tools was utilised to implement components of the model as well as the POC prototype. The criteria for selecting the implementation tools were:

1. *Ease of integration with the existing system:* Tools that would ease integration with the existing system;
2. **Tools capability to creation of a generalisable solution:** Tools that were capable of enabling encapsulation of technical implementation and expose functionality;

3. **Availability and cost of acquisition:** Freely available tools were utilised in order to remove barriers that comes with commercial implementation tools;

The following main tools were utilised in this research to implement the model’s components:

1. **Data repositories:** MySQL version 5.2 was the tool that was utilised to implement the main backend repositories. MySQL is free and easy to use with a graphical user interface (code named MySQL WorkBench) made implementation of database functionalities easy. Furthermore, the original system also utilised a previous version of MySQL (MySQL version 4.0) which made integration easier. Temporary data repository for the cache was implemented by a standard XML file. The cache file was easy to read with only relevant content as such XML implementation was a suitable option for this purpose.

2. **Business Logic:** The main operations of the components were implemented using a number of tools, but the main ones were JavaScript and PHP. PHP was mainly utilised in the context sensor component to compute context values as well as generating parameter through the use of built-in APIs. For example, PHP DateTime and PHP WURFL APIs were utilised for date and time, and device features determination respectively. JavaScript was principally utilised in capturing context from the environment because of its lightweight capability. For example, user login credentials were captured from user interface and processed using JavaScript code. HTML5 Geolocation capability was utilised sparingly in the backend for the purpose of determining location.

3. **Presentation Logic:** Flexible CSS were created for the layout of user interface and its associated controls. Open source UI tools including jQuery, HTML5, and PHP were utilised to implement the actual UI controls. jQuery provided suitable presentation for flexible UI controls while HTML5 was mainly utilised to render the data from sliced cache. PHP in presentation logic was mainly utilised for performing ad-hoc computations such as dynamic context listeners (Figure 6-9).
4. *Hosting environment:* The application was hosted on a SUSE Linux Enterprise Server. A number of application web servers such as Apache Tomcat and HTTP servers and database server, MySQL was installed.

5. *Internal communication:* Various web services and processes exchanged information using various standard formats including XML, JSON and SQL Stored Procedures over the HTTP/HTTPS platforms.

6. *Running environment:* The prototype was implemented as a web application that enabled it to run on any Internet-enabled mobile device. A link address would be accessed over the HTTP protocol.

**6.8 CONCLUSION**

The mobile software development industry is expanding as a result of the increasing popularity of high computing powered portable mobile devices such as tablets and smartphones. Organisations are increasingly opting for additional investments in mobile applications to give customers (or users) flexibility when interacting with their products. Various mobile software and hardware manufacturers continue to implement vendor-specific applications and device capabilities that result in interoperability challenges. On the other hand, mobile web application users are hampered with numerous applications presenting online information in a resource limited mobile environment, thereby affecting usability and flexibility. Part of the objective of this research was to address such challenges and to improve usability of information presented on mobile devices by proposing a context-aware model that can be utilised to streamline retrieval and presentation of information on mobile devices.

The specific objective of this chapter was to present and discuss a context-aware model which is a core deliverable of this research. The chapter achieved the objective by presenting the context-aware model proposed in this research (Section 6.4). Various techniques were taken into consideration during conceptualisation of the model. Background overview to the various techniques utilised during design and development of the model was presented, for example, MDE in which MBSE emanated from (Section 6.2.1), Mathematical optimisation (Section 6.2.2) and mobile information visualisation (Section 6.2.3). Core components of the model and their respective functions were covered (Section 6.4). The numerous mobile software implementation options available on the market made it impossible to implement the model with each and every development tool. As such a POC prototype was implemented.
using few selected implementation tools in order to demonstrate the feasibility of the proposed model (Section 6.7.4).

Various diagrams were presented to aid understanding of the model, its functions and implementation (Figure 6-9, Figure 6-11 and Figure 6-12). The conceptual model developed in this research presents the core part of the core deliverable of the research (Figure 6-9). General implementation of the model utilised the MBSE and a generic UML class interface diagram for the proposed model was presented (Figure 6-12). Figure 6-11 presents the various implementation options that can be utilised to implement the model. The chapter summed up everything with a use case discussion in which applicability and usefulness of the model is demonstrated (Figure 6-15).

The next chapter discusses evaluation of the model of the entire research. Various evaluations that were conducted during the course of the research will be discussed. The chapter further discusses the findings of the evaluation and the implications of the findings.
CHAPTER 7: RESEARCH EVALUATION AND ANALYSIS OF RESULTS

7.1 Introduction

7.2 Data Collection and Analysis Instruments

7.3 Evaluation of the Research

7.4 Evaluation Results

7.5 Evaluation Results Summary and Discussion

7.6 Conclusion

7.3.1 Context Sensor Evaluation Validation Survey
7.3.2 Context Sensor Evaluation
7.3.3 Pilot Study
7.3.4 Context-Aware Model Evaluation (Main Evaluation)

7.4.1 Context Sensor Evaluation Results
7.4.2 Pilot Study Results
7.4.3 Context-Aware Model Evaluation Results

Deliverables: Usefulness of the context-aware model in addressing usability challenges with browsing a catalogue on a mobile device.

A Context-Aware Model to Improve Usability of Information Presented on Mobile Devices

Figure 7-1: Chapter 7 context
7.1 INTRODUCTION

Each chapter of the thesis has outlined specifically a deliverable, the objectives achieved and the methodology utilised in line with Table 1-1. For example, Chapter 1 presented the research objectives, Chapter 2 presented the research design, Chapter 3 to 5 discussed the related work and Chapter 6 discussed the background, design and implementation of the context-aware model for product catalogue information retrieval and presentation on a mobile device. The discussion in Chapter 6 presents one part of the ultimate deliverable of this research which is implementation of the context-aware model and Chapter 7 complements the second part.

The objective of Chapter 7 is to discuss the research evaluation and present the analysis of the evaluation results. Evaluation is one important phase in a research process that usually signifies the end of a research process and provides useful feedback from the research (Edmonds and Kennedy, 2012). Research evaluation can be defined as a process in which research objectives are systematically assessed in order to determine merit, worth, significance or useful feedback about a research (Edmonds and Kennedy, 2012; SocialResearchMethods, 2012). The goal of this chapter is to test validity of the model’s features including: applicability, usefulness and effect on usability (Section 7.3.4.1). Chapter 4 indicated that currently there is no agreement on specific methods for evaluating mobile applications. This research therefore utilised layered user-based methods for evaluation (Section 4.3.2.1). A combination of in-house and field study evaluations was utilised in specific studies.

The chapter firstly provides an overview of the data collection and analysis instruments that were utilised across the various progressive evaluation phases that were conducted during the course of the research in line with the evaluation design discussed in Section 2.3.3 (Section 7.2). End user and pilot studies were mentioned as one method that will be utilised in this research during evaluation (Section 2.3.3). The chapter discusses the evaluation environment settings and the procedures that were followed during the three evaluations that were carried out in this research. The following evaluation phases were conducted in this research:

1. Context sensor evaluation validation survey (Section 7.3.1);
2. Context sensors evaluation (Section 7.3.2);
3. Pilot study evaluation (Section 7.3.3);
4. Context-aware model evaluation/main evaluation (Section 7.3.4).

The chapter provides details of above listed evaluations that were conducted during the course of this research in order to test the usefulness, effectiveness and correctness of the context-aware model that was implemented in this research. Furthermore the chapter explores methods employed in data collection and analysis for each evaluation phase in line with the instruments discussed in Section 7.2 and Section 2.3.3. Lastly the chapter presents and discusses the results of the evaluation as well as major implications of the findings (Sections 7.4 and 7.5). The main evaluation of the research was conducted after an ethical clearance for the research was granted by the NMMU Research Ethics Committee: Human (REC-H) (Section 7.3.4.4).

This chapter addresses the following research objective and question (Table 1-1):

\[
RO_5: \text{Evaluate and present results of the context-aware model’s usefulness in improving usability with regard to product catalogue browsing on a mobile device.}
\]

\[
RQ_5: \text{How useful can a context-aware model for optimal retrieval and presentation of product catalogue information be in addressing usability problems in m-commerce with regard to browsing a product catalogue using a mobile device?}
\]

### 7.2 DATA COLLECTION AND ANALYSIS INSTRUMENTS

Data collection and analysis are important steps in research evaluation in which pieces of information are collected and deductions are made based on the research goals and objectives (Section 2.2.4). There are many instruments for data collection and analysis that can be utilised to collect and analyse data during a research evaluation (Section 2.3.3.3). Usually a particular research setting determines what data collection and analysis tools can be utilised (Section 2.2.4). For example, most qualitative research utilises techniques such as workshops and interviews with participants in order to collect data and deductions are normally made with limited statistical analyses. This section will present the selected data collection and analysis tools that were utilised across the various evaluations that were conducted in this research (Section 7.2). The data collection tools utilised in this research are questionnaires and system log files, while data analysis and presentation tools include descriptive statistics, inferential statistics, graphs and tables. Data collection and analysis instruments are as follows:
- **Questionnaires:** Questionnaires were the main data collection instruments utilised in the various evaluations that were conducted in this research. The questionnaires utilised in this research collected both quantitative and qualitative data. Questionnaires are the most common and reliable data collection instrument in research. The setup of the evaluations made questionnaires more appropriate for data collection in this research. Each evaluation phase of this research had a different questionnaire that was designed for that particular evaluation aiming at collecting responses from participants that would help achieve specific evaluation objectives;

- **System log files:** Additional evaluation data was collected through the use of a system log file. The log file was created and populated with interaction log data while the participants were interacting with the prototype. The log file contained information that was utilised to provide quantitative evidence of a particular interaction. For example, during the context sensor evaluation, a log file was utilised to verify that remote participants indeed interacted with the prototype before completing the post-task questionnaire. Furthermore the log file entries were utilised to validate participants’ responses on the post-task questionnaire;

- **Descriptive statistics:** Descriptive statistics provide summaries of the data obtained from a sample without giving statistical meaning (SocialResearchMethods, 2012; Tullis and Albert, 2013). Descriptive statistics give a description of what is going on in the collected data (SocialResearchMethods, 2012). Measures of central tendency such as the mean and measures of dispersion such as standard deviation are two commonly used descriptive statistics in data analysis (Tullis and Albert, 2013). Microsoft Excel is the software package that was utilised to perform the statistical analyses of the data. The motivations for selecting Microsoft Excel as the statistical data analysis package were easy to use and available;

- **Inferential Statistics:** Inferential statistics are used to describe or draw conclusions from the characteristics of the general population based on the results obtained from a sample of that particular population. A number of inferential statistics calculations or tests exist; for example, *t*-test, chi-square and Analysis of Variance (ANOVA). The selection of what calculation to use depends on various factors such as the type of data collected and the size of the sample. For example, the *t*-test is useful but it can be utilised only when the sample is less than or equal to 30, otherwise a *z*-test is used.
There are two types of inferential statistics tests: parametric and non-parametric tests. Parametric tests are tests that can be applied to data that has a certain value attached to each item, for example, Likert scale responses. Examples of parametric tests include the $t$-test and analysis of variance (ANOVA). Non-parametric tests are tests that can be applied to nominal and ordinal data. Nominal data is data that has no degree or order, for example, male and female, while ordinal data have some degree of order, for example, categories of users can be experts, intermediates or novices. An example of such a test is the chi-test (Tullis and Albert, 2013).

The paired $t$-test was utilised in this research because of the setup of the research in which a within-subject test group was utilised (Tullis and Albert, 2013). The paired $t$-test is usually used to compare the sample group’s scores before and after a certain intervention (quantitativeskills, 2013; Tullis and Albert, 2013). The same sample in this research was subjected to two similar systems, however, during the second testing, the system had a context-aware model incorporated;

- **Results Presentation:** Graphs and tables are the main tools that were utilised to present the data analysis results. Graphs were a preferred method to present the results because of ease of readability and interpretation (Tullis and Albert, 2013). Tables were sparingly utilised to present the results wherever a graph would not fit to present the results.

The next section discusses the evaluation of the research. The section provides the details of the various evaluations that were conducted in this research as outlines in Section 7.1.

### 7.3 EVALUATION OF THE RESEARCH

Conceptualisation and development of the context-aware model underwent three evaluations with specific objectives geared towards addressing the various research questions as outlined in Table 1-1 (Section 1.1.4). The three evaluations involved different sets of participants interacting and performing specific tasks with parts and a completed POC prototype in order to assess the viability of the research at different progressive stages (Sections 1.1.4 and 2.3.2). Section 2.3.3 discussed end user evaluation as one of the methodologies to be utilised in this research. This section discusses the three evaluations that were conducted during the course of this research as well as an additional context sensors evaluation validation survey that was conducted to test the context sensors prototype and its evaluation procedure. The sub-sections discuss the objectives of a particular evaluation, sample of participants and the
specific procedures that were followed, including the task list. Results of the various evaluations are summarised in the results section of this chapter (Section 7.4).

7.3.1 Context Sensor Evaluation Validation Survey

A mini context sensor evaluation validation survey was conducted prior to the main context sensor evaluation. The goal for conducting the validation survey was to test the application and also validate the questionnaire. The context sensor evaluation was conducted online where the participant had to access a link and perform predetermined tasks in the absence of the researcher. It was necessary to ensure that the system was bug free, and the evaluation procedure and questionnaire were unambiguous. Objectives of the validation survey were:

- Identify any bugs with the context sensors application;
- Validation of the questionnaire and evaluation procedure.

The survey was conducted with a sample of 6 randomly selected participants from across the world. This sample of participants was eventually excluded from the context sensor evaluation that was conducted world-wide. Table shows the participants profile.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Country</th>
<th>Age Group</th>
<th>Ethnicity</th>
<th>Highest Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>South Africa</td>
<td>25-29</td>
<td>Mixed Race</td>
<td>Master’s Degree</td>
</tr>
<tr>
<td>02</td>
<td>South Africa</td>
<td>25-29</td>
<td>Black</td>
<td>Honours Degree</td>
</tr>
<tr>
<td>03</td>
<td>Egypt</td>
<td>25-29</td>
<td>Arab</td>
<td>Bachelor’s Degree</td>
</tr>
<tr>
<td>04</td>
<td>China</td>
<td>30-34</td>
<td>Chinese</td>
<td>Master’s Degree</td>
</tr>
<tr>
<td>05</td>
<td>Japan</td>
<td>35-39</td>
<td>Black</td>
<td>Master’s Degree</td>
</tr>
<tr>
<td>06</td>
<td>United States of America</td>
<td>30-34</td>
<td>Black</td>
<td>Bachelor’s Degree</td>
</tr>
</tbody>
</table>

Table 7-1: Context sensor validation participants profile (n=6)

The table shows that the participants were educated with a minimum qualification of a Bachelor’s degree. This was a requirement to enable the participant to critique the procedure and also the questionnaire utilised in the evaluation as part of the validation. Four of the participants had computer degrees while two had other degrees. This was deliberate to determine how non-computer science participants would fare in the context sensor evaluation.
Results obtained from this evaluation enabled improvements of the context sensor prototype and the evaluations procedure. The following are the main results that were obtained:

- The participants were able to successfully complete the evaluation which showed that the evaluation procedure and the questionnaire were unambiguous;
- Minor problems were identified in the prototype, for example, a slight difference was identified in the time displayed for some countries and also users expressed some concern with regard to the displayed bandwidth.

The participants’ comments were utilised to improve the prototype in order to streamline the evaluation of the context sensors. The next section discusses context sensor evaluation.

### 7.3.2 Context Sensor Evaluation

Context sensor is the first and one of the core components of the implemented context-aware model. The main function of the context sensor component is to determine current context information about a particular user or a participant’s environment in real-time (Section 6.4.1). The objective of evaluating the context sensors was to verify real-timeliness and accuracy of the determined context parameters within the participants’ environment. Quality, accuracy and real-timeliness of the determined context parameters have been highlighted in literature as major challenges in context-aware computing (Brgulja et al., 2009; Turban et al., 2011; Asif and Krogstie, 2012; Lowe et al., 2012). These factors determine whether context can be relied upon and utilised within an application and are collectively referred to as Quality of Context (QoC) (Brgulja et al., 2009). No evidence could be found of implemented techniques for verifying real-timeliness, accuracy and quality of gathered or determined context parameters or information in existing context-aware solutions specifically in South Africa. Limited international techniques were found that were based on probability measures of QoC (Brgulja et al., 2009; Brgulja, Kusber and David, 2010).

Verifying quality, accuracy and real-timeliness of the determined context information was a significant progressive step in this research in order to ensure that any implemented context-aware application based on the model’s gathered context represents a true picture or actual context value. This section discusses the context sensor evaluation with specific focus on the evaluation objectives, the evaluation procedure that was followed and profile of the participants (Ntawonga et al., 2013). The analysis of the evaluation data, results and limitations of this evaluation are discussed in the results section of the chapter (Section 7.4).


7.3.2.1 Context Sensor Evaluation Objectives
The following were the main goals of the evaluation:

a) To ascertain accuracy of the determined context information;
b) To assess real-timeliness of the context determination process;
c) To assess user satisfaction levels of the two statements above with regard to the determined context information.

7.3.2.2 Context Sensor Evaluation Sampling and Participants’ Profile
Thirty participants from various locations across the world participated in the evaluation. Recruitment of the participants involved contacting different people through email, requesting them to voluntarily participate in the evaluation. Participants who responded to the request email were then provided with the evaluation information package discussed in Section 7.3.2.3 to enable them to complete the evaluation. A list of alumni from the Department of Computing Sciences at NMMU residing and working in various countries across the world was a useful source of reliable participants. About 60% of the participants who took part in the evaluation were alumni from the Department of Computing Sciences working and residing in various countries across the world such as United States of America, Australia and China.

The general participants’ profiles were regular mobile Internet and/or application users with at least a first college degree and 2-5 years of general Internet experience. These characteristics formed vital requirements so that participants could critically analyse context information determined (or gathered) and presented by the context sensor onto a mobile device screen. The participants had to be able to make predictions on information that needed confirmation based on general experience (that is previous experience and current experience gained from interacting with the application.). For example, participants were asked to score the way they perceived their connection speed by using a 5-point Likert scale (Appendix D). This rating was compared with the bandwidth value that was displayed on the screen and also recorded into the system log file (Section 7.4.1). The sample consisted of both male (n=20) and female (n=10) participants.

173
Figure 7-2 shows the gender and age groups of the participants. The figure shows that 67% (n=20) of the sample were male while 33% (n=10) were female. The age range of the majority of the participants (93%, n=28) was between 20-35 years.

Figure 7-3 shows the locations from which the participants come. Locations of the participants are presented based on continents as individual countries were diverse; for example, participants from 13 different countries (Australia, Botswana, China, Egypt, Germany, Japan, Kenya, Malawi, South Africa, Tanzania, Uganda, United Kingdom and Zambia) evaluated the application across 5 continents (Africa, Asia, North America, Europe and Australia). Figure 7-3 shows how scattered across the world the participants came from. Fifty percent (n=15) of the participants came from 8 different countries in Africa, 20% (n=6) came from Europe and North America each, Asia 7% (n=2) and Australia 1% (n=1).
Forty three percent (n=13) of the participants had a bachelor’s degree followed by 36% (n=11) who had a master’s degree. Thirteen percent (n=4) had other tertiary qualification and 7% (n=2) had a PhD. The sample met the requirements of the evaluation in terms of age, Internet experience, education level and diverse location. The next section discusses the procedure that was followed during the evaluation.

7.3.2.3 Context Sensor Evaluation Procedure

For the purpose of this evaluation, the context sensor component was packaged as a standalone web or online application that had to be accessed using any Internet-enabled mobile device. Figure 7-4 shows example screen shots of the user interface for the standalone context sensor component that was utilised for evaluation purposes. Participants’ profiles were created and each participant was allocated different system login credentials. Email communications explaining the evaluation procedures and instructions were sent to participants who indicated that they were willing to participate in the evaluation.

Documentation sent to the participants included:

1. Evaluation Information: This was introductory information about the goals and objectives of the evaluation. The evaluation information further detailed the objectives of the main research;

2. Informed Consent form: The consent form contained information including the participants’ rights during the course of the evaluation as well as the purpose of the evaluation. Participants were supposed to indicate and confirm their willingness to
voluntarily participate in the evaluation by reading, acknowledging and signing the consent form (Appendix B);

3. **Task list:** A task list was also sent to the participants with step-by-step details of how the evaluation was to be conducted (Appendix C). Unique login credentials for each participant were also included in the task list. The login credentials were utilised to map each participant to a specific preset profile during interaction;

4. **Evaluation questionnaire:** An evaluation questionnaire was sent for the participants to complete before and after performing the certain tasks of the evaluation (Appendix D). The questionnaire collected both static and dynamic context information. Static information included: city and country where a particular participant resides, make and model of the device to be utilised for the evaluation as well as demographics such as gender, age and highest qualification. The second part of the questionnaire, to be completed after the performing the tasks of the evaluation, collected the dynamic information such as the GPS coordinates, bandwidth and determined make and model of the device as determined by the context sensors within the application.

During the evaluation, participants had to log into the application by using the login credentials that were sent to them. Upon successful login, the application was mapping a specific participant’s login details to a preset profile in order to create a unique log file with entries that would be utilised as additional source of evaluation data. The application then invoked a number of context sensor modules implemented and the results of the determined current context information were displayed on the participant’s mobile device screen. Figure 7-4 is an example of the interface for login screen and determined context information.
Participants were asked to record the displayed context information onto the questionnaire regardless of whether the information was correct or not. When the displayed information was correct, participants were asked to confirm by clicking a “Confirm” button on the screen. This action uniquely saved the displayed information from a particular participant into the system log file (Figure 7-5). The context sensor user interface allowed participants to edit some incorrect (or inaccurate) information displayed on the user interface and to send the correct information to the server. Information that was collected from the participant’s environment and stored in the system log was utilised in the data analysis for this evaluation.

The evaluation was conducted online and participants were requested to access a link where the logical context sensor was hosted. The participants were given the freedom to use any Internet-enabled mobile device, such as smartphones and tablets. They were, however, notified that any Internet costs that will be incurred during the evaluation were to be covered by themselves.

7.3.2.4 Context Sensor Evaluation Data Collection
A specific questionnaire was designed to collect data during this evaluation phase. The questionnaire collected information about the participant including demographics and also a rating after performing the evaluation tasks. Completed questionnaires were sent back to the researcher via email. Additional evaluation data was collected from the system log file that
was generated for each participant during interaction with the application. Figure 7-5 shows an extract example of the system log file that was created for each participant who interacted with the standalone context sensor application during the evaluation.

![Log file example](image)

**Figure 7-5: Standalone context sensor application log file**

Analysis of the evaluation data was conducted using Microsoft Excel and only descriptive statistics were presented. Section 7.4.1 discusses results of the context sensor evaluation. A comprehensive account of this evaluation phase was presented in a conference paper (Ntawanga et al., 2013) (Appendix M). Results of the context sensor evaluation assisted to improve the accuracy and real-timeliness of context sensor for the final evaluation of the context-aware model (improvements to the context sensor component have been discussed in Section 7.4.1.5). The next section discusses the pilot study that was conducted upon completion of the implementation for the context-aware model that was incorporated into an existing m-commerce website.

### 7.3.3 Pilot Study

A pilot study is defined in Section 2.3.3.2 as a small experiment conducted prior to the main study or evaluation in order to test logistics, validate the data collection instruments and to gather information that can be utilised to improve the latter’s quality and efficiency (Sharp et al., 2011; Edmonds and Kennedy, 2012). The main objective for conducting a pilot study prior to the main study is to assess the readiness of the main study. The pilot evaluation in this research was conducted on the online m-commerce application with the context-aware model backend (context-aware Rustica system) upon completion of integrating all the components of the POC prototype. This section discusses specific objectives of the pilot
study, the sampling procedure and profile of participants. The evaluation procedure that was followed and the data collection techniques will also be discussed. Data analysis and results of the pilot study provided valuable information regarding design and implementation amendments that were implemented before the main evaluation. In addition some changes to the evaluation procedure of the main evaluation were made. Section 7.4.2 discusses the pilot study results and how they influenced the prototype and planning of the main evaluation.

7.3.3.1 Pilot Study Objectives

The pilot study was conducted before the main evaluation and the following were the main objectives:

d) To identify and fix bugs and other problems with the integrated m-commerce application with context-aware model;

e) To identify any usability issues that could affect the results of the main evaluation;

f) To ensure the system’s readiness for the main end user evaluation, for example, testing and ironing out any ambiguities in the evaluation procedure and the task list.

7.3.3.2 Pilot Study Sampling and Participants’ Profile

Purposive sampling was used to recruit participants for this evaluation phase. A purposive sample is a sample in which subjects are selected based on certain criteria that will have an influence on the results of the research (Kothari, 2009; Daniel, 2011; Edmonds and Kennedy, 2012; SocialResearchMethods, 2012). The motive for utilising a purposive sample in this evaluation phase was to find and recruit participants who possessed experience in various computing aspects, for example, Internet browsing using mobile devices, online shopping experience as well as some software application development exposure.

Members of staff from SAP Next Business and Technology, Pretoria met the criteria and with the assistance of the directors of the unit, 19 participants voluntarily agreed to take part in the evaluation. The sample consisted of 37% (n=7) male and 63% (n=12) female participants. Figure 7-6 shows the age range of the participants. Sixteen percent (n=3) of the participants were between 20-24 and 35-39 years ranges, 47% (n=9) were between 25-29 years and 10% were between age ranges 30-34 and 40+ each.
Figure 7-6: Pilot Study evaluation participants’ age range

Figure 7-7 shows the participants’ highest qualification and their ethnicity. Twenty six percent (n=5) of the participants had an honours degree in various fields including Computer Science, 53% (n=10) had a Master’s degree, 11% (n=2) had a PhD and diploma each. Fifty three percent (n=10) of the participants were black, 37% (n=7) were white, Indian and mixed race were 5% (n=1) each.

The sample had extensive experience in browsing online websites using mobile devices. Seventy nine percent (n=15) of the participants indicated that they had browsed an online shopping website using a mobile device more than three times in the past 6 months. Examples of online websites and applications that the participants indicated that they had browsed on a mobile device include: bidorbuy.co.za, Google play, incredible.co.za (Incredible Connection), istore, kulula.com, Loot.co.za, marcjacobs.com, picknpay.co.za, Takealot.co.za, timberland.com and Woolworths.co.za. The implications of the participants’ background and profile on the results are discussed in the results section of the chapter (Section 7.4.2).
Figure 7-7: Pilot study evaluation participants profile: Highest qualification and ethnicity

7.3.3.3 Pilot Study Procedure

This pilot study took place in a controlled environment in which participants had to come into the evaluation room and a one-on-one briefing session with the researcher was conducted prior to the evaluation. The motivation for choosing a controlled environment to conduct the evaluation as opposed to a field evaluation was that it was cheaper and faster to conduct the evaluation in a controlled environment. In addition, the evaluation setup and procedure (Section 7.3.3.3) were formulated in such a way that the controlled environment would not compromise the quality of the results for assessing evaluation objectives.

The researcher set up one-on-one appointments with each participant during specific, agreed time slots and the evaluation was planned to take not more than 25 minutes each. Participants had to conduct evaluation tasks on two different mobile devices. The first device was the participants’ own Internet-enabled mobile devices such as a smartphone or tablet. Participants were found to possess a wide variety of smartphones among them. Figure 7-8 shows the various mobile devices that the participants possess.
The second device from which the participants accessed the application, was a device that was unfamiliar to the participant and had device features different to the participants own device. The second device was provided by the researcher from a set of the following devices: HTC Legend, Nokia E52 and Blackberry 9790. Figure 7-9 show examples of devices utilised by the researcher.

The purpose of using two different devices was to determine whether the two different devices would give the participants a similar user experience since the retrieval and presentation was based on context, including device specification. The researcher decided which device to hand to a particular participant as a second device based on the type of device the participant owned. For example, if the participant possessed and utilised a touch wide screen device then a decision was made to hand the participant a smaller screen,
keyboard-based phone such as a Nokia E52 or Blackberry 9790. This was done in order to give the participant a completely different device that would ordinarily give the participant a different user experience. Participants conducted similar tasks on the different devices.

The researcher was present during each evaluation session with a participant in order to observe any problems particularly with the evaluation procedure. Participants were also requested to indicate any problems with the evaluation procedure in the post-task questionnaire. Ensuring efficiency in the evaluation procedure was a critical requirement for the main evaluation as it was to be conducted in the field by participants in their own free time without the presence of the researcher.

7.3.3.4 Pilot Study Task List
A comprehensive task list was carefully devised and utilised in this evaluation phase. The tasks aimed at evaluating a number of metrics and achieving several goals such as:

- General system performance, for example, page loading times;
- Specific task completion times, for example, long, short and average;
- Sources of confusion, for example, the way the product catalogue was presented on the user interface;
- Other areas that may need amendments.

During this evaluation phase participants were asked to perform a number of tasks which included confirming the determined context information displayed and purchasing at least three products from at least three different product categories that were displayed on the screen. Appendix F is the task list that was utilised in this evaluation phase.

7.3.3.5 Pilot Study Data Collection
An online survey was created in order to allow participants to complete a post-task evaluation questionnaire online. A free academic version of eSurvey Creator was utilised to develop the online survey (eSurveyCreator, 2013). Appendix G is the example of the questionnaire that was utilised and Appendix H is a screen shot example of the online survey that was created using eSurvey Creator for participants to complete online. The online version of the survey assisted in improving the efficiency with regard to questionnaire completion by the participants and data collection as the data was automatically collected and basic descriptive statistics were being updated as the survey progressed. After completion of the tasks participants were asked to complete the online survey on a desktop computer. Completion of
the questionnaire involved simply selecting options such as radio and option buttons presented on the questionnaire screen and entering additional information where necessary.

A system log file was also utilised as an additional source of evaluation data. An example of the log file that was generated is shown in Figure 7-14. Software Engineering metrics that were recorded in this log file included:

- Date and time;
- Total interaction time;
- Device make and model;
- GPS coordinates from which the application was accessed.

Data recorded in the log file of this evaluation phase was not meant to be utilised for analysis but rather to assess the accuracy of the logged data and the log file itself. The data was also utilised to confirm the participants’ responses collected from the questionnaires. Results of the pilot study evaluation are discussed in Section 7.4.2. The next section discusses the main evaluation of the context-aware model.

7.3.4 Context-Aware Model Evaluation (Main Evaluation)

The context-aware model evaluation which is regarded as the main evaluation of the research was conducted after a process that saw conceptualisation and development of the POC prototype of the model as well as a context-aware application using the implemented model in the background. Specific steps that were carried out during this research process before the main evaluation in line with addressing specific research questions which include:

- Thorough literature review on theoretical and practical related work including context-awareness, usability and online business (RQ1, RQ2a, RQ2b and RQ3);
- Conceptualisation and implementation of the model that demonstrated feasibility of the proposed model (RQ4);
- Incorporating the model into an existing m-commerce application (Rustica) a process that validated applicability of the model (RQ5);
- Incorporating amendments, constructive suggestions and fixing bugs discovered in the two prior evaluations namely context sensor and pilot study evaluations.

This section discusses how the main evaluation was conducted.
7.3.4.1 Context-Aware Model Evaluation Objectives
Specific objectives of the context-aware model evaluation were:

a) To validate usefulness of the context-aware model;
b) To assess the model’s effect on usability of product catalogue information presented on mobile devices;
c) To collect end user based evidence to support and validate recommendations to be made in the research.

7.3.4.2 Context-Aware Model Evaluation Sampling and Participants’ Profile
Purposive sampling was utilised in this evaluation phase in order to identify participants who had prior experience with an existing Rustica system in which the context-aware model was incorporated (Section 1.1.4). A suitable sample was found in Kgautswane community in Limpopo Province. Kgautswane community is located in the Sekhukhune district municipality in Limpopo Province, South Africa. The community is located about 400 kilometres north east of Pretoria (Figure 7-10). The community is made up of a series of 20 villages with a population of over 120,000 people (Gumede, Plauche and Sharma, 2008).

Unemployment is widespread, commercial farming is non-existent and crops like maize are scantily grown by villagers for subsistence purposes. Water is scarce, although boreholes and rivers are within walking distance of all villages (Friedland, Merz and van Rensberg, 2008; Gumede et al., 2008). The main economic activities in the area are small-scale retailing and slate mining (Gumede et al., 2008). There are about 100 small-scale traders in the community, which are the only conveniently situated suppliers of essential foodstuff within the community. Figure 7-10 shows map of the Republic of South Africa indicating the location of Kgautswane community.
Figure 7-10: Map of South Africa indicating the location of Kgautswane community

Despite challenges that exist in the community such as non-existence of fixed communication lines, dirt roads and lack of municipal services, the community is equipped with a reliable mobile data communication system. Most people in the community own lower-end smartphones and use Vodacom\(^1\) as a mobile service provider (Ngassam et al., 2010; Ngassam et al., 2013). Various mobile ICT initiatives have been implemented in the area by several research institutions including Centre for Science and Industrial Research (CSIR) and SAP Next Business and Technology, Africa (formerly SAP Research). Small-scale retailers from the community were among the main beneficiaries in these initiatives, with the community benefiting indirectly from efficient and cost-effective services. During these research studies small-scale retailers who provide the community with basic needs were actively involved as end users (Friedland et al., 2008; Ngassam et al., 2010; Ngassam et al., 2013). Different mobile based solutions were implemented for use by the retailers in order to purchase stock online. Figure 7-11 shows an example of a typical shop and operators.

\(^1\) Vodacom is one of South Africa’s mobile telephone services providers.
This current research utilised a prototype and the sample that was involved in the Rustica Project (Sections 2.3.3 and 6.7.1). Motivations for selecting the Rustica project, its participants and the community for use in the evaluation of this research are discussed in Section 6.7.3. Rustica is a project implemented by SAP Research, Pretoria with an aim of linking small-scale retailers in rural areas such as Kgautswane to stock suppliers (Ngassam et al., 2010; Ngassam et al., 2013). The system enabled retailers to order stock online by using a mobile application. Orders from individual retailers were aggregated into one bulk order by the intermediary partners (Sociopreneurs) and sent to the supplier (Ngassam et al., 2010; Ngassam et al., 2013). The supplier would then package each individual order and organise a bulk delivery for all the received orders.

The next section discusses the descriptive statistics of the sample in Kgautswane.

7.3.4.3 Descriptive Statistics of the Sample

The sample consisted of 50% (n=15) male and 50% (n=15) female participants. Ninety-seven percent (n=29) of the sample was black and 3% (n=1) was mixed race. Ninety-three percent (n=28) mentioned Sipedi as their home language and 3% (n=1) were Afrikaans and Zulu. Figure 7-12 shows the age range of the participants as well as their highest qualifications. The figure shows that the majority of the participants, 46% (n=14) had attended high school but did not matriculate. Forty percent (n=12) had reached matric, 3% (n=1) had a tertiary qualification and 10% (n=3) had gone up to primary school level.
Figure 7-12: Context-Aware Model evaluation participant’s highest qualification and age group range

7.3.4.4 Context-Aware Model Evaluation Procedure

Prior to conducting the context-aware model evaluation, the researcher applied for Research Ethics clearance before pursuing the research as per University’s research policy. Research Ethics Committee: Human (REC-H) clearance reference number: Hll-Sci-CS-010 was granted on the 25 November 2011 and the clearance was valid for a period of three years (Appendix A). REC-H clearance is a process in which a research process is scrutinised by a research ethics committee of the NMMU in order to ensure that research conducted at the University is ethically correct and no infringements on subjects is tolerated (NMMU, 2013). Documents that were submitted as part of the research ethics application included an REC-H application form, Consent Form (Appendix I), information for the participants and task list.

The evaluation was a field study and it was planned to take 10 days in which the researcher had to go and stay in the community. During evaluation, the researcher and one research assistant visited the shop owners (participants) in their respective shops. The research assistant was one well-known member of the community who has been working with the shop owners as an intermediary partner in the Rustica project. The assistant helped the researcher to explain the purpose of the research and the evaluation procedure to the shop owners in addition to the information brochures (evaluation package) that were also handed to the participants. An evaluation package consisted of the following documentations that
were translated into Sipedi language which is a common language spoken by people in Kgautswane community:

1. **Information about the research and consent form:** This document introduced the research and explained its goals and objectives. The researcher, with the help of the assistant, provided additional clarification when requested by a participant. The document also outlined the rights of the participants during the evaluation. Participants who agreed to take part in the research were asked to complete an informed consent section of the document indicating that they were not forced or influenced with an incentive to be part of the sample;

2. **Task list:** The task list described the step-by-step tasks that the participants were supposed to undertake during the evaluation with specific focus on actual user interaction with the application and completing the questionnaires. A carefully devised task list was developed and improved with feedback that was acquired from the pilot study (Section 7.3.3.4). The task list for the main evaluation aimed at enabling participants to interact with the components of the system that interfaced with the backend context-aware model. For example, the task list included tasks for the participants to browse through the catalogue and purchase items they were looking for. The list of products displayed to the participants was deemed a priority list based on the participants’ current profile, and in addition the information was displayed to match current context information such as bandwidth connectivity and device features. Appendix J shows the task list that was utilised during the research.

3. **Two sets of questionnaires:** The questionnaires were designed to gather responses from the participants on their experience with the original Rustica application and how they felt after interacting with the improved version of the Rustica ordering system (context-aware Rustica system). The questionnaire further aimed at assessing a comparison between the two systems from the participants’ perspective. The first questionnaire was designed to assess the participants’ prior experience with the Rustica system. The questionnaire was more comprehensive and collected information such as: participants’ demographic information, business information, and computer and Internet experience as well as usability section with regard to browsing a catalogue. The second questionnaire was a post-task questionnaire that was designed to assess the usability of the context-aware Rustica system specifically.
with regard to the product catalogue information presentation on the device screen. The second questionnaire was designed to collect only the participants’ opinion with regard to interacting with the improved application. The participants were also asked to score improvements with regard to the information presentation on the second system as compared to the original system.

The participants were given data bundles that they could utilise for Internet charges during interaction with the application for completing of the evaluation tasks. The evaluation was estimated to take no more than 15 minutes each with an additional 15 minutes for completing the two questionnaires. Figure 7-13 shows the research assistant clarifying issues about the evaluation to a participant.

Figure 7-13: Research assistant and a participant during the evaluation

### 7.3.4.5 Data Collection

Survey questionnaires were the primary data collection tools utilised during evaluation of the research to collect responses from the participants. As discussed in Section 7.3.4.4 the questionnaires were translated into Sipedi in order to remove the language barrier for the participants who could not fully comprehend English. An independent Sipedi quality
assurance consultant was utilised to validate the translation of the questionnaires as well as the additional documents that were translated into Sipedi for the purpose of the evaluation. Appendix K and L shows the Sipedi version of the questionnaires.

Secondary data was collected via the system log file. The system log file collected details of the interaction between the participant and the context-aware Rustica system. Amendments were made to the log file on the backend server with details of each participant’s interaction session. Information collected in log file included:

- User login code (or username);
- Date and time when participant logged into the application;
- Total interaction time in minutes;
- The GPS coordinates of the position where the participant accessed the application;
- The make and model of device that was used to access the application;
- Categories and specific items the participants browsed;
- Items that the participant selected for purchase during the evaluation.

The log file also helped to verify participants’ interaction with the system before completion of the questionnaires since the participants had to complete the interaction on their own free time. Figure 7-14 shows an extraction of part of the system log file for interactions that was stored on the backend server of the system. Some participants interacted with the system more than once in which case the succeeding interactions were appended to the log file and were distinguished by the recorded date and time of the interaction.

![System log file](image)

Figure 7-14: System log file

The next section covers evaluation results in which data analysis and results of each evaluation phase that was conducted in the research is presented and discussed.
7.4 EVALUATION RESULTS

This section presents and discusses results of the various evaluations that were conducted during the course of the research, namely, context sensor, pilot study and the main evaluation as discussed in Section 7.3. Implications of the context sensor and pilot study evaluation findings on the progressive development of the research will also be discussed. Discussions of the evaluation results will cover the data analysis and presentation of evaluation findings for a particular evaluation. Statistical findings for the evaluation results discussed in this section have been presented with a confidence interval of 95%. The main evaluation results constitute the core findings of the research and portray the viability of the research’s contribution.

7.4.1 Context Sensor Evaluation Results

Completed questionnaires that were utilised to gather responses from the participants during the context sensors evaluation were collected from all the participants. The questionnaires captured both quantitative and qualitative data (Appendix D). Additional quantitative data was collected through a system log that recorded the system-user interaction summary. Apart from collecting valuable quantitative data the log file also provided proof of participants’ interaction with the application as the evaluation was conducted remotely across the world in the absence of the researcher (Section 7.3.2.3). This section discusses the results obtained from the context sensors evaluation by looking at the quantitative and qualitative results, major findings and limitations of the evaluation.

7.4.1.1 Quantitative Results

Data captured by the participants on the questionnaires was compared to the information that was logged by the system and saved in the system log. The system log contents comprised the actual context information according to the participant while the questionnaires consisted of context information determined and displayed by the system (that is participants were asked to record the displayed context information prior to effecting any changes to the original displayed information (Section 7.3.2.3)). The two sets of information were utilised during the analysis in order to ascertain the accuracy of the information determined and displayed by the integrated implemented context sensor.
Descriptive statistical analyses were conducted on the collected data and the analysis results of the four main context parameters that were determined by the context sensors are summarised as follows:

1. **Device context information**: Participants were asked to indicate “yes” on the questionnaire if the make and model of device displayed on the interface matched the one a particular participant was using to access the application (or “no” if otherwise). Results show that the context sensor was able to determine the correct make of the device being used by the participant 80% of the time (n=24), and it was also able to determine the correct model of the device 63% of the time (n=19).

2. **Time**: Participants were asked to indicate “yes” if the correct current time was displayed on the screen (or “no” if otherwise). Time accuracy evaluation went through a number of phases. The actual time that participants indicated on the questionnaires (in hours and minutes) was verified by the time of the day participants indicated on the background section of the questionnaire. For example, if a participant indicated that in his or her location, the time of the day was morning, it was expected that the actual time recorded by the system in hours should be between 00:00-12:00 (using a 24-hour clock). Results show that the logical context sensor correctly determined current time 73% of the time (n=22).

3. **Location**: A particular location was determined and displayed with GPS coordinates and therefore participants were only asked to record the displayed coordinates. Participants were not asked to update or edit location details because it was found to be a cumbersome process for the participant to determine the actual GPS coordinates. Verification of the location represented by the GPS coordinates on the interface was conducted manually by searching the actual location of recorded GPS coordinates on the Internet. That is, the GPS coordinates that a participant had recorded on the questionnaire, GPS details automatically recorded in the log file and the actual location found by searching the Internet for a particular location was compared. The results were further compared with the static location details which participants recorded in the background section of the questionnaire. This information was utilised to see whether the displayed (recorded) GPS coordinates matched the details on the questionnaire. Results indicated that the system was able to determine correct location 57% of the time (n=17). Figure 7-15 summarises the
accuracy of device, time and location context information gathered by the logical context sensors.

4. Bandwidth: Bandwidth determination utilised a novel approach discussed in Section 6.4.1. Literature could not be found that provided tried and tested techniques to implement and evaluate a bandwidth sensor. Therefore, in this research, a participant’s Internet experience was used in order to ascertain the accuracy of the determined bandwidth. The determined bandwidth was only for download speed. Participants were asked to record the displayed bandwidth and, based on their experience and opinion indicate how they perceived the speed of the application on a 5-point Likert scale with 1 being very fast and 5 being very slow (Tullis and Albert, 2013).

Table 7-2 shows the relationship between the Likert scale and actual bandwidth values that was initially established by running several simulations. Average results of the determined bandwidth indicate that participants’ perceived speed was scored as ‘fast’ (average Likert point 2.1) while the average recorded bandwidth was in the ‘very fast’ range (average bandwidth 3.2Mbps).
<table>
<thead>
<tr>
<th>Likert Point</th>
<th>Meaning</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Very slow</td>
<td>0-1Mbps</td>
</tr>
<tr>
<td>4</td>
<td>Slow</td>
<td>1-1.5Mbps</td>
</tr>
<tr>
<td>3</td>
<td>Average</td>
<td>1.5-2Mbps</td>
</tr>
<tr>
<td>2</td>
<td>Fast</td>
<td>2-2.5Mbps</td>
</tr>
<tr>
<td>1</td>
<td>Very fast</td>
<td>2.5+Mbps</td>
</tr>
</tbody>
</table>

Table 7-2: Bandwidth measure

7.4.1.2 Qualitative Results

Qualitative feedback as defined in Section 2.2.4 is non-numerical feedback received from subjects in a research sample. As indicated in Section 7.3.2.1 the majority of the participants who participated in the context sensor evaluation were Computer Science graduates who have acquired experience from working in the field and therefore their non-numerical feedback was very useful to validate the current phase of the research as well as improving the subsequent phases of the research. This section highlights some of the qualitative feedback that was received from the participants in the context sensor evaluation.

Positive feedback: Participants felt that the context sensor was able to gather relevant, useful and accurate information within a very short period of time. For example, one participant stated that “she was happy to interact with an application that was able to know who she is in a very short time without even disclosing herself to the application”.

Negative feedback: Some participants indicated that the application had missing functionalities and it seemed incomplete. For example, the purpose for which context information was collected or determined for. This feedback was utilised to improve the completeness of the context-aware m-commerce application that was implemented to utilise the context determined by the context-aware model in order to perform various adaptations.

7.4.1.3 Limitations of the Context Sensor Evaluation

The following are the main limitations that were encountered during the context sensor evaluation phase of the research:

- Most participants were not willing to share location information with the application. This observation resulted in some inconsistencies in the determined GPS coordinates that were determined. For example, only 57% (n=17) of the participants’ locations were correctly determined (Section 7.4.1.1);
• The Tera WURFL file (Version 2.1.5, last updated on 6\textsuperscript{th} June 2011) that was utilised in the context sensor was out-dated. At the time of implementation of the context sensors’ development an updated version of the file was not available because the original company responsible for updating the WURFL was going through a transition. The out-dated WURFL file might have caused some inconsistencies in determining the device model;

• The researcher had no control over other context factors during the evaluation. For example, the Internet connectivity options participants decided to utilise during the evaluation (Wi-Fi or 3G and 4G) and actual position within a location where participants chose to interact with the application (for example, inside a building or travelling on the road). These factors might also have affected the results, for example, connection speed might be affected based on actual locations.

7.4.1.4 Context Sensor Evaluation Discussion

The objective for conducting the context sensor evaluation was to ascertain accuracy and real-timeliness of the determined context information. In addition, user satisfaction levels were collected in order to explicitly confirm usefulness, accuracy and real-timeliness of determined context information. Results obtained from the evaluation indicated that the context sensor component achieved its goals and objectives. From the results it can be concluded that the context sensors performed better in determining device make and time than when determining model and location. This can be attributed to the fact that to determine device model and actual location, there is need for additional drill-down operations on parent categories of the device’s make and time (different areas can share the same time zone). However, the inconsistencies observed in the location context information of the determined device model imply that there is a need to improve accuracy of the responsible specific context sensors.

Bandwidth determination and verification were found to be rather cumbersome as it largely depended on the participant’s experience and opinion on the connection speed. The obtained values for bandwidth and the participants’ perception of their connection speed indicated that the bandwidth sensor has the potential to determine accurate bandwidth. However, accuracy of the determined bandwidth cannot be ascertained in this case because there was lack of verification mechanisms at the time of recording the bandwidth values. The evaluation phase achieved its goals and objectives. Results and participants’ comments were utilised to
improve capabilities of the context sensor of the model in order to ensure high level of accuracy and efficiency when context is utilised in an application.

7.4.1.5 POC Improvement Suggestions
A number of participants’ comments and feedback were taken into consideration during implementation of the next phase of the context-aware model prototype and context-aware m-commerce application. The following are considerations that were incorporated in the model and also the context-aware m-commerce application in response to the comments and feedback that was obtained in the context sensor evaluation:

- The WURFL XML database was updated with particulars of additional recent devices in order to ensure that many devices can be ably determined by the context sensor;
- Clear indication of the use of context information was implemented in the context-aware application that was developed.

The next section presents and discusses results obtained in the pilot study.

7.4.2 Pilot Study Results
Nineteen participants from the SAP Next Business and Technology, Pretoria took part in the evaluation as discussed in Section 7.3.3.2. Eighty four percent (n=16) of the participants accessed the application using Wi-Fi connection while 16% (n=3) accessed the application through a mobile service provider. The participants completed a set of tasks and also completed an online post-task evaluation questionnaire as discussed in Section 7.3.3.3. This section discusses the results that were obtained from this evaluation phase. The section discusses both quantitative and qualitative results that were obtained, discussion on the results and improvement suggestions that were made in preparation for the main evaluation.

7.4.2.1 Quantitative Results
Quantitative data that was collected during the pilot study evaluation was utilised to assess the objectives of this evaluation phase. The data was mainly collected from two sources namely the post-task evaluation questionnaire and the system log file that was created for every participant during interaction with the application (Section 7.3.3.5). This section highlights the quantitative findings obtained from the evaluation.

a. Participants Mobile Internet Browsing and Online Purchasing Experience
Mobile Internet browsing experience was regarded as one important quality for the participants in this evaluation that would enable the participant to provide relevant feedback. The Internet experience of the participants, especially with regards to browsing online shopping website, was assessed during the pilot study evaluation. Participants were asked to rate their Internet experience with regard to browsing mobile shopping websites as: novice (less than 1 year Internet experience), intermediate (between 1 to 3 years of Internet experience) and expert (more than 3 years of Internet experience). Fifty two percent (n=10) of the participants indicated that they are experts in Internet browsing and 47% (n=9) indicated that they have intermediate expertise in browsing the Internet. Seventy four percent (n=14) of the participants indicated that they had browsed an online shopping website using a mobile device while 26% (n=4) indicated that they had browsed through an online shopping website, but using a desktop. These findings indicate that all the participants that took part in the pilot study had experience browsing an online shopping website, which was vital for obtaining relevant feedback during the evaluation.

b. Context Information Determination

The pilot study evaluation included a second round of context sensor evaluation. This evaluation aimed at assessing the impact or effect of the changes that were implemented in the context sensor component of the model based on the participants’ feedback and evaluation results obtained from the first context sensor evaluation (Sections 7.3.1 and 7.4.1). The first context sensor evaluation determined the accuracy of the five parameters including: bandwidth, location, time of the day, device model and device make (Section 7.3.1). However, due to the limitations and the setup of the in-house evaluation of the second context sensors evaluation that was conducted as part of the pilot study, it was difficult and irrelevant to re-evaluate all the parameters. The pilot evaluation was conducted within a closed environment and participants were subjected to the same environment (Section 7.3.3.3). This means location, bandwidth, time of the day were irrelevant as the results from the entire sample could have been similar. Therefore, the device characteristics, namely, make and model, were the only context parameters that were re-evaluated.

Improvements were made on the WURFL XML database that was utilised in the context sensors’ component of the context-aware model and the context-aware application for the pilot study. Manual addition of device features for some new devices were added into the database. The goal was to improve the capability of the context sensors with regard to
determining device features. Evaluation results indicated evidence of increased capability for the context sensor’s component with regard to determination of device features. Figure 7-16 shows the comparison of the accuracy in the determined device features through make and model between the pilot study and the context sensor evaluation. Results clearly indicate that during the pilot study, more makes of devices (89%) were correctly determined compared to 80% of the makes that were correctly determined during the context sensor evaluation. The same applies to device model determination in which 79% of the device models were correctly determined in the pilot study as compared to 63% which were correctly determined during the context sensor evaluation. During this evaluation, participants utilised two different devices to perform the evaluation task (Sections 7.3.3.4 and 7.3.3.3). Results presented in this section are based on device determination for the first device only (participants’ own device) as device characteristics for the types of mobile phones utilised as second devices were already known. The results were a clear indication that the context sensors of the context-aware model will be able, in most cases to correctly determine features of a device that can be utilised for implementing various adaptations.

![Figure 7-16: Context determination-pilot study vs. context sensor evaluation](image)

c. **Adaptation effects**

The application’s capability to adapt its interface and amount of information to display during interaction based on the current context information was assessed. The goal for this assessment was twofold: firstly to ascertain whether the context-aware model was able to successfully provide accurate context information in real-time for implementing effective
adaptations, and secondly to determine if the adaptation was effective. As discussed in Section 7.3.3.3 the pilot study participants were asked to compare how the information was presented on the two different devices. The goal for using two different devices was to assess any change in user experience when the participants utilised a completely unfamiliar device (or a device they do not have much experience with) to interact with the application. Table 7-3 shows the Likert scale values that were utilised during the evaluation. Participants had to provide separate scores for the two devices that they used to interact with the application during the course of evaluation. Figure 7-17 shows the results obtained when participants were asked to rate their reaction to the system.

<table>
<thead>
<tr>
<th></th>
<th>Too Little</th>
<th>Enough</th>
<th>Too Many</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of products displayed on the screen of the device</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The time it took to load the products on the screen</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Readability of information</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of products presented in relation to the screen size of the device</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 7-3: Likert scale for information presentation on a mobile device evaluation

The application’s adaptation engine had the capability to display different number of items on the screen for each dissimilar device depending on context that was utilised during presentation (Figure 6-9).
Figure 7-17 shows that there was no indication of any difference that was observed between the participants’ experience on the two devices although the actual presentation been adapted to a specific device and context. These findings imply that the adaptation of the application based on context information was able to provide similar or the same user experience regardless of the device the participant used. There is, however, one exception observed on readability of information on the screens of the first device (participants’ own device) and second device (new device). On average the participants scored higher readability of information on their device (first interaction), that is, participants found that information was more readable on their own devices. Prior experience in using their devices might have affected the participants’ objectivity with regards to scoring how readable information was on the screen. As a result a slight bias might have resulted in participants feeling more comfortable reading the information that was presented on their own devices as compared to reading the same information but using an unfamiliar device. This observation further confirms that adaptation based on context was effective.

The participants were further directly asked to indicate whether they noticed any adaptation (or change) when interacting with the application between the first and the second devices. Sixty three percent (n=12) indicated that they noticed the adaptation effects on the two devices while 37% (n=7) indicated that they did not notice any adaptation effects. These responses reflected the true opinion of the participants. Prior experience with the second device and experience with the application gained from first interaction with the first device
are two factors thought to have influenced the difference in responses. For example, participants who indicated to have noticed the adaptation were those who were using a completely different phone such as, the first device, a touch screen, and the second device being a smaller screen device with a keypad. While all the participants who indicated that they did not observe any difference were the participants who used touch screen devices as both the first and second device. This indicates that adaptation effects were more evident in devices that were very dissimilar as compared to those that had similar features.

d. Efficiency Results

Efficiency is one attribute of usability that had to be tested during the pilot study in order to know in advance whether the system was performing fast enough or whether additional improvements had to be made in order to improve the speed before evaluation. Efficiency evaluation during the pilot study was very important as the main evaluation was to be carried out in an environment where connectivity can be erratic at times. An efficient system would ensure smooth running of the evaluation. Participants were asked to score overall efficiency of the system. The overall efficiency score was 2.82 on a 5-point Likert scale which is above the halfway mark for average efficiency. Specific participants’ comments however indicated that the catalogue loading was taking longer than in similar applications they had had experience with. This was an anticipated observation as the catalogue loading operation had a number of processes that had to run in the background including: context gathering, information retrieval, prioritising, optimisation and presentation. Efforts were made to ensure that the catalogue loading time was minimised for the main evaluation by optimising the code. For example, various code optimisation techniques were utilised in order to ensure that the system itself was efficient.

e. Learnability Results

Learnability of the application was also assessed in order to determine how easily the main evaluation participants would be able to learn the system and perform the evaluation. Participants were asked to indicate how easy it was to learn interacting with the application. Results show that learnability of the system scored 4 out 5 on a Likert scale where 1 is difficult and 5 is easy. This observation was confirmed by analysing an additional learnability metric that was collected in the log file which indicated the total time of interaction on the two devices. Results from the log file indicate that although the participants were using a
different and unfamiliar device in the second interaction, for the same task list there was a decline in the total time they took to complete the tasks.

Figure 7-18 shows descriptive statistics of the total time taken by the participants to complete the same set of tasks on the two different devices. The figure indicates that on average the first interaction took longer than the second. These findings imply that the participants were able to quickly learn how to use the system within a short period of time as indicated by the general decline in total interaction time. The larger values for standard deviation Figure 7-18 indicate that the specific times each participant spent interacting with the application were not as close to the mean.

![Figure 7-18: Total interaction time between first device and second device](image)

### 7.4.2.2 Qualitative Results

During completion of the questionnaire, observation and other interaction between the researcher and each participant, various qualitative feedback was obtained from the participants. As discussed in Section 7.3.3.2 the sample participating in this research consisted of well-educated employees with wide experience in mobile computing and application use from SAP Next Business and Technology, Pretoria. Their experience was thought to generate valuable input during the evaluation that would help improve the evaluation procedure as well as the functionality of the prototype prior to conducting the main evaluation. The analysis of the qualitative feedback that was obtained was divided as follows:

**Positive feedback:** Positive feedback was feedback that highlighted the positive features of the prototype from the participant’s perspective. This feedback helped to ascertain functionalities of the context-aware model and that the m-commerce website had been
effectively and efficiently implemented. The following are the main positive comments that were received:

- **Usefulness:** The system was found to be useful especially the model and its use in adaptation. For example, one participant categorically stated that the adaptation and use of context was very useful and could be an important feature for every online shopping website (not only mobile);

- **Ease of use:** The system was found to be easy to use. For example, adaptation helped to remove excess information that made the screen clutter free;

- **Exciting:** Participants found the adaptation to be exciting. For example, one participant stated that knowing that an application can automatically change its behaviour according to the user and his current context was intriguing;

- **Display of current context information was useful:** For the purpose of this evaluation current determined context was displayed to the user on the screen, for example, the specific type of device the user was using to access the application. This feature does not normally exist in online applications. Participants were impressed with this feature and most of them indicated that it can be very exciting if it is included in many online websites.

**Negative feedback:** Negative feedback was feedback that highlighted shortfalls and aspects of the prototype that would probably require improvement from the participant’s perspective prior to conducting the main evaluation. Some negative comments were received from the participants during the pilot evaluation. The negative comments were regarded as most useful feedback because they indicated problematic areas and also highlighted what could be changed or improved before the main evaluation. The following were the main negative comments that were received from the participants:

- The system was not able to provide feedback on which step within the application the user was currently at and there was no clear go back buttons. For example, from a certain page such as the product catalogue page users would get lost because there were no clear instructions on how to get back and access the previous functions;

- The system was sometimes slow especially when loading the catalogue items. This resulted in some items not loading onto the screen;

- The system’s interface did not have a search functionality for advanced users;
- Rendering of items on the screen looked better on bigger screen devices when compared to smaller screen devices.

7.4.2.3 Limitations of the Pilot Study

Lack of exposure of participants to different environmental settings was the main limitation that was encountered during the course of this evaluation. The evaluation was conducted within a closed environment that exposed the participants to almost similar context settings (motivations for selecting a controlled environment were presented in Section 7.3.3.3). For example, location, bandwidth strength, and only two devices were used by the one participant during the evaluation, one device after another. The lack of exposure to various environmental settings might have had an impact on the results that were obtained in this evaluation.

7.4.2.4 Pilot Study Evaluation Discussion

Objectives of the pilot study (Section 7.3.3.1) included identifying bugs, usability issues and ensuring readiness of the main study. The overall goal of conducting the pilot study was to ensure readiness and smooth operation of the main evaluation. The pilot study evaluation was conducted with a sample of 19 participants, the majority of whom had vast experience in browsing mobile online shops. Participants conducted the evaluation using own devices and repeated a similar set of tasks using another device that was unfamiliar to them. Evaluation data was automatically collected using an online questionnaire that was developed and both qualitative and quantitative data analyses were conducted.

Results show that the pilot study achieved its goals and objectives. Validation of various frontend and backend functionality of the application was conducted. The system was found to have no major bugs in the code and the implemented adaptation effects of the application were verified. However, some concerns were raised with regard to other functionalities such as loading time of product catalogue that was found to be too slow. Pilot study results also indicate that the application’s context sensor was capable of providing more accurate context information in real-time that can be utilised to implement effective adaptation on functionality and user interface.

Importantly, an evaluation procedure for the main evaluation study was tested and verified to be effective for collecting useful data for the research evaluation. For example, a task list that was utilised during the pilot study aimed at letting the participant interact with all aspects of
the application and the background context-aware model components. This enabled assessment of the effectiveness and efficiency of all the implemented components of the POC prototype including the context sensor, information retrieval and presentation of the model. The next section highlights some improvements that were implemented in the POC prototype following comments and feedback from the pilot study evaluation.

7.4.2.5 POC Improvements Suggestions
Results from the pilot study were utilised to determine and assess the readiness of the main evaluation. Furthermore the pilot study was utilised as a platform to expose the prototype to users who could help identify shortfalls and suggest improvements prior to conducting the main evaluation. Selected negative qualitative feedback was chosen to be addressed based on factors such as the relevance of problems to achieving overall research and main evaluation goals and objectives, expected time to address the problem and criticality of the identified problem and its anticipated effects on the main evaluation and research results. The following were the main improvements that were implemented in an attempt to address the negative feedback factors that were identified by the participants during the pilot study:

- Improvement was made on the login and user welcoming message. Users were welcomed with a short message such as “Welcome back Felix”;
- Code optimisation was conducted in order to identify instructions within the prototype’s code that might have been consuming time during run-time. This was done in order to improve the efficiency of the system especially with regard to information loading on the device screen. As a result of the code optimisation several chunks of flowery code were removed in order to remain with only the necessary code;
- A clear navigation back button was implemented. This button was implemented to help users to go easily to the immediate previous step as opposed to the visible menu button that would take users back to the main menu.

The next section presents and discusses context-aware model evaluation results.

7.4.3 Context-Aware Model Evaluation Results
Thirty small-scale traders from Kgautswane community in Limpopo Province agreed to take part in this evaluation. The evaluation involved the participants completing two questionnaires with a participant-system interaction session in between the completion of the
questionnaires. The main evaluation was the final evaluation phase that was conducted in order to assess the overall objectives and contribution of the research. Section 7.3.4 provides a thorough discussion on how this evaluation was conducted. This section discusses the results that were obtained from this evaluation phase. The section discusses quantitative, inferential statistics and qualitative results that were obtained. Implications of overall research findings are documented in Section 7.5.

7.4.3.1 Quantitative Results

Descriptive statistics of the sample composition that participated in this research were discussed in Section 7.3.4.2. This section focuses on the quantitative results that were concerned with achieving goals and objectives of the research. The quantitative results were divided into two sections: the first section presents results of participants’ technical characteristics that validate the suitability of the sample (as opposed to results discussed in Section 7.3.4.2 that focuses on demographics of the sample) and the second section presents results that were obtained from the usability evaluation.

a. Mobile Device Ownership and Experience

Possession of and experience in efficient use of Internet-enabled mobile devices were important factors for a participant to effectively conduct the evaluation. Participants who were recruited and took part in the main evaluation survey indicated that they at least own a smartphone. During the pilot study it was discovered that participants felt more comfortable using their own devices to access the application. This finding was taken into consideration during the main evaluation phase. Participants were encouraged to use their own smartphones to conduct the evaluation as it was empirically found that user experience can be affected when a participant uses an unfamiliar device to access an application. The use of their own devices also ensured that lack of experience with a particular device would not affect the results as the participants would use devices they use and are familiar with.

Figure 7-19 shows results obtained on the range of smartphones that the participants utilised to complete the evaluation. The majority of the participants owned low cost, lower-end smartphones from manufacturers such as Nokia, HTC, Huawei, Samsung, LG and Blackberry with Internet browsing capability. A few indicated that they owned more complex mobile phones such as HTC Wildfire and Blackberry 9800.
Experience with regard to using the smartphones (or devices) was assessed by analysing the reported main uses of the mobile phones. The reported main uses of the smartphones ranged from making and receiving calls to instant messaging using an application such as WhatsApp. Figure 7-20 summarises the findings of major uses of smartphones by the participants. These findings show that the sample owned suitable devices and had enough knowledge in using mobile phones. The results validate the sample’s suitability to effectively complete the evaluation and provide useful feedback during the evaluation.
b. Computer and Internet Experience

Computer and Internet experience were additional useful factors for a participant to successfully complete the evaluation. During the evaluation survey it was found that 47% (n=14) of the participants indicated that they neither have access to a computer nor computer experience. Ninety-three percent (n=28) however indicated that they do have Internet experience. This indicates that the participants were able to access the Internet using the smartphones that they own. Figure 7-21 summarises the participants’ Internet experience. Sixty percent (n=18) of the participants rated themselves as possessing intermediate level Internet experience. This response was deemed a true reflection taking into consideration the number of participants who had access the mobile web and would usually access Internet every day for less than 1 hour. Thirty percent (n=9) indicated that they have novice Internet experience and only 3% (n=1) indicated to be an expert Internet user. The novice levels of Internet experience did not pose a danger to affect the participant’s performance during the evaluation because the participants were trained during the Rustica project. Furthermore the improved Rustica system was found to be easy to learn during the pilot study.

![Figure 7-21: Participants’ Internet experience in years and Internet browsing time per day](image)

The Internet experience results above show that the users had knowledge and experience in browsing the Internet. One interesting factor emerging from the results is that almost half of the participants had no computer experience and yet had access to the Internet and had gained experience in using the mobile web. This observation confirms reports and findings by other researchers of the potential of mobile Internet in solving social-economic problems that exist in many rural areas (Ngassam et al., 2010; Ngassam et al., 2013).
c. Shop Ownership and Number of Years of Business Existence

Ownership of the shop was a factor that was utilised to assess the level or the extent to which a participant drives decision making for the shop. For example, if the shop belonged to the participant only, then he or she is solely responsible for making all the decisions. The number of years of business existence was a factor utilised to assess the levels of knowledge of best practices that ensured survival and successful running of a profitable business. This information was deemed useful in order to determine if there could be any relationship in the data or excluded factors that could influence the participants’ choice of scores during the evaluation. For example, if a participant is an employee, it implies that he or she is very unlikely to be involved in the decision making of the business and therefore a usable application to assist in the decision making process would not be useful.

The participants were asked to indicate who owns the shop and the number of years the business has been in existence. Results indicated 50% (n=15) of the shops belonged to a family, 40% (n=12) were owned by the participant and 10% (n=3) of the participants were employed by someone to run the shop. Most of the shops (57%, n=17) were found to be older than 5 years, 30% (n=9) were between 2-4 years old while 13% (n=4) were less than a year old. Figure 7-22 summarises the results obtained with regard to business ownership and number of operating years.

![Business Ownership and Number of Operating Years](image)

Figure 7-22: Business ownership and number of operating years
Prior experience of participants with using an existing system (in this case the Rustica system) has been highlighted as a critical factor for a participant to effectively note any differences between the Rustica system and the improved version of the system. Participants were asked to indicate whether they had access and experience in using the Rustica system. Results indicated that 97% (n=29) of the participants had access to the Rustica system. Seventy three percent (n=22) indicated that they had purchased stock online using the Rustica system. Access to the Rustica system was not enough to determine the required experience with the system for a participant to provide useful feedback. In order to determine experience level, the frequency of ordering and the Rand value of stock ordered via the Rustica system were assessed. The goal was to determine the experience levels of the participants with regard to using the Rustica system. For example, the higher frequency and more Rand value spent when a retailer ordered stock using the system, the greater the experience. Frequency of orders was measured by the number of replenishments made in a week and in a month. Knowing that not all replenishments are made via the system, the participants were also specifically requested to indicate how many times they ordered stock without using the Rustica system in a week and in a month. These assessments were conducted in order to ascertain the experience levels of the participants with regard to using the Rustica system.

These results show that the users had reasonable experience using the Rustica system. Based on the participants’ experience with the Rustica system the sample was deemed suitable for the evaluation to provide feedback that can be utilised to assess the objectives of research and the evaluation. With a suitable sample at hand, expectations were that useful feedback will be obtained that can effectively assess the research goals and objectives. The next section discusses results of the main evaluation that are specific to meeting the goals and objectives of the research.

e. **General Usability of Rustica System**

General usability aspects of the Rustica system were evaluated by asking users questions to score specific usability features of the Rustica system using a 5-point Likert scale (Appendix K). Usability has been discussed in Section 4.3 as consisting of the following elements: effectiveness, efficiency and satisfaction (Usabilitynet, 2006; Tullis and Albert, 2013). The
usability features that were utilised to assess usability (effectiveness, efficiency and satisfaction) of the Rustica system were made up of a combination of aspects obtained from various well-known usability assessment questionnaires such as the Computer System Usability Questionnaire (CSUQ) and Questionnaire for User Interface Satisfaction (QUIS) (Usabilitynet, 2006; Tullis and Albert, 2013).

Figure 7-23 shows the summary of the scores obtained with regard to the usability of the Rustica system. The figure shows that the mean, mode and standard deviation of the ratings that participants scored in each aspect of usability of the Rustica system. According to Tullis and Albert (2013) a usability score of less than 60% is considered poor, score of between 60% to 80% is considered good while above 80% is considered pretty good. The usability factors of the Rustica system scored “good” because the average ratings are between 2.9 to 3.4 (58%-68%). The figure shows that most of the participants’ rating values were very close to the mean as indicated by the mode and the smaller standard deviation. This means that participants had almost similar feelings about the usability of the Rustica system.

<table>
<thead>
<tr>
<th>General Usability of the Rustica System (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigation of the system</td>
</tr>
<tr>
<td>Learnability of the system</td>
</tr>
<tr>
<td>Efficiency of the system</td>
</tr>
<tr>
<td>Help provided by the system</td>
</tr>
<tr>
<td>Layout of items on the screen</td>
</tr>
<tr>
<td>Screen Design</td>
</tr>
<tr>
<td>Overall reaction to the system</td>
</tr>
</tbody>
</table>

**Figure 7-23: General usability of the Rustica system**

**f. General Usability of the Context-Aware Rustica System**

Implementation of the context-aware model did not affect any user interface based functionality of the system, but rather the content and presentation of product catalogue on
the user interface. For example, the general layout of the screen design, help and navigation were not changed. The goal was to avoid presenting a completely new system to the users but rather present a system that has the same interface and functionalities on the frontend, with only improvements happening in the backend. During the evaluation, participants were notified about the context-aware model, however, to avoid bias, the technicalities of the functions of the model in the new system were not disclosed to the participants. Consequently, it was decided not to assess the usability of the improved system independently because the results would have been almost similar to the usability of the original system.

g. Usability of Product Catalogue in the Rustica System

The focus of this research was to determine how information presentation on mobile devices can be improved when context information is utilised during retrieval and presentation. Product catalogue data was selected as the example of information case to be utilised in this research. This section specifically focuses on the product catalogue usability of the Rustica system. Results of the general usability assessment of the system discussed in Section e shows that the system itself was usable and therefore usability of product catalogue would not be affected by usability shortfalls of the system. The results obtained from this evaluation form a basis on which to compare any improvements in the context-aware system.

Participants were asked to score a number of statements that were set up using a combination of existing usability evaluation methods for general information presentation because no specific evaluation methods for product catalogue could be found. However, the questions were adapted to suit the purpose of the research, for example, words like general information were represented by product catalogue information in the specific questions (Tullis and Albert, 2013). Figure 7-24 shows the results that were obtained from this phase. The results show that the mean score for usability of product catalogue information was in the range 2.90-3.48 out of 5. Therefore the results can be generalised as only “good”.
h. Usability with Regards to the Product Catalogue (Rustica System vs. Context-Aware Rustica System)

A comparison of descriptive statistics results of the two systems was conducted on the way participants viewed the product catalogue presentation. Figure 7-25 shows the side-by-side comparison of the standard deviation, mean and mode of the results obtained. Results displayed in the figure show that the context-aware Rustica system performed better with regard to the usability of the displayed product catalogue information. For example, most aspects of the context-aware Rustica system were scored at around point 4 out of 5 which is “pretty good” (Figure 7-25), while ratings for the Rustica system were in the ranges of around 3 out of 5, only “good” (Figure 7-24).

Figure 7-26 summarises the comparisons in Figure 7-25 by looking at the average scores of mean, mode and standard deviation. Figure 7-26 shows that the average ratings for the context-aware Rustica system were higher than those of the Rustica system. Furthermore the figure shows that the average standard deviation for the rating between the two systems is in
favour of the context-aware Rustica system. From these descriptive statistics it can be concluded that the context-aware model had a positive impact on improving the way product catalogue information was presented on the mobile device interface.

![Product Catalogue Usability Comparison Between the Rustica System and the Context-Aware (CA) Rustica System](image)

**Figure 7-25: Usability of product catalogue: Rustica vs. Context-aware Rustica system**
Descriptive statistics have a limitation that they only show what is going on in the data collected from the sample without mentioning or clarifying the implications of the results on the whole population (SocialResearchMethods, 2012). Inferential statistics are often utilised to provide more clarification on descriptive statistics by showing the statistical significance of the results in order to confirm the impact of the observation on the whole population from which the sample was collected (Tullis and Albert, 2013). The next section discusses inferential statics to demonstrate whether the observed descriptive静态s have any statistical significance.

7.4.3.2 Inferential Statistics

Descriptive statistics show that there is a difference in the scores between the Rustica system and the context-aware Rustica system with the improved system scoring higher. Inferential statistics were used in order to determine the significance of the difference between scores observed between the Rustica System and context-aware Rustica system in the descriptive statistics. Significance of the results reveals whether the observed difference in descriptive statistics happened by chance or if it can be applied to the whole population, that is, the difference is real although it was discovered by using a sample of the population.

Paired t-test was utilised in this exercise because it allows determining $p$-values from the same sample when exposed to different scenarios with the latter being performed after an
intervention has been done on the testing case, normally called pre-test vs. post-test. In order to determine the significance of the results using $t$-test inferential statistics, a null hypothesis is setup. The null hypothesis usually states that there is no difference between the pre-test and post-test results and the following null hypothesis was proposed for the $t$-test in this research:

$$H_0: \text{There is no difference in usability between the Rustica system and the context-aware Rustica system with regard to browsing the catalogue.}$$

The calculated value for $t$ determines whether the hypothesis will be rejected or accepted. If the hypothesis is accepted it is concluded that the observed difference between the two sets of results happened by chance, otherwise statistical significance is shown.

Results that were utilised to determine the statistical significance of the observed difference were obtained from the average scores of participants in all the 7 usability questions that participants scored separately in the two questionnaires. The questions/statements were specifically set regarding product catalogue usability. Table 7-4 shows the $t$-test result.

<table>
<thead>
<tr>
<th>$t$-Test: Paired Two Sample for Means</th>
<th>CA Rustica</th>
<th>Rustica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.05</td>
<td>3.06</td>
</tr>
<tr>
<td>Variance</td>
<td>0.10</td>
<td>0.52</td>
</tr>
<tr>
<td>Observations</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>8.46</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>1.25763E-09</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.70</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>2.51526E-09</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.05</td>
<td></td>
</tr>
</tbody>
</table>

Table 7-4: $t$-test results

The table shows that $p$-values for both one-tail and two-tail $t$-tests were far less than 0.05 which is the confidence level. These $p$-values indicate that the hypothesis was rejected. The conclusion therefore is that:

**There is a significant difference in usability between the Rustica system and the context-aware Rustica system with regard to browsing the catalogue.**
7.4.3.3 Qualitative Results

Qualitative feedback was collected from the users mainly via the open-ended questions sections of the questionnaire. Participants were asked to make comments with regard to any general differences that they observed between the two systems, as well as specific differences with regard to the way product catalogue information was presented on the mobile interface. The responses were grouped and classified into two: positive feedback and negative feedback as follows:

Positive feedback: About 70% of the participants indicated that they noticed a difference between the two systems. For example, some indicated that the context-aware Rustica system was easier to use than the original Rustica system. Of particular importance was the observation that the product catalogue was easier to navigate and also products of interest were easily found. Two participants specifically stated that they easily found the products that they were interested in without much browsing.

Participants also indicated that the fewer products in the catalogue of the context-aware Rustica system made navigation through the product catalogue much easier than in the Rustica system.

Negative feedback: The main negative feedback that was received was that some participants found the system to load very few products that limited their choices. During analysis of comments participants made, it was noted however that the participants were able to find items they were looking for despite the complaint about fewer products being loaded on the interface. This indicates that model was able to determine the most appropriate products to present to the user and a conclusion was made that the fewer products did not affect the participants in finding items of interest.

7.5 EVALUATION RESULTS SUMMARY AND DISCUSSION

Evaluations conducted in this research were based on incremental development of the model, that is, a specific evaluation was conducted at the end of a phase and provided input and basis for next developmental phase of the research. For example, the context sensors evaluation was meant to ensure that the context sensors phase was complete and that accurate context could now be utilised in the entire model. The research proposed a context-aware model that could be utilised to improve usability of information presented on a mobile device. Product catalogue was selected as the case on which the model’s functionalities can be tested (Section
1.2). The model was conceptualised and implemented into a POC prototype to demonstrate its feasibility. Evaluation of the model was conducted to validate the model’s usefulness and confirm its applicability.

Empirical results that were obtained in the various progressive evaluation phases conducted during the development of the context-aware model as well as the context-aware m-commerce application that utilised the model to perform adaptation indicate that the model achieved its proposed goals and objectives. As discussed in Section 2.3.3 end user evaluation surveys were the main sources of evaluation data in this research. Results of the context sensor provide evidence that context information can be obtained online in real-time for use in various adaptation purposes within an application. These results were further confirmed again in the pilot study in which an improved version of the context sensor was re-evaluated.

The second evaluation of the determined context information shows that accuracy of context information had improved.

The pilot study furthermore discovered a number of usability challenges that might have had an impact on the final evaluation. Useful findings of the pilot study that helped improve readiness of the main evaluation can be summarised as follows:

- Usability of the system was verified;
- Confirmation of context-aware model functional specification, for example, context-determination, adaptation capabilities and effects based context;
- Usefulness of the adaptations were verified by a sample of participants who were experienced in using the mobile Internet and online shopping;
- Efficiency challenges were highlighted and improvements were made in readiness for the main evaluation.

Results from the pilot study were utilised to ensure smooth running of the main evaluation that was conducted when all developmental work and amendments on the context-aware model were completed. Useful findings obtained from the main evaluation in relation to meeting objectives of the research include:

- Empirical evidence of the suitability of the sample that was utilised;
- Descriptive statistics that show increased usability in product catalogue information presented on a mobile device in the context-aware Rustica system;
• Statistical significance of the difference in usability of the product catalogue between the Rustica system and the context-aware Rustica system.

7.6 CONCLUSION

Research evaluation is an important phase of any research project. Evaluation usually determines practicality of the results and also outlines whether a particular research project achieved its goals and objectives (Edmonds and Kennedy, 2012; SocialResearchMethods, 2012). The goal of this chapter was to discuss this significant phase for this particular research endeavour. The chapter has presented detailed accounts of the various evaluations that were conducted in this research namely: context sensor evaluation, pilot study and the main evaluation (Section 7.3). Section 7.3 covered each evaluation phase in terms of the specific objectives that were set out, the participants’ sample profile and the procedure that was followed to conduct the evaluation.

During the evaluation both qualitative and quantitative data was collected. Additional evaluation data was collected through the system log files that recorded a summary for each participant’s interaction, for example, total interaction time, GPS coordinates and date and time (Figure 7-14). The log files collected quantitative data that was utilised during data analysis mostly to verify the participants’ interaction with the prototype as well as validate some responses on the post-task questionnaire. Descriptive and inferential statistics were conducted on the data that was obtained and the results have been presented and discussed in various sections of the chapter, specifically under Section 7.4. Of particular importance are the implications of the obtained results in relation to the goals and objectives of the research. Section 7.5 provide an overall picture of the findings in relation to achieving the research goals and objectives. Results of the evaluations have been presented in the respective results sections of the chapter. The overall finding in line with the main research question is that the context-aware model has shown to improve usability of product catalogue information presented on mobile devices from good to pretty good. Inferential statistics that were conducted in order to determine statistical significance of the descriptive statistics show that the observed change or improvement in product catalogue usability did not happen by chance (Section 7.4.3.2).

The various evaluations conducted in this research shows that objectives have been achieved, both planned and unplanned (unplanned outcomes are discussed in Section 8.4.3). One
outstanding unplanned objective that has been achieved in this research is the finding that prior computer experience is not a pre-requisite for becoming an expert in browsing the Internet. The unplanned objectives will be useful during the future research in which some findings may be followed up. The next chapter concludes the thesis in which findings and contributions of the research to the body of knowledge have been presented.
CHAPTER 8: CONCLUSIONS

8.1 Introduction
8.2 Revisiting Research Objectives
8.3 Research Achievements
8.4 Research Contributions
8.5 Recommendations
8.6 Limitations and Challenges
8.7 Concluding Remarks

8.3.1 Theoretical Achievements
8.3.2 Practical Achievements
8.4.1 Theoretical Contributions
8.4.2 Practical Contributions
8.4.3 Unplanned Output
8.5.1 Recommendations for Theory
8.5.2 Recommendations for Practice
8.5.3 Recommendations for Future Research

Figure 8-1: Chapter 8 context
8.1 INTRODUCTION

Mobile computing and associated applications continue to play significant roles in people’s everyday lives. Many activities that were restricted only to desktop computers a few years ago can now be effectively accomplished on a mobile device through mobile computing. Examples of such activities include: route planning using mobile map applications, social media, news, banking and online purchasing. Factors such as the decreasing cost of smartphones, improved wireless networks capability and developments in web development technologies have influenced these rising trends. Businesses have utilised this opportunity to implement m-commerce initiatives that have the potential to connect people, including those in rural areas, to established markets.

Browsing product catalogues on m-commerce interfaces is beset with a number of usability challenges as is the case with any information presented on mobile web interface. The usability challenges are a direct consequence of the limitations in the mobile web environment such as low memory, limited processing power, small screen size and limited user input modes, for example, a small keyboard (Ho and Kwok, 2003; Glissmann et al., 2005; Issel and Mrozik, 2008; Schmeidl et al., 2009; Xining et al., 2010; Zhang and Lai, 2011). The mobile environment however contains context information that literature indicates can improve usability of mobile web applications including m-commerce systems (Asif and Krogstie, 2012; Poulcheria and Costas, 2012).

The use of context to improve usability, popularly referred to as context-aware computing, aims to utilise context within the mobile environment for the purpose of improving usability of mobile applications. Many context-aware computing development efforts, however, fall short of addressing critical usability issues. Reasons for shortfalls include lack of quality and lack of accurate context information for use during various adaptations and lack of techniques to determine context in real-time, security and privacy among others (Lawton, 2010; Turban et al., 2011; Asif and Krogstie, 2012).

This research set out to implement a context-aware model that will be able to determine accurate context information in real-time. The context information was to be aggregated, processed (interpreted/transformed) and utilised to improve the usability of product catalogue information with regard to retrieval and presentation on a mobile device interface. Various progressive activities were carried out during the research in order to address research
objectives and questions outlined in Sections 1.4.1 and 1.4.2. A context-aware model was conceptualised and implemented in this research (Chapter 6). A number of evaluations, such as the context sensors evaluation, pilot study and main evaluation were conducted. The main evaluation was conducted on a final POC prototype of the model in addition, an m-commerce application was utilised as a platform in order to test the model’s feasibility, applicability and usefulness (Section 7.4.3).

Results of the main evaluation indicate that the proposed and implemented model was able to achieve its goals and objectives. The model proved to have improved usability of product catalogue information retrieved and presented on a mobile device interface. Inferential statistics results indicate that the observed improvements results did not happen by chance, and could be generalised for the whole population from which the sample was selected.

The purpose of this chapter is to conclude the thesis by discussing achievements, contributions and recommendations made in this research. The chapter consolidates the findings made from addressing each research objective and question (Sections 1.4.1 and 1.4.2) and to present contribution of the findings to the achievement of research objectives, as defined in Chapter 1. Section 8.3 discusses both theoretical and practical achievements of the research. Specific contributions of the research to the body of knowledge are discussed in Section 8.4. Limitations of the study are identified in Section 8.5. This chapter addresses the following research objective and question:

**RO6:** Make and present theoretical and practical recommendations with regard to impacts of context-aware computing on improving the usability of information retrieval and presentation on mobile applications.

**RQ6:** What recommendations can be made with regard to utilising context during retrieval and presentation of product catalogue information in order to improve usability of product catalogue in m-commerce applications?

The chapter also discusses recommendations for possible future research that can emanate from this research (Section 8.5.3). Research contributions and recommendations for developing usable context-aware applications that can be utilised to efficiently retrieve and present different types of information on mobile devices constitute the main deliverable of this chapter.
8.2 REVISITING RESEARCH OBJECTIVES

The research followed a positivist research philosophy paradigm (Section 2.2.2) in which the following thesis statement was developed (Section 1.3):

A context-aware model for optimal retrieval and adaptive presentation of product catalogue information can help address usability problems in m-commerce with regard to online product catalogue browsing on a mobile device.

The thesis statement assisted in driving underlying methodologies for addressing the various research objectives and questions. A number of research objectives and questions were set in this research (Table 1-1). The research was addressing the following main research objective and question:

RO\textsubscript{M}: Conceptualise (and design), implement and evaluate a context-aware model for the optimal retrieval and presentation of product catalogue data on a mobile phone.

RQ\textsubscript{M}: How can a context-aware model for optimal retrieval and presentation of product catalogue information be implemented to improve usability of online product catalogue browsing on a mobile device?

The POC prototype of the context-aware model was implemented and a detailed description of the model’s components and functionality was presented (Section 6.4). Figure 6-9 summarised the conceptual context-aware model that was implemented into a POC prototype. The main research objective was fully addressed and the main research question was answered. Conceptualisation and implementation of the context-aware model was based on synthesis of a literature analysis covered in Chapters 3 to 5. Chapters 3 to 5 of the thesis analysed and elaborated various topics of interest in addressing research objectives and questions set out in this research (Table 1-1) that were geared towards addressing the main research question. Table 8-1 shows a revised Table 1-1 that shows the research questions, the chapter in which a research question has been addressed, methodology that was utilised to address the questions, the deliverable and whether the question was answered or not. Motivations for utilising particular research instruments and techniques to address specific research questions were discussed in Chapter 2.
<table>
<thead>
<tr>
<th>Research Objectives (RO)</th>
<th>Research Questions (RQ)</th>
<th>Chapter</th>
<th>Methodology</th>
<th>Deliverable</th>
<th>RQ Answered?</th>
<th>RO Achieved?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RO1:</strong> Understand the state of the art in online business with regards to development and online consumer behaviour.</td>
<td><strong>RQ1:</strong> What is the state of the art in online business?</td>
<td>3</td>
<td>Literature study</td>
<td>Background literature on online business</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>RO2a:</strong> Investigate usability problems experienced by customers when browsing product catalogue using a mobile phone.</td>
<td><strong>RQ2a:</strong> What usability problems are experienced when browsing a product catalogue in m-commerce using a mobile device?</td>
<td>4</td>
<td>Literature study</td>
<td>Usability challenges with regards to browsing a product catalogue on a mobile device and limitations in existing techniques to address the challenges</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>RO2b:</strong> Explore and analyse gaps in current techniques designed to address usability problems identified in RO2a;</td>
<td><strong>RQ2b:</strong> How are problems identified in research question 2a addressed?</td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>RO3:</strong> Explore the state of the art in context-aware computing with regards to background and implementation building blocks in m-commerce.</td>
<td><strong>RQ3:</strong> What is the state of the art in context-aware computing?</td>
<td>5</td>
<td>Literature study</td>
<td>Context parameters useful in information retrieval and presentation</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>RO4:</strong> Conceptualise, design and</td>
<td><strong>RQ4:</strong> How can a context-aware model for</td>
<td>6</td>
<td>Literature study</td>
<td>Implemented context-aware</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
implement a POC prototype of a context-aware model to be utilised for optimising retrieval of personalised product catalogue and presentation on a mobile device in m-commerce.

RO5: Evaluate and present results of the context-aware model’s usefulness in improving usability with regard to product catalogue browsing on a mobile device.

RQ5: How useful can a context-aware model for optimal retrieval and presentation of product catalogue information be in addressing usability problems in m-commerce with regard to browsing a product catalogue browsing using a mobile device?

RO6: Make and present theoretical and practical recommendations with regards to impacts of context-aware computing on improving usability of information retrieval and presentation mobile applications.

RQ6: What recommendations can be made with regards to utilising context during retrieval and presentation of product catalogue information in order to improve usability of product catalogue in m-commerce applications?

<table>
<thead>
<tr>
<th>Research Objectives</th>
<th>Research Questions</th>
<th>Study</th>
<th>Model POC Prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO5</td>
<td>RQ5</td>
<td>Field user evaluation</td>
<td>Empirical usability field study results</td>
</tr>
<tr>
<td>RO6</td>
<td>RQ6</td>
<td>Recommendations</td>
<td>Research achievements and contributions</td>
</tr>
</tbody>
</table>

Table 8-1: Summary of research objectives and questions
8.3 RESEARCH ACHIEVEMENTS

This section discusses the achievements of the research. The section covers theoretical and practical achievements.

8.3.1 Theoretical Achievements
Theoretically, the research attained a number of achievements that were mainly attributed to the rigorous analysis of related literature. Rigorous analysis of existing literature including a thorough examination of examples of existing models resulted in the discovery of best practices, shortfalls and possible improvements that can enhance context-aware computing especially with regard to information retrieval and presentation on mobile devices. The analysis did not only compel a new and improved context-aware model, but also provided ideas for core components that have to be included in every context-aware model. Examples of such components include context sensor and transformers (Poulcheria and Costas, 2010; Poulcheria and Costas, 2012). These components did not get the required emphasis in the previous models that were analysed.

Theoretical achievements culminated with a proposal and development of the conceptual context-aware model that guided practical implementation. A high-level conceptual context-aware model was developed by combining various tried and tested standards and techniques, and best practices obtained from the analysis of literature. The model was developed using MBSE as an underlying methodology.

Evaluation of the proposed and implemented context-aware model is an additional, valuable theoretical achievement. Accomplishment of the main research objectives (RO_M) could be ascertained by an evaluation. Successful identification of a suitable application and a sample of users with prior experience in using the identified application that could be utilised for evaluation to address research objectives was the key theoretical achievement in this research. The research evaluation was conducted in a remote area with an exceptional sample of real end users interacting with the application that was implemented in the research. Evaluation was successfully conducted and met all the objectives. Conclusion of the evaluation in a remote area was a secondary theoretical achievement in this research as innovative ways of conducting similar research within the context of this research were discovered.
8.3.2 Practical Achievements

Practical achievements of the research include the practical conceptualisation of the context-aware model that was designed, based on the outcomes of the rigorous analysis of existing theory and accessory innovation. General and specific context-aware models were analysed in order to determine the position of the proposed model within the existing literature and also to outline the specific unique contribution (novelty) of the model.

Meticulous analysis of technical implementation of the existing models provided a basis for determining best practices in context-aware model development that were essential during conceptualisation and practical implementation of the context-aware model proposed in this research. The identified and utilised general practicalities useful for successful implementation of the model constitute a key practical achievement in this research. The conceptual model that was designed and developed into a POC prototype was utilised for evaluation in order to test whether the research achieved its main objective (Section 6.4).

Successful simplification and presentation of the conceptual context-aware model using MBSE as the underlying methodology constitutes an additional valuable practical achievement in this research (Figure 6-9). Identification of suitable, tried and tested techniques for incorporation into the model, such as SOC and Mathematical optimisation in order to enhance the quality also contributed to the practical achievement (Sections 6.2 and 6.3). Appropriate implementation tools that were identified and utilised to support development of the conceptual model into a POC prototype while ensuring that the model achieved its objectives is a secondary practical achievement (Section 6.7.4). The next section discusses the research contribution.

8.4 RESEARCH CONTRIBUTIONS

Overall the research made two significant theoretical contributions as follows:

1. Contribution to the field of mobile usability (Mobile Human Computer Interaction): The research outlined in a concise manner specific features to be taken into consideration when it comes to evaluating usability of information presented on mobile devices. The research utilised the case of product catalogue to demonstrate key usability features for information presentation on a mobile device. Product catalogue was defined and discussed in detail in order to provide an understanding of the domain the research would focus on. The research claims that the model
developed in this research can be generalised and utilised to improve usability of information presented on mobile devices in other different domains.

2. **Contribution to the field of context-aware computing:** Context-aware computing is a relatively emerging field in computing that is gaining much attraction because of popularity and increased adoption of mobile computing. Many concepts in context-aware computing remain to be clarified. The research presented an analysis on critical concepts of context-aware computing that can provide other researchers with a starting point to conduct further research. For example, the research presented a general definition of context synthesised from a number of definitions proposed by various authors. The research further analysed the context-aware model in order to determine the best practices that can be utilised as reference points during development of context-aware applications as well as shortfalls that can be guarded against. Most context-aware models including the ones analysed in this research focus on acquisition, consolidation and dissemination of context. This research showed a step further and presented basic outline structure for a context-aware application.

A minor contribution was also made to the field of IR. The model implemented in the research can be utilised to improve IR systems by utilising context. Contextual IR exists, however, clarity remains a challenge. Techniques utilised and implemented in this research can be applied to IR systems in order to enhance clarity and effectiveness. Implementation of such an initiative would comprise testing the model’s robustness and scalability capabilities as outlined in the recommendation for future research (Section 8.5.3).

An additional uniqueness of the research is that main evaluation of the model’s functionality and usefulness specifically utilised a sample of users in a remote area with very little computer experience and where access to information is principally through the mobile web. This research can claim to be the first of such a kind to be conducted within the South African context and especially focusing on rural communities. Similar international studies focus on users who have prior experience in using computers and the Internet and have a number of options from which they can access information, for example, newspapers and the deep web (Chang et al., 2006; Bohmer et al., 2010; Chin-Chih and Shih-Tsung, 2012). Other studies utilised simulations during the evaluation (Pushpa and Venkataram, 2011). Specific similar work in a South African context could not be found.
Results obtained from the research can help other researchers implement more usable mobile applications that can also cater for users at the bottom of the pyramid by exploiting the huge potential concealed in accurate and real-time context information. This can be achieved by utilising or extending the context-aware model designed, implemented and evaluated in this research. The following sub-sections provide clarity on the specific contributions of the research. Theoretical and practical contributions are covered.

8.4.1 Theoretical Contributions

Context-aware computing is a relatively new area in computing having appeared in literature in early 90s and a number of aspects still remain to be thoroughly explored. This research aimed to present an insight into context-aware computing and provides the definitions for context and context-awareness that can enlighten the subject to other researchers. Furthermore the research aimed at demonstrating usefulness of a context-aware model in improving usability of information presented on mobile device interfaces. Literature on context-awareness and usability was rigorously analysed and relevant findings were synthesised into topics that emerged as specific contributions to theory. The following are the theoretical contribution from the research:

- **Chapter 3**: An overview of online businesses was presented in which clarifications and definitions for various types of online business were discussed. The chapter also discussed the concepts of consumer behaviour and decision making that influence customers to make purchase decisions. The chapter laid a foundation for the domain in which the solution implemented in this research belong. A specific contribution of the chapter was the demonstration of how usable product catalogues influence consumers to make efficient purchasing decisions in m-commerce environments.

- **Chapter 4**: This chapter presented the challenges experienced when browsing a catalogue on a mobile phone in m-commerce. The chapter also discussed product catalogue and usability as the main concept that forms the basis for evaluation of the research. For example, the research evaluated usability with regard to browsing a product catalogue on a mobile phone when context is utilised to improve retrieval and presentation on a mobile device interface. A specific contribution from this chapter is linked to Chapter 3 contribution by a discussion on the effects of usability of product catalogues in m-commerce that affect efficiency in consumers’ purchasing decisionmaking process.
• Chapter 5: Chapter 5 discussed context and context-awareness. The goal of the chapter was to present the context parameters to be utilised in this research. Concepts related to context-aware computing such as definition of context as well as context-awareness have been presented in order to bring an overall understanding of this new concept in computing. Specific contribution of the chapter is an outline of context parameters that can be utilised to improve retrieval and presentation of product catalogue data on a mobile device interface. Best practices and core components for context-aware applications were outlined. Such an analysis was found to be missing in existing context-aware literature.

• Chapter 6: Chapter 6 discussed the development of the context-aware model. The chapter presented a number of background techniques related to the technical implementation of the model. These techniques include: Model Based Software Engineering (MBSE), Mathematical optimisation and mobile information visualisation. The chapter also discussed the conceptual context-aware model as well as its MBSE implementation. Theoretically, the chapter contributed the analysis of MBSE and the various technical concepts of the model’s development. The context-aware model design consideration in which tried and tested computing techniques were utilised in order to enhance context-aware models objective functions constitutes an additional specific theoretical contribution.

8.4.2 Practical Contributions
The context-aware model implemented in this research can be extended and utilised to improve usability of applications designed to retrieve and present information on mobile web interfaces. Previous research in recommender systems dwelt much on theory and practical implementation for desktop applications leaving out critical issues associated with mobile computing. In this research it has been proven that an improved, flexible user interface driven by context can effectively improve usability of information presented on mobile device interfaces.

A practical model that was implemented can easily be customised and utilised to improve usability of information presented on a mobile interface through the use of context, from various domains such as news, social media and banking. The following are main practical contributions from the research:
A logical way of determining accurate context information in real-time: The research implemented a context sensor that was evaluated to test the accuracy and real-timeliness of the determined context. Results indicated that the context sensor performed well and according to the researchers knowledge this was the first evaluation of this type of context accuracy. Other probability simulation-based QoC measure techniques were implemented by other researchers (Brgulja et al., 2009; Brgulja et al., 2010). In this research users from various parts of the world interacting with the application in different contextual setting were utilised;

Conceptualisation of the context-aware model using a number of trusted standard, techniques and methodologies: The research presented a conceptual context-aware model (Figure 6-9) that was developed by utilising a number of other techniques such as Mathematical optimisation and Service-Oriented Computing (SOC) in order to enhance core functionalities. Functional specification of each component and how components can fit together or be utilised as individual services were discussed;

Successful implementation of the POC prototype of the model proved the feasibility of the conceptual model: The MBSE that was utilised for conceptual design of the model provides flexibility in terms of implementation techniques and run-time platform. Furthermore the SOC paradigm that was utilised for implementation made it possible for components to expose behaviour and functionalities without disclosing internal implementation (Erl, 2005; Erl, 2008). This implies that other researchers or developers who may want to utilise the outcome of the research in their work can choose to utilise only relevant components or the whole model in order to achieve their goals;

The implemented model was proven to be applicable and useful: Applicability was demonstrated through the model’s incorporation into an existing application and usefulness was demonstrated through the main evaluation that was conducted with a sample of unique real end users of the original existing system. Empirical evaluation results that were collected from the sample of real end users in Kgautsванe community in Limpopo Province show statistically that the context-aware application utilised during evaluation has the potential to improve usability with regard to browsing a product catalogue on a mobile phone and indeed any type of information that can be presented on a mobile device interface.
### 8.4.3 Unplanned Output

During the evaluation and analysis of the results, a number of achievements were observed that were not part of the planned outcomes and objectives of the research. These observations could form a good basis for future research in order to validate them. This section highlights the findings that were not part of the planned outcomes for the research as follows:

- The research observed that the use of mobile web and smartphones to access information and services has penetrated into rural areas where computer skills are scarce or non-existent;
- The research also found that people in rural or remote areas can grasp the usefulness of mobile applications; however, full adoption and usability might be affected by factors such as limited background computer experience and limited involvement of remote end users during the application development process.

Table 8-2 shows a comparison of the existing models and the context-aware model proposed in this research. The table highlights an analysis of the models’ properties adapted from Poulcheria and Costas (2012). Furthermore, the table shows the major differences and improvements in the proposed model as compared to the existing context-aware models (Dey, 2001, Dey and Abowd, 2001b; Lowe, *et al.*, 2012; Pushpa and Venkataram, 2011; Poulcheria and Costas, 2012).
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Context Aware M-commerce Services: C-IOB Model Approach (Pushpa and Venkataram, 2011)</td>
<td>Context Aware M-commerce Services: C-IOB Model Approach (Pushpa and Venkataram, 2011)</td>
<td>Use of Middleware and controlled server in ASP.NET to expose context information that can be accessed by an application</td>
<td></td>
</tr>
<tr>
<td>Context Sensor</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Comprehensiveness of context</td>
<td>Yes (too comprehensive and lack clarity)</td>
<td>No (specific within m-commerce, but still lack clarity)</td>
<td>Specific context parameters covered and provide clarity within the m-commerce product catalogue presentation (Sections 5.3 and 6.4)</td>
</tr>
<tr>
<td>Limited (would require many modifications)</td>
<td>Limited (would require many modifications)</td>
<td>Yes</td>
<td>Yes (specifically to improve usability of product catalogue presentation on mobile devices (Figure 6-9))</td>
</tr>
<tr>
<td>Suitable for mobile computing and m-commerce</td>
<td>Yes (but with some modifications)</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Components implementation and management

- Context widgets were implemented to expose context information that can be accessed by an application.
- Utilised Android platform to implement context APIs that can be accessed by an application. The implementation was restricted to Android applications only.
- General tightly classes were implemented to expose context information that can be accessed by an application.
- Use of Middleware and controlled server in ASP.NET to expose context information that can be accessed by an application.
- Utilised tried and tested UML and SOC techniques to enable easy plug and play of loosely coupled services within the model (Sections 6.2.1 and 6.3). Standardised model components can be accessed by any application across platforms, for example, native and web mobile applications.
### Table 8-2: Comparison of existing context-aware models and the proposed model

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential for generalisation</td>
<td>Too general</td>
<td>No, too specific to m-commerce services</td>
<td>Yes (can be easily extended and generalised to improve usability of other types of information to be retrieved and presented on mobile devices)</td>
</tr>
<tr>
<td>QoC Determination</td>
<td>No</td>
<td>No</td>
<td>Yes (function of each context parameter utilised in the model was discussed and Mathematical models were utilised to ensure optimal results (Section 6.2.2))</td>
</tr>
<tr>
<td>Context use clarity</td>
<td>No (too general)</td>
<td>Yes (but with limited discussion)</td>
<td>An evaluation was conducted with a sample of real end users. Statistical results indicated that the model’s usefulness in improving usability of information presented on mobile devices did not happen by chance (Sections 7.3.4 and 7.4.3.2).</td>
</tr>
<tr>
<td>Evaluation</td>
<td>No</td>
<td>Utilised simulation to determine usefulness</td>
<td></td>
</tr>
</tbody>
</table>

- **Potential for generalisation**: The potential for generalisation is evaluated. Too general models can be generalised to mobile computing with a lot of effort, while models too specific to m-commerce services are not easily generalised.
- **QoC Determination**: QoC (Quality of Context) determination is evaluated. Models that are not able to determine QoC are marked as No.
- **Context use clarity**: The clarity of context use is evaluated. Models that are too general are marked as No (too general), while models with limited discussion on context use are marked as Yes (but with limited discussion).
- **Evaluation**: The evaluation methods used are utilised simulation to determine usefulness. An evaluation was conducted with a sample of real end users. Statistical results indicated the model’s usefulness in improving usability of information presented on mobile devices did not happen by chance.
8.5 RECOMMENDATIONS

Recommendations from the research have been developed following research findings and contributions discussed in Sections 7.5 and 8.4. The objective of this section is to highlight significant lessons from the research that can be utilised by other researchers in the general field of context-aware computing, and also specifically within the domain of information retrieval and presentation on mobile devices. Three main recommendations discussed in this section include: recommendations for theory, practice and future research.

8.5.1 Recommendations for Theory

Recommendations for theory are based on the analysis of the literature and synthesis of novel concepts that resulted into the development of the proposed conceptual context-aware model. Various topics related to the main theories covered in this research were analysed in the literature chapters. Theoretical recommendations comprise unique recommendations from the research because recommendations for practice could not necessarily be separated from existing recommendations for general computing. The main theoretical recommendations from the research include:

- Proper definition of context within a specific domain is paramount to developing effective context-aware models. The proper definition control techniques for accurate determination of context information, that can affect, for example, usability of information and influence effectiveness of information retrieval models and improve confidence in decision making process when incorporated into a context-aware application;

- Well known computing and context-aware computing best practices should be followed when developing context-aware applications in order to develop easy to use and effective models. For example, incorporation of tried and tested techniques such as Mathematical optimisation and SOC can enhance usefulness and effectiveness of context-aware models;

- Context-aware computing is relatively new and complex. In order to cope with complexity and disruptive future changes (new discoveries or improvements) this research recommends that MBSE offers a suitable alternative to conceptualise and simplify context-aware solutions. Furthermore, conceptualisation of context-aware models using techniques such as MBSE can provide flexibility in terms of implementation and run-time options that remove the confusion that can emerge due
to numerous effective implementation tools, devices and platforms that exist in mobile web computing:

- Evaluation of properties of context-aware models such as usefulness and applicability can yield vital results when the evaluation goes beyond the model with a suitable sample of real end users wherever possible.

### 8.5.2 Recommendations for Practice

Recommendations for practice are based on the successful implementation of the conceptual context-aware model into a POC prototype that was utilised for research evaluation purposes. Recommendations discussed in this section can be applicable to general computing because actual implementation of the conceptual context-aware model could not be separated from general computing application development guidelines. The following are recommendations for practice from the research:

- Empirical evidence proved that MBSE-based context-aware conceptual model offers a suitable alternative to facilitate research and development of context-aware information retrieval and presentation applications. Clarity of the model depicted in Figure 6-9 eases complexity and simplifies context-aware application development. Developers can directly utilise the loosely coupled components of the model or extend in order to suit specific applications specification;

- Context-aware models are not standalone and therefore they must be developed with flexible implementation tools that would ease extension and integration into desired context-aware applications.

### 8.5.3 Recommendations for Future Research

The increased attraction of the emergent context-aware computing field opens up enormous opportunity for future research. This research could stimulate further future context-aware research. The following are examples of identified recommendations for possible future research that can follow this research:

1. The sample utilised in this research’s main evaluation came from the same environment and possessed similar characteristics, for example, the majority of the participants had no prior computer experience. A comparison of the results obtained in this research with different samples using the same or different evaluation procedure can be of value to further validate the results obtained in this research. For
example, conducting the evaluation with a similar sample of users interacting with the two prototypes or a similar sample interacting with only the improved prototype;

2. For the purposes of proving the concept, the model implemented in this research utilised a minimal list of context parameters to optimise retrieval and presentation of product catalogue data on a mobile device. Results indicate that the model has the capacity to improve retrieval and presentation of product catalogue data. Future research can include many more context parameters in the model and different information data sets can be utilised in order to test the model’s robustness and applicability across different data sets or domains;

3. Future research may also utilise a more realistic and larger mobile website, for example, a news website such as news24 or online shopping website such as Amazon.com and Kalahari.com in order to test the model’s accuracy in determining the recommendations and usefulness. The numerous numbers of visits or daily transactions in real life websites such as news24.com and Amazon.com can be a better test to ascertain the model’s capabilities in improving usability of information presented on mobile devices.

8.6 LIMITATIONS AND CHALLENGES

There were a number of limitations and challenges that were experienced during the course of this research. Limitations and challenges that were encountered in this research include:

a. The smaller number of transactions that passed through the m-commerce application affected the model’s adaptation capabilities: The model developed in this research had an implicit learning module in which users’ previous transaction patterns were recorded. The previous customer purchasing patterns were utilised to determine recommendations for the customer during future visits. Determination of particular customers’ recommendations during future visits could have been improved if the number of transactions were more. The model presented in this research can be perfected by utilising a larger number of customer transactions, for example, Amazon boasts to have millions of daily transaction, half of which are made on mobile devices. Information such as user purchases and profiles that can be obtained from such a large volume of transactions could help improve the model’s effectiveness;
b. Limited sample of participants and challenging environment: The research setting was to incorporate the implemented context-aware model into an existing information retrieval and presentation system in order to assess the model’s impact on improving usability. Finding a suitable sample of users with prior experience of using the existing system was a challenge. A suitable system and limited sample of participants with prior experience with the system was found in Kgautswane community in Limpopo Province, South Africa. The sample was useful during the evaluation; however, a number of factors might have influenced the results. For example, the sample was found to be rigid in terms of size and Internet connectivity options (only Vodacom Internet was available and provided a reliable connection). These factors might have influenced the results. Efforts were however made to ensure that collected data was validated to avoid bias that might have been influenced by the said factors. Section 7.4.3.1 discussed some efforts with regard to sample characteristics that were evaluated to ensure suitability of the sample.

8.7 CONCLUDING REMARKS

Accessing information anytime anywhere using mobile devices is more commonplace due to the increased use of mobile devices by end users. This research focused on accessing a product catalogue on a mobile device interface and a context-aware model was developed and incorporated into an existing m-commerce application. A number of evaluations were conducted in this research aiming at addressing various research questions, for example, the context sensors evaluation, pilot study and the main evaluation. Different research methods and techniques were utilised in this research, for example, the interpretivist approach, and qualitative and quantitative methods were utilised to gather data. Statistical methods were utilised for data analysis and presentation of results.

A context-aware model was conceptualised, designed and a POC prototype of the model was also implemented using open source software development tools, such as MySQL database management system, PHP and JavaScript. Conceptualisation of the model utilised a number of techniques such as SOC, MBSE and UML. Additional techniques such as Mathematical optimisation and mobile information visualisation were also incorporated in the model in order to enhance functionalities and effectiveness. During the implementation of the POC prototype of the model, a number of evaluations were conducted including context-sensor and a pilot study evaluation. These evaluations were conducted in order to verify the model’s
functionalities at various phases during development. The final working prototype of the model was incorporated into an existing m-commerce shopping website. This was done to validate applicability and usefulness of the entire model.

A field experiment was conducted with a sample of small-scale retailers from Kgaustwane community in Limpopo Province who utilise the application to make daily orders of their stock. The evaluation involved users performing a number of carefully determined tasks related to the daily use of the existing application. Users were asked to complete two questionnaires: first for their experience with the original application and second their experience with the improved application.

The research achieved its goals and objectives. The context-aware model was designed and implemented (Chapter 6). A number of critical success factors of the research and the model that was implemented as a core deliverable have been demonstrated throughout the research. For example, a conceptual model was developed whose theoretical basis was discussed in the literature chapters. The practicality or feasibility of the conceptual model was demonstrated through the POC prototype of the model and its applicability was shown by incorporating it into an existing m-commerce website. Usefulness of the model was validated by the results of the main evaluation. Results of the evaluation provided evidence that the model has the potential to improve usability of information presented on mobile devices. The conceptual context-aware model proposed in this research provides the basic building block for determining and utilising context information during retrieval and presentation of information on mobile devices. The context-aware model can be utilised by other researchers as a blueprint to implement complex, usable context-aware information retrieval and presentation applications.

------------------------The end-------------------------------
REFERENCES


Bohmer, M., Bauer, G. and Kruger, A. (2010): Exploring the design space of context-aware recommender systems that suggest mobile applications. Workshop on context aware and recommender systems (CARS 2010), Barcelona, Spain. 26 September.


Faridani, H. (2011): A guide to selecting software development methodologies. Available online:


2012 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), Lugano, Switzerland. 19-23 March, pp. 76-81.


APPENDICES

Appendix A: University Research Ethical Clearance – Human (REC-H)

Chairperson of the Faculty RTI Committee (Faculty of Science)
Nelson Mandela Metropolitan University
Tel: +27(0)41 - 504 2249    Fax: +27(0)41 - 504 2369

Ref: H11-Sci-CS-010

Student No: 207059758

Date: 25 November 2011

Contact person: Mrs C Venter

Mr Felix Ntawanga
C/o Department of Computing Sciences
NMMU, South Campus
Port Elizabeth
6000

Dear Mr Ntawanga

TITLE OF PROJECT: A CONTEXT-AWARE MODEL FOR PRODUCT CATALOGUE DATA RETRIEVAL AND PRESENTATION ON A MOBILE PHONE.

Your above-entitled application was considered and approved by the Sub-Committee for Ethics approval in the Faculty of Science on 14 November 2011.

The Ethics clearance reference number is H11-Sci-CS-010, and is valid for three years. Please inform the FRTI Committee, via your faculty officer, if any changes (particularly in the methodology) occur during this time.

An annual affirmation to the effect that the protocols in use are still those, for which approval was granted, will be required from you. You will be reminded timeously of this responsibility, and will receive the necessary documentation well in advance of any deadline.

We wish you well with the project. Please inform your co-investigators of the outcome, and convey our best wishes.

Yours sincerely

Chairperson: Faculty Research, Technology and Innovation Committee
(Faculty of Science)

cc: Department of Research Capacity Development
Faculty Officer, Faculty of Science
Dear Participant,

Thank you for volunteering to participate in this research study for the evaluation of a mobile environment context sensor that aims at determining and collecting context information about the environment you are currently accessing the application from. The determined context information for your environment will only be used for evaluation of the context sensor implemented in the backend and nowhere else. The feedback you will provide in this evaluation will help to improve the accuracy of the context sensor. Detailed steps and a task list have been sent together with this information (in Appendix 2) to guide you conduct the evaluation. (Read the task list carefully before attempting to complete the questionnaire) Please feel free to ask the researcher (Felix Ntawanga) to explain anything that is not clear to you. As a participant you have the right to query concerns regarding the evaluation at any time. Immediately report any problems during the study to the researcher via emails provided.

Furthermore, it is important that you are aware of the fact that the ethical integrity of the study has been approved by the Research Ethics Committee (Human) (REC-H) of the University. The REC-H consists of a group of independent experts that has the responsibility to ensure that the rights and welfare of participants in research are protected and that studies are conducted in an ethical manner. Studies cannot be conducted without REC-H's approval. Queries with regard to your rights as a research subject can be directed: Research Ethics Committee (Human), Department of Research Capacity Development, PO Box 77000, Nelson Mandela Metropolitan University, Port Elizabeth, 6031.

You have the right to withdraw at any given time, during the evaluation without penalty or loss of benefits. Although your identity will at all times remain confidential, the results of the research study may be presented at scientific conferences or in specialist publications.

Yours sincerely

Felix Ntawanga

RESEARCHER
APPENDIX 2: TASK LIST

As a participant in this evaluation you will be required to perform tasks on your mobile device and later on you will need to complete an evaluation questionnaire (Questionnaire 1). This task list explains the steps you will have to follow in order to conduct and complete this evaluation. The first step of the evaluation is to complete the Biographical Details and Static Context Information sections of the questionnaire (Sections A and B). Secondly you will need to perform some tasks (listed below) on the system and complete Section C of the questionnaire. For questions that have several options delete the inappropriate alternative answers to remain with the correct answer. The actual interaction with the system should take not more than 8 minutes.

(Please note that the Internet charges you may incur when interacting with the application during the evaluation will not be reimbursed)

The following is the list of steps that will guide you to complete interaction with the application:

1. (Complete Sections A and B of the questionnaire: Background Details and Static Context Information)

2. Launch or access the application using a mobile device
   a. Type the following link in the address bar of the default mobile device browser: http://196.214.84.245/prj2012

3. When the applications loads, login into the system using a test user account. Please note that the login details are valid for this evaluation only.

4. Upon successful login the application will take you to the Context Information page
   a. Please accept the application to access your location if asked

5. While on this page (the Context Information Page) complete Section C of the questionnaire: Displayed Context Information

6. When you complete Section C of the questionnaire, click Confirm to exit the system

This marks the end of the evaluation. Please email the complete questionnaire to the researcher using any email address listed on top of this page.

Thank you for your participation.
Appendix D: Context Sensor Evaluation Accuracy Questionnaire

## CONTEXT SENSOR EVALUATION QUESTIONNAIRE

### Section A: Background Details

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>20-24</td>
<td>25-29</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>Highest qualification</td>
<td>Bachelors</td>
<td>Masters</td>
</tr>
</tbody>
</table>

### Section B: Static Context Information

1. Which country are you currently residing?
2. Which city in the country mentioned above are you currently in?
3. What time of the day is it now in your current city? | Morning | Afternoon | Night |
4. What is the make and model of the mobile device you will use to access the application?

### Section C: Displayed Context Information

1. Is the current date and time displayed by the application on your mobile device screen correct? [Record the time displayed, regardless of whether it is correct or wrong]
   - Yes | No
   - Recorded time
2. Record the GPS coordinates the application has displayed on your mobile device screen
   - First set of 4 digits (Latitude)
   - Second set of 4 digits (Longitude)
3. Is the make of the device displayed by the application on your mobile device screen the same as the one you are using to access this application? [Record the displayed make only if it is wrong]
   - Yes | No
   - Displayed make
4. Is the model of the device displayed by the application on your screen the same as the one you are using to access this application? [Record the displayed model only if it is wrong]
   - Yes | No
   - Displayed model
5. Record the bandwidth displayed by the application on the screen of your mobile device in MB/s?
   - Displayed speed
6. In your opinion what can you say about the speed at which the pages of the application loaded?
   - Very fast | Fast | Average | Slow | Very Slow
Appendix E: Pilot Study Evaluation Written Information for Participants

INFORMATION FOR PARTICIPANTS

Dear Participant,

Thank you for volunteering to participate in this pilot study. The goal of this pilot study is to help identify any challenges or problems with the application and the evaluation process so that they can be addressed prior to conducting the main evaluation. Therefore the researcher would like to ask for your critical analysis and feedback that can help to improve the smooth running of the main evaluation. The application will not ask any personal information from you (apart from sharing your location in some instances) and it will not keep any personal information. Context information will be collected within the environment you are currently accessing the application including the device you are using, the bandwidth of your connection and user profile (already set). The collected context information will be utilised to determine what amount of product catalogue information should be retrieved from the repositories and how the retrieved information should be displayed on your specific mobile device screen.

A task list with detailed steps to guide you through this evaluation will be handed to you. Briefly, during this evaluation you will need to complete an online questionnaire prior, during and after interacting with the application (please carefully read the task list before attempting to complete the questionnaire). Please feel free to ask the researcher (Felix Ntawanga) to explain anything that is not clear to you. As a participant you have the right to query concerns regarding the evaluation and you have the right to withdraw at any given time during the evaluation without penalty or loss of benefits. Although your identity will at all times remain confidential, the summary results of the research study may be presented at scientific conferences or in specialist publications.

It is important that you are aware of the fact that the ethical integrity of the study has been approved by the Research Ethics Committee (Human) (REC-H) of the Nelson Mandela Metropolitan University (Ref No. H11-Sci-CS-010). The REC-H consists of a group of independent experts that has the responsibility to ensure that the rights and welfare of participants in research are protected and that studies are conducted in an ethical manner. Studies cannot be conducted without REC-H’s approval. Further queries with regard to your rights as a research subject can be directed to: Research Ethics Committee (Human), Department of Research Capacity Development, PO Box 77000, Nelson Mandela Metropolitan University, Port Elizabeth, 6031.

By adding your initials, surname and signature in the list of participants it indicate that you have read, understood and consent that you voluntarily agree to participate in this study.

Thank you once again for your participation.
Appendix F: Pilot Study Evaluation Task list

**TASK LIST (EVALUATION PROCEDURE)**

As a participant in this evaluation you will be required to perform a number of tasks on your mobile device (cell phone or tablet) and later on you will need to complete an online evaluation questionnaire available at the following link: https://www.esurveycreator.com/s/93acc24. This task list explains the steps you will have to follow in order to conduct and complete this evaluation. The first step of the evaluation is to complete the Biographical Details and Static Context Information sections of the online questionnaire (Sections A and B). Secondly you will need to perform the tasks (listed below) on the system and thereafter complete Sections C, D and E of the questionnaire. The actual interaction with the system should take not more than 12 minutes.

*(Please note that the Internet charges you may incur while interacting with the application during the course of the evaluation will not be reimbursed.)*

The following is the list of steps that will guide you to complete the evaluation:

1. Complete Sections A and B of the questionnaire: Background Details and Background experience that is on the desktop screen *(Leave the questionnaire, do not click the green “next” button at the bottom of the page for now)*

2. Go to your mobile device, launch or access the application
   a. Open the browser you use on your mobile device
   b. Type the following link in the address bar of the “default” mobile device browser: http://196.214.84.245/eprocure

3. When the application loads, login into the system using the provided user name and password set.

4. Once you have successfully logged in to the application
   a. The application will take you to the Context Information page
   b. Allow the application to access your location if prompted
   c. While on this page (the Context Information Page) go back to the desktop questionnaire and complete Section C of the questionnaire
   d. Once you have completed Section C of the questionnaire *(Leave the questionnaire, do not click the green “next” button for now)*, go back to the application on the mobile device and click Confirm to go to the next page

5. On the Main Menu page that will load, click on Order Stock

6. Select any three products in any quantities, one product from each category of your choice displayed on the screen *(if the product catalogue doesn’t load on the page try to refresh the page if after refresh the product catalogue still does not load then go to step 10)*.

7. Click confirm order
8. Check that the order is correct
9. Click order now
10. Go back to the main menu
11. Log off
12. **Get a second device**
13. Go to your mobile device, launch or access the application
   a. Open the browser you use on your mobile device
   b. Type the following link in the address bar of the “default” mobile device browser:
      http://196.214.84.245/eprocure
14. When the applications loads, login into the system using the provided user name and password set.
15. When Context Information Page loads, click Confirm to proceed
16. On the Main Menu page that will load, click on Order Stock
17. Select any three products in any quantities, one product from each category of your choice displayed
   on the screen (if the product catalogue doesn’t load on the page try to refresh the page if after
   refresh the product catalogue still does not load then go to step 21).
18. Click confirm order
19. Check that the order is correct
20. Click order now
21. Go back to the main menu
22. Log off
23. Leave the mobile device and go to the online questionnaire
24. **Click the green “next” button to go to the next page of the questionnaire**
25. Complete Sections D and E of the questionnaire
26. **Click the green “next” button to go to the next page of the questionnaire (last page)**
27. Submit the questionnaire by closing the window and data will be automatically saved

This marks the end of the evaluation. Thank you for your participation.
Appendix G: Pilot Study Evaluation Questionnaire

Pilot Study Questionnaire

Section A: Background Details

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 20-24</td>
<td>25-29</td>
<td>30-34</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>Highest qualification</td>
<td>Honours</td>
<td>Masters</td>
</tr>
</tbody>
</table>

Section B: Background Experience

What is the make of the cell phone (or Tablet) you will use to access the application?
What is the model of the cell phone (or Tablet) you will use to access the application?
For how long have you been using your current cell phone (or Tablet)?
- 0-6 Months
- 7-12 Months
- 13-18 Months
- 19-24 Months
- >24 Months
What wireless Internet connectivity will you be using to access the application during the evaluation?
- Wi-Fi
- Mobile Service Provider
- Other
How can you rate your experience wrt browsing on a cell phone (or Tablet)?
- Novice
- Intermediate
- Expert

1. Have you ever browsed any online shopping system (website) using a cell phone (or Tablet)? [If yes from which website(s) and when last did you browse the website?]
   - Yes
   - No
   Website name
   Last time

2. Have you ever purchased any product online using a cell phone (or Tablet)? [If yes from which website and when last did you perform this purchase?]
   - Yes
   - No
   Website name
   Last time

Section C: Displayed Context Information (on the Context Information Page)

3. Is the make of the device displayed by the application on your mobile device screen the same as the one you are using to access this application? [Record the displayed make only if it is wrong]
   - Yes
   - No
   Displayed make

4. Is the model of the device displayed by the application on your screen the same as the one you are using to access this application? [Record the displayed model only if it is wrong]
   - Yes
   - No
   Displayed model

5. Record the bandwidth displayed by the application on the screen of your mobile device in MB/s?
   Displayed speed
### Section D: Reaction to the System (After performing the tasks with the first device)

<table>
<thead>
<tr>
<th>How do you rate the following with regards to the product catalogue?</th>
<th>Too little</th>
<th>Enough</th>
<th>Too many</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of products displayed</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>No. of products displayed per tab relative to the size of your device screen</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>The time it took to load the products on the screen</td>
<td>Very long</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

### Section E: Reaction to the System (After performing the tasks with second device)

<table>
<thead>
<tr>
<th>How do you rate the following with regards to the product catalogue?</th>
<th>Too little</th>
<th>Enough</th>
<th>Too many</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of products displayed</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>No. of products displayed per tab relative to the size of the device screen</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>The time it took to load the products on the screen</td>
<td>Very long</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

### How do you rate the following with regards to the system?

<table>
<thead>
<tr>
<th>How do you rate the following with regards to the system?</th>
<th>Very frustrating</th>
<th>Very satisfying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall reaction to the system</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Screen design</td>
<td>Very pleasant</td>
<td>Very unpleasant</td>
</tr>
<tr>
<td>Navigation of the system</td>
<td>Very difficult</td>
<td>Very easy</td>
</tr>
</tbody>
</table>

Did you notice any difference in the way product catalogue information was presented on the two devices, first device and second device? [If NO Skip the next set of rating questions]

- Yes
- No

<table>
<thead>
<tr>
<th>How do you rate the following statements with regards to the observed difference in the way product catalogue information was presented on the two devices?</th>
<th>Very difficult</th>
<th>Very easy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readability of the information</td>
<td>1st Device</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2nd Device</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Amount of information presented in relation to the screen size of the device</td>
<td>Too little</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Useful Not useful</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>The change/adaption in information presentation depending on device</td>
<td>1st Device</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2nd Device</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Mention any observed positive aspects of the system.

Mention any observed negative aspects of the system.
Appendix H: Screenshot Example of the Online Pilot Study Evaluation Questionnaire

**Pilot Study: Usability of Information Presented on Mobile Devices-Product Catalog Data**

**Pilot study: Reaction to the System (After performing the tasks)**

**SECTION D: COMPARISON OF INFORMATION PRESENTATION (AFTER PERFORMING THE TASKS, FIRST DEVICE=YOUR DEVICE, SECOND DEVICE=ONE YOU GOT)**

### Number of products displayed on the screen of the device

<table>
<thead>
<tr>
<th></th>
<th>Too little</th>
<th>Enough</th>
<th>Too much</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Device</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second Device</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### The time it took to load the products on the screen

<table>
<thead>
<tr>
<th></th>
<th>Short</th>
<th>Average</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Device</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second Device</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Readability of information

<table>
<thead>
<tr>
<th></th>
<th>Difficult</th>
<th>Easy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Device</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second Device</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Number of products presented in relation to the screen size of the device

<table>
<thead>
<tr>
<th></th>
<th>Too little</th>
<th>Enough</th>
<th>Too many</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Device</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second Device</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Did you notice any difference in the way product catalogue information was presented on the two devices, first device and second device? [If No go to Section E]

- [ ] Yes
- [ ] No

The change/adaption in information presentation depending on device

<table>
<thead>
<tr>
<th></th>
<th>Useful</th>
<th>Not useful</th>
</tr>
</thead>
</table>
Appendix I: Context-Aware Model POC Prototype Evaluation Information for participants and Consent Form

WRITTEN INFORMATION AND CONSENT

Motsea karolo,

Re leboga go dumela ga lena go tsea karolo dinyakišišong thlatlobo tsa ‘context-aware online shopping system’. Modira dinyakišišo, (Felix Ntawanga) o tla go tlabakela ka tshedimošo eo e hlokegago go go thuša go kwešiša dinyakišišong tse le go hlaloša gore bjalo ka motsea-karolo, go nyakega eng go wena. Hle! Lokologa go botšiša modira dinyakišišo dipotšišo le go hlalosha tsohle tseo di sa hlakago go wena

Go tsea karolo go dinyakišišo thlatlobo tse, le tlo kgopolwa go neelana ka tumelelo ye ye ngwadilwego kua mafelelong a tokomane e. Tshedimošo e nyakwago e akaretsa moloko (sefane) le tlhaka tsa mathomo tsa leina goba maina a gago, leswao la gago (signature), nomoro ya gago ya mogala le tsatsi kgwedi go kgonthišiša kwišišo le tumele go mbaka ao a beilwego. Ga gona kotsi tseo di tsebjago go dinyakišišo thlatlobo goba di dirišwa (Dilla-thekeng le di potšišo) tse.

Tlhokomela tse di latelago:

- Dinyakišišo tse di ka tselo- tshomo. Ga di ame wena bjalo ka mo šomiši ka fao o kgopolwa go araba ka tokologo le botšepegi bja maleba tsele-tshomong e le go arabeng dipotšišo.
- Tshedimošo eo e humanwago ka tsele-tshomišo e ile go šomišetswa feela tsheka-tshekong ya tsele-tshomišo (system) ke modira dinyakišišo (Moseka-seki) go lekola tsele-tshomo.
- Bowena bja gago (Identity) bo ka se tsweletswa matlakaleng (dikuranteng) morago ga dinyakišišo; gape
  - O na le tokelo ya go ikgogela morago go se nako efe goba efe ka mabaka afe goba afe.

Nakong ya dinyakišišo, o tla swanela go diragatsa mediro e mmalwa ka tsele-tshomo (e hloswa go letlakala tshomo). Tsele-tshomišo eo o tlago šoma ka yona e swana le tsela ya Rustika eo ga bjale o e tsebago. Di phapano ke fela gore tsela-tšhomo e šomiša tshedimošo e itsego ya Lefelo leo o neelanago ka tshedimošo o le go lona go kgonthišiša gore naa ke tshedimišo efe eo e humwago go ‘data base’ le gore tshedimošo eo e ka tsweletswa bjang mollwaneng wa sella-thekeng. O tla swanela ke go fetola dipotšišo morago ga go diriša tsele tshomo e.

Nako le maitapišo a gago di tla thabelwa kudu. Leswao la gago (ka tlase) le bontsha gore o badile le go kwišiša foromo ya tumelelo gape le gore o dumetse go tsea karolo ntle le kgapeletšo goba kgatelelo

Yours sincerely

Felix Ntawanga

RESEARCHER

<table>
<thead>
<tr>
<th>Surname and initials</th>
<th>Contact Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature</td>
<td>Date</td>
</tr>
</tbody>
</table>

274
Appendix J: Context-Aware Model POC Prototype Evaluation Task List

**TASK LIST**

As a participant in this evaluation you will be required to perform a number of tasks on online system using your cell phone and later on you will need to complete a questionnaire (Questionnaire ii). This document explains the task list with the steps you will have to follow in order to perform and complete this evaluation. The first step of the evaluation is to interact with the online application. The internet cost you may incur during the evaluation will be reimbursed.

**Please take note that the orders you will place in this evaluation are not going to be delivered. The purpose of placing the orders is to evaluate the application only.**

The following is the list of steps that will guide you to complete the evaluation:

1. Go to your cell phone
2. Load the airtime/data bundles provided by the researcher
3. Only when the airtime/data bundles have been successfully loaded into the cell phone, launch or access the application by performing the following sub tasks:
   a. Open the browser you use on your mobile device
   b. Type the following link in the address bar of the mobile device browser: http://196.214.84.245/eprocure
4. When the applications loads, login into the system using the provided user name and password set (Alternatively you can use the user name and password you use for the Rustica system).
5. Once you have successfully logged in to the application a main menu page will be loaded on the screen
6. On the Main Menu page that will load, click on Order Stock
7. Select any three products in any quantities, one product from each category of your choice displayed on the screen *(if the product catalogue doesn’t load on the page try to refresh the page. If the product catalogue still does not load after refreshing the page then go to step 11).*
8. Click confirm order
9. Check that the order is correct
10. Click order now
11. Go back to the main menu
12. Log off
13. **Get another device**
14. Load the airtime/data bundles provided by the researcher
15. Only when the airtime/data bundles have been successfully loaded into the cell phone, launch or access the application by performing the following sub tasks:
   a. Open the browser you use on your mobile device
   b. Type the following link in the address bar of the mobile device browser:
      http://196.214.84.245/eprocure
16. When the application loads, login into the system using the provided user name and password set. (Alternatively you can use the user name and password you use for the Rustica system).
17. On the Main Menu page that will load, click on Order Stock
18. Select any three products in any quantities, one product from each category of your choice displayed on the screen (if the product catalogue does not load on the page try to refresh the page. If the product catalogue still does not load after refreshing the page then go to step 22).
19. Click confirm order
20. Check that the order is correct
21. Click order now
22. Go back to the main menu
23. Log off
24. Leave the mobile device and go to the questionnaire
25. Complete all sections of questionnaire ii

This marks the end of the evaluation. Thank you for your participation.
Appendix K: First Sipedi Translated Version of the Context-Aware Model POC Prototype Evaluation Questionnaire

Bokgoni Bja Motšea karolo le kwišišo tshepidišo ya Letlakala Potšišo

Molaetša o Bohlokwa:
Dikgetho tse di bontšhwago ka leswao le, e hlaloša gore o ka dira kgetho e tee feela bjalo ka karabo ya gago.
Dikgetho tšeo di bontšhwago ka leswao le e hlaloša gore o ka dira 'kgetho tše mmalwa bjalo ka dikarabo tša gago

Karolo A: Tshomišo Ya Sellathekeng.
1. Naa o na le mogala wa sellathekeng? (Ge Karabo ya gag e le Aowal fetela go Karalo B.)
   - Ee!
   - Aowal

2. Naa o nale nako e kae o šomiša Sellathekeng?
   - 0-1 Year
   - 2-4 Years
   - 5+ Years

3. Naa ke mohuta ofe wa Sellathekeng wo o nalego wona, ebile o ošomišago?

4. Naa nako e kae o šomiša Sellathekeng sa gago?
   - 0-1 ngwaga
   - 2-4 mengwaga
   - 5 mengwaga go ya godimo

5. Naa o šomiša moaba-tirelo ofe wa tirelo ya Sellathekeng?
   - MTN
   - Vodacom
   - CellC
   - Virgin Mobile
   - 8Ta

6. Naa Sellathekeng sa gago o se šomosetša go dira eng? [Kgetha tšeo o se šomisetšago tšona]

<table>
<thead>
<tr>
<th>Ka nako tše dintšhi</th>
<th>Ka nako enngwe</th>
<th>Ka sewelo</th>
<th>(Aowa) Le ga tee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letša / Amogela Megala</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Romela / Amogela Melaetsa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Go shomisha internet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Go phetla internet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tšedingwe (Hlaloša)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Karolo B: Nyakišišo ka kgwebo
1. Naa kgwebo ya gago e dira eng? [kgetha tšohle tšeo di lego maleba]
   - Rekiša didirišwa tša gae
   - Rekiša dikago

   - Thekšo ya dinotagi
   - Thekišo ya Leruo

   - Leselaga
   - Tše dingwe [hlaloša]____________________________________

2. Naa kgwebo e o ke ka mang?
   - Ya gago
   - Ya lapa
   - Ya motho e mongwe

3. Naa kgwebo yeo e nale nako e kae e soma?
   - 0-1 ngwaga
   - 2-4 Mengwaga
   - 5+ Mengwaga

Karolo C : Tsebo Ya Khomputha
4. Naa o tseba go šomiša khomputha? [Ge ele gore Karabo ya gago ke aowa, fetela go karolo ya D]
   - Ee
   - Aowa

5. Naa o na le bokgoni bja mengwaga e mekae ka go go šomiša khomputara?
   - 0-1 ngwaga
   - 2-4 Mengwaga
   - 5+ Mengwaga

6. O ka hlaloša bokgoni bja gago bja go šomiša khomputha?
   - Setsebi
   - Magareng
   - Moithutwane
7. Naa o hwetša kae tumelelo ya go šomiša khomputa? [kgetha tšohle tšeo dilego maleba]
☐ Gae ☐ lebenkeleng ☐ Mošomong ☐ Tše dingwe [hlaloša]

Karolo D: Bokgoni bja go šomiša intanete
1. E kaba o kgona go hwetša Intanete (Ge ele gore Karabo ya gago ke aowa, fetela go karolo ya E)
☐ Ee! ☐ Aowa!

2. Naa o nale tsebo ya mengwaga e mekae ka go šomiša internet?
☐ 0- Ngwaga o 1 ☐ Mengwaga e 2-4 ☐ Mengwaga ya 5 le go feta

3. E kaba o tšea bonnyane bja di iri tše kae go internet ka letšatsi
☐ 0-1 Hour/Iri ☐ Di iri tše 2-4 /Hours ☐ Di iri tše 5+ Hours

4. Ke ke (Lefelo) mo o humanagō internet (Bontsha lefelo)
☐ Lefelo la internet ☐ Sellathekeng ☐ Mošomong ☐ Lefelope leleng (Hlalosha)

5. O ka hlalosa bjang maitemogelo a gago a Internet?
☐ Ona le bokgoni bja godimo ☐ Bokgoni bja Magareng ☐ Moithutwane

6. Ke mohuta ofe wa tsebo/tshedimošo oo o o nyakago mo go Internet.
☐ Reka ☐ Ditaba ☐ Panka ☐ Tshedimošo [Hlalosa]

Karolo E: Karolo Ya Tshumišo
Frequency of Use
1. Naa o ile wa phehla khataloko ya Rustica ya tsela-tshumišo ya go reka ka tsela ya technology?
☐ Ee! ☐ Aowa!

2. O šomiša mohuta ofe wa sellathekeng go phehla tsela-tshumišo ya Rustica

3. E kaba o ile wa reka setsweletsa ka tsela-tshumišo ya Rustica? (Gee le Aowa, fetela go Potsišo 6)
☐ Ee! ☐ Aowa!

4. E kaba ke di dilo/tšweletšwa tše kae tšeo o ilego ya Rustica ya Internet
☐ Selō (Setsweletšwa) 0-1 ☐ Dilo/Ditsweletšwa 2-4 ☐ Dilo/Ditsweletšwa 5+

5. O reka ga kae pahlo/ditšweletšwa ka go šomiša tsela-tshomišo ye (E fa palo-gare)


7. Bontšha ka diranta gore o šomiša bokae go reka di dilo goba pahlo/ditšweletšwa?

Tšomišo ka kakaretšo
8. Bontšha ka tsela ya dintšha dipolelwana tse dilatelago ka tsela tshepedišo ya Rustica

<table>
<thead>
<tr>
<th>8.1 Phetogo ka botlalo mabapi le Tsela (system)</th>
<th>HLAKAHLAKANYA KUDU</th>
<th>KGOTSOFATŠA KUDU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8.2 Tsweletso ya Sekirini</th>
<th>FOKOLA KUDU</th>
<th>BOTSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8.3 Kalo ya dilo mo sekirining</th>
<th>GAKANTŠHA KUDU</th>
<th>SEKEGILE KUDU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8.4 Thušo yeo re e fiwago ka tsela tshepedišo</th>
<th>GA YA LEKANA</th>
<th>ELEKANE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8.5 Tshepedišo thelelo ya tsela tshepedišo</th>
<th>HLAKAHLAKANYA KUDU</th>
<th>KGOTSOFATŠA KUDU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
8.6 Go ithuta Tirišo

<table>
<thead>
<tr>
<th>E THATA KUDU</th>
<th>E BONOLO KUDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

8.7 Nyakišišo Ya Tirišo

<table>
<thead>
<tr>
<th>E bothata kudu</th>
<th>E bonolo kudu</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Tshomišo ya lenaneo la ditšweletšwa

9. Bontsha ka tse ka diphla dipolelwana se ditšwela ka khataloko dikhalo ya Rustica

9.1 Tshedimošo eo e fiwago ka Ditšweletšwa

<table>
<thead>
<tr>
<th>E A HLAELELA</th>
<th>E LEKANE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9.2 Tirišego ya Tshedimošo ya Ditšweletšwa

<table>
<thead>
<tr>
<th>GA E NA MOHOLA</th>
<th>E NALE MOHOLA KUDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9.3 Tsweletso Ya khataloko ya Ditšweletšwa mo Sekirining

<table>
<thead>
<tr>
<th>GA E KGAHLE</th>
<th>E A KGAHLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9.4 Go balega ga molaetsa wa ditšweletšwa tše bontšhwago

<table>
<thead>
<tr>
<th>GA E BALEGE</th>
<th>E A BALEGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9.5 Go kgetha ditšweletšwa go reka

<table>
<thead>
<tr>
<th>E BOTHATA KUDU</th>
<th>E BONOLO KUDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9.6 Gohwetšagala ga molaetsa wa ditšweletšwa tše o di nyakago

| KE E TELELE | KE E KOPANA |
|            |            |
| 1           | 2           |
| 3           | 4           |
| 5           |            |

9.7 Gohwetšagala ga molaetsa wa ditšweletšwa tše o di nyakago

<table>
<thead>
<tr>
<th>GA SE KA NAKO TŠOHLE</th>
<th>NAKO TŠOHLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9.8 Molaetsa wa ditšweletšwa o go thuša go tšea sepheto sa go reka ditšweletšwa tše o sa ditlwaelago

<table>
<thead>
<tr>
<th>Ga se ka nako tšohle</th>
<th>Nako Tšohle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Karolo F: Ditšhwao-tshwao kakaretšo

1. Ke eng seo o seratago ka tse ka theko ka Rustica ya Mohuta ya ‘online’

2. Ke eng seo o sa se ratišišego ka tse ka theko ya Rustica sistemo

3. Naa o kgotsofatša ke molaetsa wa ditheko tsa ditšweletšwa tše di tšweletšwago mo selia thokeng sa gago? [Hlaloša]

4. Go ka oketswa eng go Tirešo-Tshepedišo
5. Ke eng se o ka dirago gore o tswele pele ka go šomiša sisteme ya Rustica.

6. Maikutlo a gago ka ga Projekte ye ya Rustica?

### Section G: Taodišophelo

<table>
<thead>
<tr>
<th>Bong</th>
<th>Monna</th>
<th>Mosadi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khoutu ya mošomiši wa sisteme</td>
<td>Nomoro ya Sellathekeng</td>
<td></td>
</tr>
<tr>
<td>Mengwaga</td>
<td>18-19</td>
<td>20-24</td>
</tr>
<tr>
<td>Thuto ya Godimo</td>
<td>Sekolo sa Thuto Ya Tlase</td>
<td>Sekolo sa Thuto Ya Godimo</td>
</tr>
<tr>
<td>Morafe</td>
<td>Motho moso</td>
<td>O mongwe (Hlalosa)</td>
</tr>
<tr>
<td>Polela ya ka gae</td>
<td>Sepedi</td>
<td>Afrikaans</td>
</tr>
</tbody>
</table>

Re leboga go tšea karolo ga g ago go dinyakishi o tše.
Appendix L: Second Sipedi Translated Version of the Context-Aware Model POC Prototype Evaluation Questionnaire

Tshekatsheko Ya Letlakala Potsišo la Kataloko (Tsweletšo) ya Ditsweletswa

Karolo A: Tšhomišego ya Letlakala Tsweletso la Ditsweletswa
1. Efa dipolelwana le dipotšišwana tse dilatelago seelo (sekala) go ya ka tsweletšo ya khataloko tshedimošo go sellathekeng tirišong e mphsa

| 1.1 Tšela eo tshedimošo ya ditsweletswa e tswelelagelo ka yona sešupong sa sellathekeng | Ga se ya hlaika | E hlakile |
| 1 | 2 | 3 | 4 | 5 |

| 1.2 Tebelelego ya Khataloko-tsweletso le tshedimošo yeo e tswelelwagwageng ysella thekeng | Ga ena maatlakgoqedi | E na le maatlakgoqedi |
| 1 | 2 | 3 | 4 | 5 |

| 1.3 Go phetla ditsweletswa go khataloko-tsweletso | Bo thatha | Boleta |
| 1 | 2 | 3 | 4 | 5 |

| 1.4 Tšomišego ya kataloko tsweletso | Tswafiša | Thabiša |
| 1 | 2 | 3 | 4 | 5 |

| 1.5 E kaba o kgona go hwetsa dilo tseo o dinyakago mo katalokong ka nako tshole? | E sego nako tshole | Nako tshole |
| 1 | 2 | 3 | 4 | 5 |

| 1.6 Naa tshedimošo eo e tsweleltswego e feletse go go kgontsha go tsea sepheto? | E sego nako tshole | Nako tshole |
| 1 | 2 | 3 | 4 | 5 |

Karolo B: Tsweletso Ya Ditaba ka Lebelo
2. Efa seelo (sekala) go dipolelwana tse mabapi le lebelo la khataloko tshedimošo go sellathekeng tirišong e mphsa

| 2.1 Lebelo leo tshedimošo e tselela sekirining sa sellathekeng | Nanankela(Nanya) | Ka pela (a kgofa) |
| 1 | 2 | 3 | 4 | 5 |

| 2.2 Nako ya go leta tshedimošo ya ditsweletswa go tswelela sekirining sa sellathekeng. | Telele | Kopana |
| 1 | 2 | 3 | 4 | 5 |

| 2.3 Tirišego ya tšela-tshepedišo | E a Hlaka hlakanya | Kgotsafatsa |
| 1 | 2 | 3 | 4 | 5 |

Section C: Papetso le Sesitemo ya pele
3. Efa seelo (sekala) dipolelwana tse latelago go bontša maikutlo a gago ka tsweletso ya khataloko go Tsela-tshepedišo e mphsa ge e papetsa le tsela ya Rustica

| 3.1 Tsweletso/Ponagalo ya Tshedimošo Tirishong/Tsela-tshepedisong e Mphsa | Ga e kgotsofatse | E feletse |
| 1 | 2 | 3 | 4 | 5 |

| 3.2 Go hwetsa di dirišwa/dinyakwa khatalokong ya Tirishong/Tsela-tshepedisong e Mphsa | Ga se boleta | Boleta |
| 1 | 2 | 3 | 4 | 5 |

| 3.3 Go phetla khatalokong go Tirishong/Tsela-tshepedisong e Mphsa | Bothata | Boleta |
| 1 | 2 | 3 | 4 | 5 |

| 3.4 Nako ya goleta khataloko go tswelela sekirining Tirishong e Mphsa | Telele | Kopana |
| 1 | 2 | 3 | 4 | 5 |

| 3.5 Kwišišo ya kataloko Tirishong e Mphsa | Hlaka hlakanya | Kgotsafatsa |
| 1 | 2 | 3 | 4 | 5 |

| 3.6 Kalo ya di diriswa mokhatalokong- Tsweletso sekirining sa sellathekeng | Hlaka-hlakanya | E Hlakile |
| 1 | 2 | 3 | 4 | 5 |

Karolo D: Maikutlo ka Botlalo go Tirišo/Tsela-tshepedišo e mphsa
4. Efa (efa seelo goba sekala) go dipotišišo tse dilatelago go bontša maikutlo a gago ao a feletsego ka khataloko tsweletso ya Tsela-tshepedišo e mphsa kgahlanong le yela ya Rustica

<p>| 4.1 Ke kgotsofetse ka boleta bja khataloko ye Ke gana Nnang! | Ke dumela (ka maatla) |</p>
<table>
<thead>
<tr>
<th>4.2 ke kgotsofatsa ke nako yeo ke kgonago go fetsa go odara/reka mo khatalokong ye ya tirišo/tsela-tshepedišo e mphsa</th>
<th>Ke gana Nnang!</th>
<th>Ke dumela (ka maatla)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ke kgotsofatswa ke tsweletso ya tshepedišo ye e mphsa</td>
<td>Ke dumela (ka maatla)</td>
<td>Ke dumela (ka maatla)</td>
</tr>
</tbody>
</table>

**Karolo E: Ditshwao-tshwao ka Botlalo**

1. Bontsha di phapano tseo o di bonago go Tirišo-Tshepedišo ya bjale le ya Rustica.

2. E kaba o bone phapano ka tsela eo khataloko-tsweletso etsweleditswego ka gona go sellathekeng ke Tirišo/Tsela-tshepedišo e mphsa ge o e bapetsa le ya Rustica? (Hlalosha)

3. Ge ele gore go na le phapano go tsela eo di Tirišo tše pedi tse di tsweleditswego ka yona, ke tsela efe tsela eo wena o e ratile gofeta? (Hlalosha)

4. E kaba o na le seo o ka se bolelago mabapi le tsela ya Tshedimošo ya dikhataloko-tsweletso go di Tirišo tse tse pedi? (e fa maikutlo goba ditšhišinyo)

Tirišo/Tsela-tshepedišo ya pele (Rustica)

Tirišo/Tsela-tshepedišo e mphsa

Re leboga go tšea karolo ga g ago go dinyakišišo tše.
An Integrated Logical Context Sensor for Mobile Web Applications

Felix Ntawanga
SAP Next Business and Technology, Africa
Suite 173, P/Bag X25
Lynwood Ridge, Pretoria
Tel: (+27) 012 999 9100
Felix.Ntawanga@sap.com

André P. Calitz
Dept. of Computing Sciences
Nelson Mandela Metropolitan University
P.O. Box 77000, Port Elizabeth
Tel: (+27) 041 504 2639
Andre.Calitz@nmmu.ac.za

Lynette Barnard
Dept. of Computing Sciences
Nelson Mandela Metropolitan University
P.O. Box 77000, Port Elizabeth
Tel: (+27) 041 504 2859
Lynette.Barnard@nmmu.ac.za

ABSTRACT
Context-aware computing continues to gain recognition, especially in mobile web computing. Determining accurate context information, in real-time, for implementing various adaptations in mobile web applications remains a challenge. Physically determined context information for use during adaptation has generally produced unsatisfactory results in mobile web applications. An alternative to acquiring context information is by the use of various software-based techniques that are referred to as logical context sensors. This paper discusses the implementation of an integrated logical context sensor that can determine context information in real-time for use in various mobile web adaptations.

An international field study evaluation of the context sensor was conducted. Results indicate that the integrated logical context sensor successfully determined accurate context information in real-time. The logical context sensor discussed in this paper can be utilised by application developers to incorporate context-awareness in their applications.

Categories and Subject Descriptors
• Human-centred computing~ Empirical studies in ubiquitous and mobile computing.
• Human-centred computing~ Ubiquitous and mobile computing design and evaluation methods.

General Terms
Design, human factors, experimentation, verification.

Keywords
Context-awareness, logical context sensor, mobile web, adaptation.

1. INTRODUCTION
The term context (and context-awareness) emerged in computer application development from the early 90s. Since then, incorporating various kinds of context information into application development and runtime has proven to have a significant impact on improving usability and the way end user computer and mobile applications are developed [7, 9, 15, 30]. This has been termed context-aware computing or more generally context-awareness. Gartner predicts that by 2015 context will be influential in delivering mobile consumer services [13, 17]. The crux of context-aware computing is to acquire context information within the user’s environment and to utilise the information to adapt the application to suit the particular user’s context during runtime [23]. The overall goal of context-aware computing is to improve user experience and usability of applications [13, 17].

Determining accurate context information in real-time is one challenge developers encounter in context-aware computing [21]. Physical and logical context sensors are usually used to acquire context for use during adaptation [22]. Adaptation in computing is defined as an application’s ability to alter its appearance or functions based on some parameters. Physical context sensors utilise a form of a physical device that determines context information, while logical context sensors utilise software-based techniques to determine context information [20, 21, 22]. Early context-awareness research depended on physical context sensors. Results, however, indicated that physical context sensors fall short of delivering accurate and timely context information [21]. Furthermore, physical context sensors proved bulky and unfit for use especially in mobile web applications [16].
Logical context sensors have been investigated as an alternative to physical context sensors [13, 21]. To the authors’ knowledge, however, no integrated logical context sensor has been developed in mobile web applications to determine context information.

The objective of this paper is to discuss the design, implementation and evaluation of an integrated logical context sensor. Initial evaluation results show that the logical context sensor was able to determine a variety of relevant context information in real-time accurately for use during implementation of various adaptations in mobile web applications.

The three main research questions addressed in this paper are:

1. What is context and context-awareness?
2. How can an integrated logical context sensor be implemented?
3. To what extent is the context information, determined by the integrated logical context sensor, accurate?

The subsequent sections of the paper are structured as follows in line with the research questions above:

Section 2 discusses the background literature on context and context-awareness. Selected research similar to the work presented in this paper is covered in Section 3. Conceptualisation and implementation of the integrated logical context sensor is discussed Section 4.

An international field study that was conducted to evaluate the accuracy of the determined context information and results are discussed in Section 5. Section 6 concludes the paper.

2. CONTEXT AND CONTEXT-AWARENESS

Context-aware computing is a relatively new area in computing and a number of aspects still remain unclear. This section aims to present an insight into context-aware computing and provides the definitions for context and context-awareness adopted in the paper. This section further discusses types and classes of context information. Lastly, the section covers acquisition and uses of context information in applications.

2.1 Definition

Literature on context indicates that researchers have not yet agreed on a single definition for context [6, 21]. The context definition by Dey [9] has been extensively cited [4, 6, 9, 13, 21] and is adopted in this paper.

“Context is any piece of information that can be used to characterise a situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.”

The definition relies upon context being “relevant” which implies that any context information that can be derived for use in an application has to be relevant for a particular situation or purpose [4, 6, 13]. Context information in this case refers to the set of data elements that constitute or define context [21]. The implication is that context only becomes meaningful when context information is available. Examples of common context information which developers use to improve usability include location and user preferences [4, 15].

Incorporating relevant context information during an application’s runtime for the purposes of improving usability is what has been termed as context-aware computing (or generally as context-awareness) [9, 13, 17, 30].

2.2 Types of Context Information

Two types of context information exist, namely, static and dynamic. The time interval that elapses for a piece of information to change its value determines the type of context information [20, 21]. Static context information does not change during interaction between the user and the application. For example, the user’s mobile device (and its features) in a mobile web environment remains static for the period of interaction.

Dynamic context information is information that may change its value a number of times during an interaction session. For example, bandwidth in a mobile web environment could fluctuate during interaction [32].

2.3 Classes of Context Information

Context information is classified according to the information source. Authors classify context information differently. In this paper a three-tier context classification, that has been widely utilised by other researchers and authors, is adopted as follows [5, 8, 21] (Figure 1):

1. User specific: This is context information that is directly related to the user and provides characteristics about the user. User models (or customer profiles) are usually used as a source for such information in mobile and desktop applications. User specific context information can be further classified into two groups: external and internal information. External information includes features of the user that can be easily perceived by another party, for example, physical appearances and disabilities. Internal information is features held within the user and these cannot easily be perceived by another party, for example, a user’s previous experience in using the application, the user’s emotions and feelings.

2. Device/technology specific: This is context information that is related to the device and technologies being utilised by the user during interaction with an application. Device specific context information is also classified into two
groups: input and output characteristics. Input contextual information includes features of the device that capture input from the user into the application. Examples include keyboard (touch vs. keypad), camera and microphone for voice input. Output contextual information includes features of the device that relay output from the system to the user. Examples include the device screen and speakers.

3. Environment specific: This is context information that is available within the environment in which the user can be found during interaction with an application. Environmental context information does not relate to either the user or the device in use. Environmental specific context information is subdivided into physical, social and technical information, for example, location, availability of other individuals and bandwidth respectively.

Figure 1 illustrates the general components of context information in mobile web with selected specific examples. The figure shows the classes, sub-classes and selected specific examples of context information for each branch.

2.4 Acquisition of Context Information

Context is acquired by means of different sensors that gather pieces of context information and supply the information for interpretation and utilization in an application [7, 13]. Two types of sensors exist: physical and logical context sensors [20, 22]. Physical sensors are sensors that detect context information by the use of some form of a physical electronic device [16, 20]. A well-known example of a physical context sensor is the Global Positioning System (GPS) sensors (or receiver) that are used to detect location coordinates [20]. GPS receivers work as stand-alone devices or sometimes the receivers can be installed within a device, for example, iPhone smart phones have built-in GPS receivers.

Logical sensors are sensors that utilise some form of software in order to collect context information [16, 20]. For example, there are software plug-ins and Application Programming Interfaces (APIs) that are able to determine the parameters of mobile phone devices. One widely used example is the Wireless Universal Resource File (WURFL) which is an eXtensible Markup Language (XML) file that contains specific features of all known mobile phones and tablets [24].

Context acquisition can mainly be done in two ways namely, explicit and implicit [6]. In explicit context information acquisition, the user is aware that context information is being collected for use by an application and the user usually needs to give consent for the information to be collected [2, 6]. For example, location sensors in many web browsers require that the user gives consent to share current location information with the application [29]. The user decides whether to accept or decline sharing the location details with the application.

In implicit context information acquisition, the user is normally unaware that context information is being collected either for use by an application or for storage [2, 12]. For example, when the application uses an accelerometer to implicitly determine the speed at which the user is travelling while accessing the application. Another example of implicit context information acquisition include the recording of a user’s previous interaction with the system [2, 12].

2.5 Usage of Context Information in Application Development

Context information is mainly utilised for improving usability and user experience in applications. This section focuses on the high level description of context use. Context-aware applications perform the following four main types of adaptations during interaction with the user in order to help the users to achieve their goals and improve usability [13, 15, 21, 23]:

1. User interface adaptation: User interface adaptation refers to the ability of a system to alter the application’s user interface or interaction mode based on the user’s current context information.

2. Content adaptation: Content adaptation refers to the ability of a system to select relevant content for processing and presentation by the application. Based on the available context information, context-aware systems adapt content to meet the user’s goals for interacting with the system. For example, in most recommender systems content that the user indicated in his or her preferences is presented first or highlighted on the interface with an option given to ask for additional or different content [3, 11].

3. Functionality adaptation: Functionality adaptation refers to the ability of the system to make an intelligent selection of relevant functions or user tasks that have to be performed by an application based on the available context information.

4. Device adaptation: Device adaptation is adaptation that performs the above adaptations (1 to 3) to suit the features
of the device being utilised by the user during interaction. Device adaptation research is of major importance in mobile computing because of the increase in the use of diverse mobile devices and applications.

Adaptation is performed in one of two ways: active or passive adaptation. Active adaptations in context-aware applications are performed without the user’s intervention. However, users are given an option to revert to the original versions of the application in active adaptation. Passive adaptations in context-aware applications require the user’s intervention before presenting the user with the adapted version of the system. Users, therefore, have the right to choose to interact with either the adapted or original version of the application. VUMS project is a notable example of large scale context-aware adaptation efforts. VUMS is a collaboration of a cluster of projects including GUIDE, MyUI, VERITAS and VICON projects aiming at improving accessibility and usability of various products and application areas, taking into account various impairments and other context information [1, 28]. Figure 2 shows the architecture for a context-aware system adapted from Lowe et al. and Poulcheria and Costas [13, 21]. The figure summarises the discussion in Section 2 by showing the processes of context acquisition and use.

Figure 2. Architecture for a context-aware system.

3. RELATED WORK
Context-aware computing is becoming an active area of research in computing. This section highlights some selected context-awareness research related to the work presented in this paper.

A context management architecture for m-commerce applications was designed and implemented by Poulcheria and Costas [21]. The focus of this research was to identify context information that can be utilised for improving usability of m-commerce applications. The presented architecture has the following components: logical and physical context sensors, context storage, interpretation and utilisation. Lowe et al. [13] conducted research on context-awareness and developed a context directory which is an architecture to collect, store, interpret and disseminate context attributes to different users. The model presented by Lowe et al. has similar components to the model developed by Poulcheria and Costas [21]. Wagner et al. [30] presented the concept of context as a service in which Service-Oriented Computing (SOC) was utilised to present context services to users. The main focus in this research was activation and deactivation of heterogeneous context services on demand by a middleware component.

Developing context-aware applications is met with a number of challenges. This was confirmed by Tao et al. [25] who indicated that context-aware computing is complex. Gartner also reiterated this view by reporting that context-aware computing is currently at a stage where the web was in the early ‘90s, and further predicts that full benefits will only be realised in future. Notable challenges in context-aware computing include [4, 13, 27]:

- Defining useful/relevant context information: The fundamental question in this challenge is what information is relevant and how can such information be applied in an application;
- Quality of context information: This concerns issues such as accuracy and completeness of context information;
- Disparities in context information: The challenge in this regard is to integrate various sensors and interpret various data formats of context for use during adaptation; and
- Security and privacy: One challenge in this challenge is the users’ willingness to share context information.

Evidence of tackling these challenges could not be found in related work reviewed thus far, including work summarised in this section [12, 20, 28]. This paper took a step further to focus on defining useful/relevant context and in integrating different logical context sensors into one application. In addition, this paper discusses evaluation of the accuracy and real-timeliness of the determined context information. Current related work lacks accuracy and real-timeliness of context information. Work presented in this paper builds on the fact that accurate context information is critical for successful implementation of effective adaptations and contributes to addressing all but the security challenge above.

4. INTEGRATED LOGICAL CONTEXT SENSOR
An integrated logical context sensor was designed and implemented to determine real-time context information that
can be utilised for various adaptations in mobile web applications. The integrated logical context sensor was developed as a component that can be incorporated into mobile web applications similar to a plug and play API for the purpose of determining context information.

The sensor was developed by using a combination of various open source web application development tools and techniques. The motive for using open source was to ensure the sensor’s compatibility with a variety of other technologies running on different mobile devices. The selection of context information to be included in the sensor was determined by analysing the most commonly used context information in mobile web adaptation from a comprehensive list such as the one presented in Figure 1 [6, 10, 15, 18]. The integrated logical context sensor was developed to detect the following context information: user profile, location, time of the day, device profile and connection bandwidth.

This section discusses the two main components of the logical context sensor, namely, specific context sensors and context sensor application.

4.1 Specific Context Sensors

A number of specific context sensors exist that can be utilised in applications as plug-ins. However, the majority of these sensors work as independent units and compatibility with other technologies remains a challenge. In addition other sensors APIs are not freely available and license security features limits ease of use, for example, the World Time Engine API [31]. The goal of the integrated logical context sensor was to address two challenges, namely, compatibility and unifying context information sources. Various sensors were utilised and integrated into one component that developers can use to acquire context information. The integrated independent context sensors formed the main application logic of the integrated logical context sensor. This section discusses how context sensor units were designed and utilised in the integrated logical context sensor.

1. User profiles: User profiles, for evaluation purposes, were created in the application. A profile was created for each potential user who would participate in the evaluation. The profile contained login credentials as well as some information about the user, for example, the name of the location and country of the user. The user profile was only meant to identify and authenticate the users when performing the evaluation, rather than to contain information that could be utilised for other purposes such as adaptation.

2. Location: The location sensor utilised the HTML 5 Geolocation API to determine the location from which an application was accessed [29]. Location information in the sensor is presented as GPS coordinates, that is, latitude and longitude points. The motive for using coordinates rather than location name is to accurately determine the distance between points. For example, by using the Vincenty formula that uses trigonometry sine and cosine rules, and two sets of GPS coordinates, distance between the points can be calculated in Miles or Kilometres [14]. For privacy and security purposes, during runtime the Geolocation seeks the user’s approval to share location information [29].

3. Time of the day: The PHP DateTime function was utilised to determine the actual time of the day at which the application was accessed. PHP server localisation was used to inform the user’s browser where the server is located. The determined location from Point 2 above was utilised together with the PHP DateTime function and world clock to determine the location’s current time [19].

4. Device profile: WURFL was used to determine the characteristics of the device being used by the user to access the application. WURFL determines device properties by mapping HTTP Request headers by using user agents (UA) to the profile of the HTTP client device, be it a desktop, mobile phone or tablet, that issued the request [24]. The client UA is matched against the contents of the XML file. A match returns properties of the relevant device. Google and Facebook are examples of companies using WURFL in their websites [24].

5. Bandwidth: An existing software component used to determine bandwidth or specific bandwidth sensor could not be found. A mathematical model was therefore developed to determine bandwidth for the purposes of this research. Formula 1 was derived to determine bandwidth:

\[ b = \frac{d}{t} \]  

(1)

Where:
- \( b \) is bandwidth to be determined in \( \text{Bytes/Second} \);
- \( d \) is the predetermined amount of data to be transferred from the server to the client. (This can be any file with a known size in \( \text{Bytes} \) (or \( \text{Kilobytes} \)); and
- \( t \) is the amount of time in seconds taken between sending a request to the server and when the response or acknowledgement from the server is received by the client. This time is also called Round Trip Time (RTT) or ping time.

Figure 3 shows the pseudocode for the context sensors that shows how the code executed various components to determine context information.
Figure 3. Pseudocode for integrated logical context sensor.

4.2 Context Sensor Application

In order to evaluate the system, the integrated logical context sensor was incorporated into a web application. The application served as an evaluation platform (application presentation layer) to test various context sensor functionalities of the integrated logical context sensor (application logic layer). The following technologies were utilised for this purpose:

1. Database: MySQL database management system was utilised to implement a database that was used to store information for future use and evaluation. Examples of information that was stored in the database include: user profile information, device profile information and history of user interaction.

2. User interface: HTML and PhP were the two programming languages that were utilised to develop the mobile web user interface. The purpose of the user interface was to have an interface by means of which the user would be able to view the determined context information during the evaluation. Figure 4 shows an example of the user interfaces of the application that were presented to the users during evaluation.

3. Backend integration: The sensor utilised a number of technologies developed using various technologies. For example, HTML Geolocation is developed by using JavaScript and HTML, while a PhP version of the WURFL was utilised in this application. Integration between various technologies was achieved by using open source tools such as Java, JavaScript, PhP and HTML. Special scripts were created to enable seamless interaction between the different technologies that were utilised.

4. Web server: The application was deployed on an Apache web server so that it can be accessed as a web application via the Internet.

Figure 4 shows the login screen and the context information display page of the application. The context information screen was mainly utilised during the evaluation. Evaluation is discussed next.

5. EVALUATION AND RESULTS

This section discusses the evaluation of the integrated logical context sensor, with specific reference to the evaluation goals, sample profile and the evaluation procedure that was followed. The analysis of the evaluation data and the results are also explored. The results and limitations of the study are explained in the last two sub-sections.

5.1 Evaluation Goals

The following were the main goals of the evaluation:

a) To ascertain accuracy of the determined context information;

b) To assess real-timeliness of the context determination process; and

c) To assess user satisfaction levels of the above two statements.

5.2 Sample of Users

Thirty users from various locations across the globe participated during the evaluation. The general user profiles were users with at least any first degree and 2-5 years of Internet experience. This was a requirement so that users can critically analyse context information presented by the logical sensor. Users had to be able to make predictions on
information that needed confirmation based on experience (that is previous experience and current experience gained from interacting with the application). For example, users were asked to rate the way they perceived their connection speed by using a 5 point Likert scale (Table 1). This rating was compared with the bandwidth value displayed by the system.

Figure 5. User profile: Gender and Age groups.

Figure 6. User profile: Highest qualification and location.

Figures 5 and 6 summarise the users’ profiles. Figure 5 shows the number of users by gender and age groups. Sixty seven percent (n=20) of the sample were male while 33% were female (n=10). The age of the majority of users was between 20-35 years (n=28). Figure 6 shows locations of the users and their highest qualifications. Location is summarised based on continents as individual countries were so diverse, for example, users from 13 different countries evaluated the application across 5 continents. Forty three percent of the users had a bachelor’s degree (n=13) followed by 36% who had a master’s degree (n=11). Thirteen percent had other tertiary qualification (n=4) and 7% had a PhD (n=2). Fifty percent of the users came from 6 different countries in Africa (n=15), 20% came from Europe and North America each (n=6), Asia and Australia had 7 and 1% (n=2 and n=1 respectively). The sample met the requirements of the evaluation in terms of age, Internet experience, education level and diverse location.

5.3 Evaluation Procedure

The evaluation was conducted online and users were requested to access a link where the logical sensor was located. The users were given the freedom to use any Internet enabled mobile device, such as smart phones and tablets. They were, however, notified that any Internet charges were to be covered by themselves. Information containing the purpose of the evaluation, consent form, evaluation tasks and evaluation questionnaire was sent to all the users who accepted to participate in the evaluation.

User profiles were created and each user was allocated different system login credentials. Users were given instructions to log into the application by using the login details provided. Upon successful login, the application performed the steps in the pseudocode presented in Figure 3 and the results of the determined current context information were displayed on the user’s mobile device screen.

Users were asked to record the displayed context information into the questionnaire regardless of whether the information was correct or incorrect. When the displayed information was correct, users were asked to confirm by clicking a “Confirm” button on the screen. This action uniquely saved displayed information from that particular user into the system log file.

The logical sensor user interface allowed users to edit some incorrect (or inaccurate) information displayed on the user interface and to send the correct information to the server. Information that was collected from the users and stored in the system log was considered correct and was also included in the analysis (Figure 7).

5.4 Results Analysis

Evaluation data was collected through a post-task evaluation questionnaire that users completed during the evaluation as well as from automatic system log files. Both usability and software engineering metrics were collected during the evaluation. Usability metrics that were collected included the following:

a) The perceived application speed;
b) The perceived bandwidth; and
c) Overall satisfaction with the system.

Software engineering metrics included all the other technical information which the system collected and that which the user entered into the system and on the questionnaire. The collected software engineering metrics included:
a) Displayed information such as time, GPS coordinates, device make and model, and bandwidth which was also captured by the user onto the questionnaire.

b) Information captured into the system log for each user. Users were allowed to edit time and the device’s make and model information, only when this information was incorrect on the user interface. Figure 7 shows an extract of such information from the system log.

Figure 7. System log.

Data captured by the user on the questionnaires was compared to the information that was logged by the system and saved in the system log. System log contents contained the actual context information according to the user while the questionnaires contained context information determined and displayed by the system. The two sets of information were utilised during the analysis in order to ascertain the accuracy of the information determined and displayed by the integrated logical context sensor.

Analysis results of the four main context information sets determined by the integrated logical context sensors can be summarised as follows:

1. Device context information: Users were asked to indicate “yes” on the questionnaire if the make and model of device displayed on the interface matched the one the user was using to access the application (or “no” if otherwise). Results show that the integrated context sensors were able to determine the correct make of the device being used by the user 80% of the time (n=24), and it was also able to determine the correct model of the device 63% of the time (n=19).

2. Time: Users were also asked to indicate “yes” on the questionnaire if the correct current time was displayed on the screen (or “no” if otherwise). Time accuracy evaluation went through a number of phases. The actual time that users indicated on the questionnaires (in hours and minutes) was verified by the time of the day users indicated on the background section of the questionnaire. For example, if a user indicated that in his or her location, the time of the day was morning, it was expected that the actual time in hours should be between 06:00-12:00 (using a 24-hour clock). Results show that the integrated context sensor correctly determined current time 73% of the time (n=22).

3. Location: As discussed in Section 4.1, specific location was determined and displayed with GPS coordinates and therefore users were only asked to record the displayed coordinates. Verification of the location represented by the GPS coordinates was conducted manually by searching the actual location of recorded GPS coordinates on the Internet. The results were compared with the location details which users recorded in the background section of the questionnaire. This information was utilised to see whether the displayed (recorded) GPS coordinates matched the details on the questionnaire. Results indicated that the system was able to determine correct location 57% of the time (n=17). Figure 8 summarises the accuracy of device, time and location context information gathered by the integrated logical context sensors.

Figure 8. Accuracy of location and time Information.

4. Bandwidth: Bandwidth determination utilised a novel approach discussed in Section 4.1. Literature could not be found that provided tried and tested techniques to implement and evaluate a bandwidth sensor. Therefore, in this research, the user’s Internet experience was used in order to ascertain the accuracy of the determined bandwidth. The determined bandwidth was only for download speed. Users were asked to record the displayed bandwidth and, based on their experience and opinion indicate how they perceived the speed of the application on a 5-point Likert scale with 1 being very fast and 5 being very slow [26].

Table 1 shows the relationship between the Likert scale and actual bandwidth values that were initially established by running several simulations.
5.5 Discussion

The goal of evaluating the integrated logical context sensors was to ascertain accuracy and real-timeliness of the determined context information. In addition, user satisfaction levels were collected in order to implicitly confirm usefulness, accuracy and real-timeliness. Results obtained from the evaluation indicated that the logical context sensor achieved its goals and objectives. From the results it can be concluded that the integrated logical context sensors performed better in determining device make and time than when determining model and location. This can be attributed to the fact that to determine device model and actual location, there is need for additional drill-down operations on parent categories of the device’s make and time. Inconsistencies observed in the location context information of the determined device model indicate that there is a need to improve accuracy of the responsible specific context sensors. Bandwidth determination and verification were found to be cumbersome as they largely depended on the user’s experience and opinion. The obtained values for bandwidth and the users’ perception of their connection speed indicated that the bandwidth sensor has the potential to determine accurate bandwidth. However, accuracy of the determined bandwidth cannot be ascertained in this case because there was lack of verification mechanisms at the time of recording the bandwidth values. By utilising different open source technologies and by bringing together different sensors into one, the integrated logical context sensor achieved unification and compatibility goals.

5.6 Limitations

The first limitation of the study was the finding that most users were not willing to share location information. This observation resulted in some inconsistencies in the determined location. Second limitation was that the Tera WURFL file (Version 2.1.5, last updated on 6th June 2011) that was utilised in the context sensor was out-dated. At the time of development an updated version of the file was not available because the original company responsible for updating the WURFL was going through a transition. The out-dated WURFL file might have caused some inconsistencies in determining the device model. Third limitation was that the researcher had no control over other context factors during the evaluation. For example, the Internet connectivity options users decided to utilise during the evaluation (Wi-Fi or 3G and 4G) and actual position within a location where users chose to interact with the application (for example, inside a building or travelling on the road). These factors might also have affected the results.

6. CONCLUSION AND FUTURE WORK

Context-awareness (or context-aware computing) is becoming very useful in mobile web computing because of the popularity of mobile web applications and the diversity of context of use [13]. Predictions by renowned Information Technology research organisations such as Gartner indicate that context-awareness will be an integral part of many consumer service applications by 2015 [13, 17, 18]. Literature, however, shows that there are disagreements amongst researchers with regard to context and context-awareness. In addition, several challenges have been identified with regard to determining accurate context in real-time for implementing effective adaptation.

This paper has discussed the concepts of context and context-awareness (context-aware computing). The main outcome of the paper is the discussed conceptualisation, implementation and evaluation of an integrated logical context sensor that utilised different open source technologies to acquire and present real-time context information. The integrated logical context sensor was evaluated for accuracy and real-timeliness with a sample of 30 users in different locations across the world. Results show that the integrated logical context sensor is able to determine accurate context information in real-time that can further be utilized by application developers to implement various user-specific adaptations. The paper and its findings contribute to addressing some of the notable challenges in context-aware computing as mentioned in Section 3.

Future research will involve addressing the discovered limitations of the integrated logical context sensor and utilise it as a plug-in to an application to implement, as an example, an adaptation use case of the determined context information.

7. ACKNOWLEDGEMENTS

The financial support of SAP Next Business and Technology Africa that enabled this research is hereby acknowledged. Any opinions expressed and conclusions arrived at are those of the authors and are not necessarily to be attributed to SAP Next Business and Technology Africa.
REFERENCES


